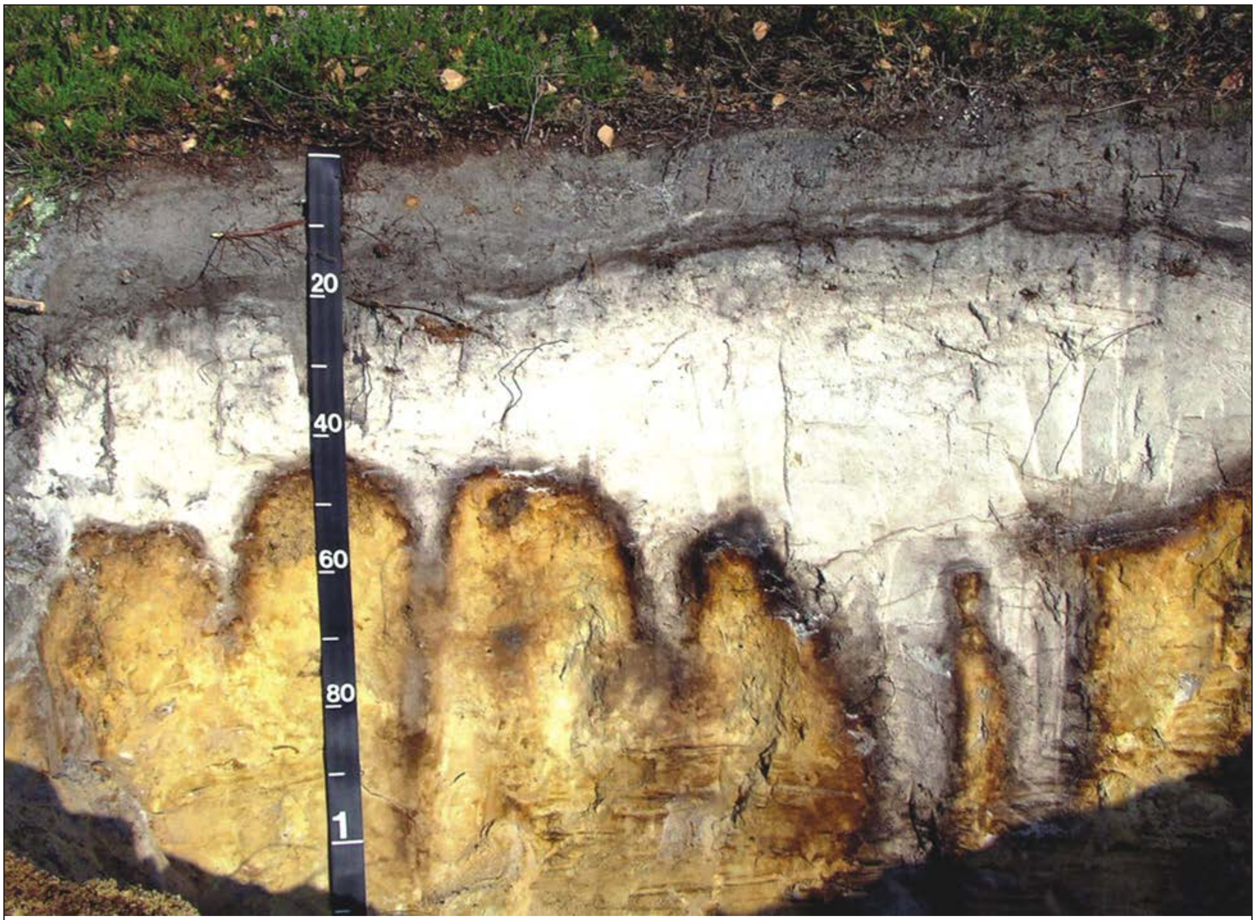

International Journal of
Soil Science
ISSN 1816-4978

Academic
Journals Inc.

www.academicjournals.com

International Journal of Soil Science 3 (3): 109-118, 2008
ISSN 1816-4978

The Effects of Iron Content of Soils on the Iron Content of Plants in the Cukurova Region of Turkey

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Abstract: Soil, leaf and grain samples were collected from wheat (*Triticum* sp.) fields in Cukurova Region of Turkey and the soil samples taken from the root area of plants where the leaf and grain samples were obtained were analysed for iron (Fe) content. The leaf samples taken during the stem development and the grain samples taken at the time of maturation were also analysed for Fe content. The correlation analysis between Fe contents of soil and Fe contents of leaf and grain was performed to determine the relationships among the variables. The Fe content of the soil samples collected in 2005 was between 2.60 and 6.00 mg kg^{-1}. The Fe content of the soil samples collected in 2006 was between 6.96 and 12.70 mg kg^{-1}. The iron content of the majority of soil samples, collected in 2005, was observed below the critical level which is 4.5 mg kg^{-1}. The Fe content of the leaf samples was ranged from 69.50 to 156.70 mg kg^{-1} in 2005 and 138.10 to 518.10 mg kg^{-1} in 2006, whereas the iron content of the grain samples was ranged from 96.00 to 299.50 mg kg^{-1} in 2005 and 11.54 to 134.01 mg kg^{-1} in 2006. Also the Fe content of the leaf and grain samples was directly correlated with the Fe content of the soil. Correlation between iron content of soil and iron content of leaf in 2005 was significant at the 0.01 level according to statical analysis. While there was a direct relation between iron content of leaves and soil samples, there was an inverse relation between iron content of grain and iron content of leaf in 2006.

Key words: Soil characteristic, iron, micronutrient elements, iron deficiency

INTRODUCTION

During the last decades, numerous attempts have been made to develop a practical solution for treating Fe deficiency, including many Fe-containing fertilizers and different placement strategies of these fertilizers. The most widely used Fe sources are inorganic Fe forms and chelates mixed with inorganic Fe (Vempati and Loeppert, 1986). Chelated forms of Fe are usually more effective in reducing Fe chlorosis than are inorganic forms (Godsey *et al*., 2003; Charlson *et al*., 2005).

Iron deficiency in plants reduces not only grain yield, but also nutritional quality of grains. As in soils and plants, iron deficiency is also a common nutritional problem in humans, particularly in developing countries. Iron deficiency is a complex disorder and occurs in response to multiple soil, environmental and genetic factors. Although the most abundant micronutrient in surface soils (Fageria *et al*., 2002), Fe is the most limiting to agricultural production throughout the world (Kochian, 2000). Plants require a continuous supply of Fe to maintain proper growth (Brown *et al*., 1972) since very little accumulated Fe is mobilized from plder to younger tissues (Zhang *et al*., 1996; Burton *et al*., 1998). Because Fe is necessary for several metabolic processes, yet potentially toxic, a plant's Fe uptake and homeostasis are tightly controlled (Motta *et al*., 2001).

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In calcareous soils with high pH and high-pH buffering capacity (elevated bicarbonate levels), severe impairment of Fe stress response mechanisms can occur (Romheld, 1987) and repeated applications of foliar sprays may be necessary to supply adequate Fe for either susceptible or resistant plant cultivars (Niebur and Fehr, 1981). Low rates of Fe probably do not satisfy the requirement of a continuous supply of Fe as plant development progress (Goos and Johnson, 2001).

As staple crops contribute substantially to daily caloric intake among people in developing countries, there has been a resurgence of interest in addressing human malnutrition through breeding of staple crops, specifically to address micronutrient malnutrition (Gregorio *et al*., 2000; Monasterio and Graham, 2000; Beebe *et al*., 2000; Long *et al*., 2004).

Iron deficiency has many negative impacts on human health and well-being, such as decreasing work capacity and slowing the cognitive development of iron-deficient children (Hercberg *et al*., 1987). Iron deficiency in developing countries results from poor access to iron-rich foods, poor bioavailability of iron in foods consumed and poor absorption of iron because of parasitic infections (Nair, 2001). Iron deficiency is often accompanied by zinc deficiency as both of these nutrients are derived from similar sources in the diet (Ronaghy, 1987; Welch, 2001).

The performed studies in recent years have showed the importance role of micro elements in human and plant nourishment. The studies made especially on zinc point out that the problem of zinc deficiency is in serious condition in Turkey. Insufficient content of micronutrient elements in soil has a negative impact on the development of crops, which, in turn, affects human health. Micro element deficiencies like zinc and iron bring out some serious health problems especially in children at developmental age. In this respect, micronutrient elements exhibit a profound significance for the condition of human health as much as they do for a successful production of crops. The objectives of this study: (i) was to determine the soil iron content of wheat production field in Cukurova region; (ii) was to assess the effect of soil iron content on Fe content of leaf and grain.

MATERIALS AND METHODS

Description of the Area

The study area, carried out in Cukurova Region (Fig. 1), is characterized by xeric climate and lies between 37 ° 03' and 36° 37' N latitudes and 35 ° 12' and 36 ° 02' E longitudes with altitude ranging between 20 and 80 m above MSL. The average amount of annual rainfall is 670.8 mm and potential

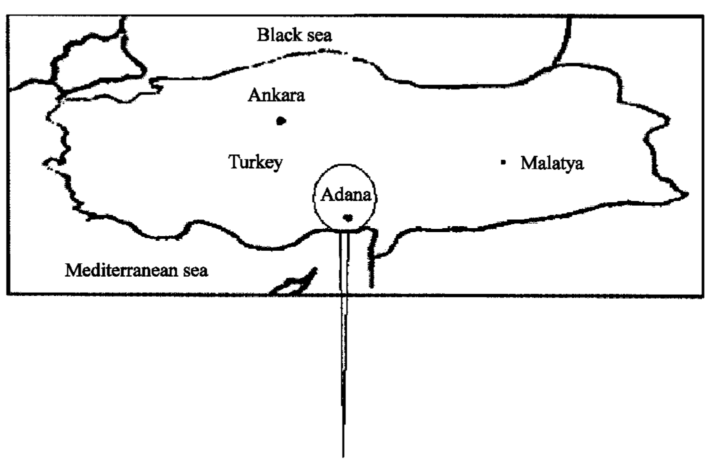

Fig. 1: Study area in Çukurova region

total evaporation is 1536.0 mm. The mean annual air temperature is 19.1. The mean annual soil temperature at 50 cm depth is 20.8°C. All the soils are xeric. The vegetation in the study area are grasses, cereal and leguminous crops. The vegetation was dominated by cereal and leguminous grasses. Wheat, cotton, maize, grape and soybean have been growing as commonly in Cukurova Plain.

Methods

In this study, 23 leaves samples, 23 grain samples and 23 soil samples in 2005 and 30 leaves samples, 30 grain samples and 30 soil samples in 2006 were researched. Plants were sampled during growing (heading) to determine Fe content of leaves. Grain samples were taken in the harvest season to determine Fe content of grains. Soil samples were taken from 0-30 from roots region for laboratory analysis. Disturbed soil samples for laboratory analysis were collected from 0-30 cm depth and air dried to pass a 2 mm siever. Soil samples for laboratory analysis were collected from 0-30 cm depth and air dried, ground to pass a 2 mm sieve. The particle size distribution of each sample was determined by the pipette method (Mc Keague, 1978) after removal of organic matter and carbonates. The pH was measured on saturation extracts (Radiometer PHM 82 standard pH meter). Organic C was measured by using a modified Walkley-Black procedure (Nelson and Sommers, 1996). Carbonate content was determined by the Scheibler calcimeter method (Black, 1965). Cation-exchange capacity by Mg saturation followed by NH_4 substitution (Mc Keague, 1978). Available P_2O_5 analysis were carried out following methods (Olsen *et al*., 1954). Extractable Fe oxides by the citrate dithionite-bicarbonate method and total chemical analysis were carried out by the HF fusion method (Kick *et al*., 1980).

RESULTS AND DISCUSSION

Some Chemical Properties of Soils

According to results from analysis of soil samples collected in 2005, the $CaCO_3$ and organic matter content were observed between 12 and 20% and 1.32 and 2.70%, respectively (Table 1). The

Table 1: Selected some physical and chemical properties of soils in 2005

Sample No.	$CaCO_3$ (%)	Org. matter (%)	CEC (cmol kg^{-1})	pH (1/1)	P_2O_5 (kg ha^{-1})	Particle-size < 2 mm (%) Silty	Sand	Clay
1	16.0	2.48	33.33	7.45	17.8	42.2	21.9	35.9
2	17.0	2.14	29.26	7.59	15.6	46.2	19.8	34.1
3	16.0	2.70	30.67	7.57	7.8	41.5	19.7	38.5
4	16.0	2.58	34.76	7.59	7.4	43.4	13.8	42.8
5	16.0	2.23	31.66	7.59	4.6	45.3	22.6	32.1
6	15.0	2.07	29.68	7.75	4.4	46.2	21.1	32.7
7	14.0	1.96	28.22	7.60	5.9	39.5	27.8	32.5
8	17.0	1.44	22.67	7.74	7.8	29.1	48.4	22.5
9	13.0	1.51	23.44	7.77	6.4	29.5	46.9	23.7
10	20.0	1.60	32.98	7.92	3.1	51.8	15.4	32.8
11	16.0	1.22	21.32	7.65	7.0	24.9	55.3	19.8
12	16.0	2.29	24.80	7.51	12.1	38.0	34.5	27.5
13	17.0	1.98	28.14	7.64	7.3	45.4	24.1	30.5
14	17.0	1.95	26.25	7.57	9.2	45.0	24.4	30.5
15	17.0	1.51	28.14	7.71	13.7	44.4	22.0	33.7
16	12.0	1.63	32.32	7.74	6.8	50.4	11.5	38.2
17	17.0	1.54	27.56	7.75	11.5	41.9	22.7	35.4
18	17.0	1.73	28.87	7.82	10.2	42.7	23.5	33.8
19	17.0	1.85	31.66	7.76	6.7	42.5	18.2	39.2
20	16.0	2.14	29.02	7.68	7.0	45.2	16.2	38.6
21	18.0	1.63	32.32	7.71	5.5	47.2	14.6	38.2
22	16.0	1.32	30.26	7.70	5.2	48.4	17.8	33.8
23	17.0	1.48	28.22	7.75	4.6	44.7	22.0	32.7

Cation Exchange Capacity (CEC) values change between 21.32 and 34.76 cmol kg^{-1}. Soil pH has changed between 7.50 and 7.99. Utilizable P_2O_5 content of soils collected in 2005 change between 31 and 178 kg ha^{-1}. The maximum amount of utilizable P_2O_5 content was observed in sample number 1 as 178 kg ha^{-1} appeared to be quite high. The optimum amount of soil P_2O_5 content to provide favourable growing condition for plants is about 110 kg ha^{-1}. High P_2O_5 content may be attributed to excess application nutrient to soil. The excess amount of utilizable P_2O_5 content seems to have a disadvantage for microelements uptake from soil (Cakmak *et al*., 1997; Long *et al*., 2004).

$CaCO_3$ and organic matter content of soil samples from 2006 were observed between 16 and 21% and 1.46 and 2.33%, respectively (Table 2). The Cation Exchange Capacity (CEC) values change between 21.24 and 38.02 cmol kg^{-1}. Also soil pH has changed between 7.50 and 7.99. The lowest utilizable P_2O_5 content was observed in sample number 23 as 16 kg ha^{-1}. The highest amount of utilizable P_2O_5 was 179 kg ha^{-1} in sample number 6 while the amount of utilizable P_2O_5 changes between 16 and 179 kg ha^{-1}. It is believed that the excess amount of utilizable P_2O_5 in soil caused by overdose application of fertiliser.

Iron Contents of Soils

Iron content of soil samples, collected in 2005, was determined as low ranging from 2.60 to 6.00 ppm according to results of chemical analysis (Table 3). Iron contents of all soil samples of 5, 6, 8, 9,10,11,14, 15, 16 and 22, was appeared to be lower than Fe critical level being 4.5 ppm. The sample number 8 have the lowest amount of iron content being 2.60 ppm and the sample number 1 have had the highest amount of iron content being 6.00 ppm. The low iron content may be associated with chemical composition of parent material. It is known that soil parent material has an effect on chemical properties of soil (Irmak *et al*., 2007).

Table 2: Selected some physical and chemical properties of soils in study area in 2006

Sample No.	$CaCO_3$ (%)	Org. matter (%)	CEC (cmol kg^{-1})	pH (1/1)	P_2O_5 (kg ha^{-1})	Particle-size < 2 mm (%) Silty	Sand	Clay
1	16	2.33	26.04	7.50	125	31.9	43.0	25.1
2	17	2.05	28.66	7.64	49	31.1	46.1	22.8
3	16	2.02	29.77	7.71	51	30.6	44.8	24.6
4	16	1.83	25.04	7.58	130	32.2	41.9	25.9
5	16	1.71	29.63	7.62	70	33.2	43.7	23.1
6	16	1.49	21.24	7.57	179	23.1	25.3	51.6
7	19	1.90	38.02	7.69	64	34.4	49.2	16.4
8	21	1.83	30.62	7.75	68	32.2	45.9	21.9
9	18	1.73	32.22	7.76	47	40.8	48.7	10.5
10	21	1.90	30.83	7.73	65	38.7	49.7	11.6
11	19	2.08	30.87	7.68	25	37.1	51.7	11.2
12	18	2.08	29.94	7.71	66	37.1	52.3	10.6
13	18	2.14	30.91	7.74	38	39.5	47.9	12.6
14	17	2.24	35.50	7.64	122	40.2	48.6	11.2
15	18	2.21	33.08	7.71	122	39.1	49.7	11.2
16	18	1.96	34.75	7.66	74	39.1	49.2	11.7
17	18	2.17	36.33	7.65	69	40.8	48.2	11.0
18	18	1.74	34.72	7.76	66	41.4	48.9	9.7
19	18	1.99	33.08	7.68	81	39.6	49.3	11.1
20	17	1.99	33.55	7.72	105	37.2	50.5	12.3
21	18	1.90	33.80	7.71	49	41.7	48.3	10.0
22	18	1.86	33.66	7.77	56	41.8	47.5	10.7
23	19	1.99	30.88	7.74	16	39.0	48.2	12.8
24	21	2.05	30.80	7.72	72	34.7	50.6	14.7
25	20	1.71	33.30	7.67	60	37.3	48.9	13.8
26	21	1.46	31.72	7.63	29	38.4	53.7	7.9
27	21	1.65	31.63	7.50	46	35.1	50.5	14.4
28	21	1.27	31.51	7.59	60	36.4	52.0	11.6
29	18	1.65	32.60	7.99	51	36.1	47.2	16.7
30	17	1.68	31.60	7.72	31	36.1	44.0	19.9

Table 3: Iron content of soil, plant and grain in 2005

Sample No.	Fe (ppm)	Fe in leaf (ppm)	Fe in grain (ppm)	$CaCO_3$ (%)	Texture
1	6.00	148.70	109.25	16.0	CL
2	5.80	156.70	116.08	17.0	SİCL
3	4.80	126.50	137.65	16.0	SİCL
4	5.80	136.80	104.69	16.0	SİC
5	4.20	81.10	200.10	16.0	CL
6	4.00	85.00	168.25	15.0	CL
7	5.60	134.40	187.80	14.0	CL
8	2.60	69.50	216.10	17.0	L
9	3.20	72.60	299.50	13.0	L
10	3.80	74.60	140.60	20.0	SİCL
11	3.60	73.30	249.15	16.0	SL
12	4.80	126.20	95.00	16.0	CL
13	4.80	123.50	141.55	17.0	CL
14	4.40	105.90	154.60	17.0	CL
15	4.40	109.30	167.70	17.0	CL
16	4.20	100.70	147.90	12.0	SİCL
17	4.80	122.00	190.25	17.0	CL
18	4.60	118.80	217.00	17.0	CL
19	4.60	121.10	154.80	17.0	SİCL
20	4.60	113.70	244.35	16.0	SİCL
21	4.80	117.50	270.50	18.0	SİCL
22	4.00	110.80	171.50	16.0	SİCL
23	5.00	114.20	179.85	17.0	CL

Table 4: Fe content of soil, leaf and grain in 2006

Sample No.	Fe (ppm)	Fe in leaf (ppm)	Fe in grain (ppm)	$CaCO_3$ (%)	Texture
1	7.30	231.50	66.26	16	CL
2	8.50	242.60	49.22	17	CL
3	7.92	330.90	51.20	16	CL
4	8.60	518.10	12.92	16	CL
5	7.10	320.20	11.54	16	CL
6	7.96	217.00	40.63	16	L
7	8.38	175.90	17.97	19	SiCL
8	8.90	244.10	36.27	21	CL
9	9.06	226.60	39.21	18	SiC
10	8.46	153.90	32.43	21	SiCL
11	7.78	214.60	61.88	19	SiCL
12	8.94	237.60	134.01	18	SiCL
13	8.18	213.80	70.06	18	SiCL
14	9.30	192.70	66.07	17	SiC
15	8.74	187.40	46.79	18	SiCL
16	6.96	210.80	55.15	18	SiCL
17	8.44	193.40	45.69	18	SiC
18	7.68	163.90	64.52	18	SiC
19	7.20	174.70	71.86	18	SiCL
20	8.58	200.40	61.78	17	SiCL
21	8.18	180.90	98.24	18	SiC
22	8.66	228.10	90.43	18	SiC
23	7.96	202.90	79.31	19	SiCL
24	9.66	199.60	54.52	21	SiCL
25	9.72	138.10	132.96	20	SiCL
26	10.78	174.30	76.58	21	SiCL
27	9.90	177.60	88.81	21	SiCL
28	9.90	186.90	56.79	21	SiCL
29	9.66	164.40	22.01	18	SiCL
30	12.70	166.50	17.21	17	SiCL

Iron content of soil samples in 2006 was determined as high ranging from 6.96 to 12.70 ppm. Iron content of all samples was higher than critical level (4.5 ppm). The sample number 16 have had the lowest amount of iron content being 6.96 ppm and the sample number 30 had the highest amount of iron content being 12.70 ppm (Table 4).

Table 5: Correlations between Iron content of soil, leaf and grain according to statistics analysis 2005

		Descriptive statics		
		Mean	SD	N
Fe in soil		4.5391	0.821160	23
Fe in leaf		110.5609	24.622440	23
Fe in grain		176.7030	53.088106	23
		Correlations		
		Fe in soil	Fe in leaf	Fe in grain
Fe in soil	Pearson correlations	1.00	0.925**	-0.543**
	Sig. (2-tailed)	0.00	0.00	0.007
	N	23.00	23.00	23.00
Fe in leaf	Pearson correlations	0.925	1.00	-0.547**
	Sig. (2-tailed)	0.00	0.00	0.007
	N	23.00	23.00	23.00
Fe in grain	Pearson correlations	-0.543**	-0.547**	1.00
	Sig. (2-tailed)	0.007	0.007	0.00
	N	23.00	23.00	23.00

**Correlation is significant at the 0.01 level (2-tailed)

Iron Contents of Leaves

Iron content of leaf samples was varied between 69.50 and 156.70 ppm according to results of chemical analysis. Iron contents of all sample leaves are appeared to be lower than critical level being 20 ppm (Table 3). Iron content of leaf sample number 8 was determined as the lowest (69.50 ppm). Also, iron content of soil sample number 8 was determined as the lowest (2.60 ppm). Other hands, iron content of sample number 2 was determined as the highest (156.70 ppm). Also, iron content of soil sample number 2 was determined as the high (5.80 ppm). As seen in the study, iron content of soils does have a direct effect on iron content of leaf (Fig. 4). Also, correlation between iron content of soil and iron content of leaf is significant at the 0.01 level according to statical analysis (Table 5).

Iron content of the leaf samples changing between 138.10 and 518.10 ppm in 2006 was relatively higher compared with values of 2005 (Table 4). Although, iron content of soil samples taken from root area of plants that the leaf samples was collected from was below the critical level (Fig. 5). Therefore, moisturized soil during the development stage of plants enhances bio-utility of iron content in soil. The relation between iron content of soil and leaf in that condition might be explained by the uniformity of rainfall regime and higher amount of precipitation received during the intensive development stage of plants in 2006.

Iron Contents of Grains

The amount of iron content in grain samples changed between 95.00 and 299.50 ppm in 2005 (Table 3). Sample number 12 contained the lowest amount of iron and sample number 9 contained the highest amount of iron. It is stated that zinc content of grain was affected by zinc content of soil, accordingly, when the amount of zinc increases in soil, the amount of zinc in grain also increases (Cakmak *et al*., 1997; Long *et al*., 2004). According to this statement, content of grain sample number 1 collected in 2005 supposed to be higher compared to other grain samples because zinc content of soil sample corresponding to grain sample number 1 was higher than the other soil samples. Zinc content of grain sample 1 was, however, observed quite low compared to zinc content of other grain samples. The case in zinc content of grain sample 1 does not comply with above statement. This can be explained by the relation between zinc content and utilisable P_2O_5 content of soil. Table 1 shows that utilisable P_2O_5 content of soil sample 1 seems to be quite high (178 kg ha^{-1}). High amount of utilisable P_2O_5 in soils generates a disadvantage in terms of zinc uptake and interacts with zinc to limit zinc uptake by plants (Cakmak *et al*., 1997). High P_2O_5 content of grain also impede zinc storage in grain

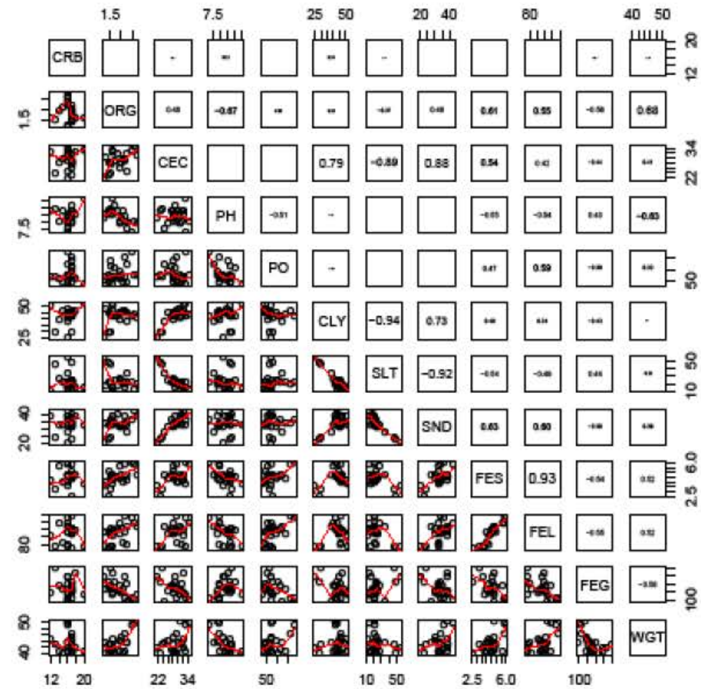

Fig. 2: Correlations between some soil properties and iron contents in 2005 according to statistics analysis

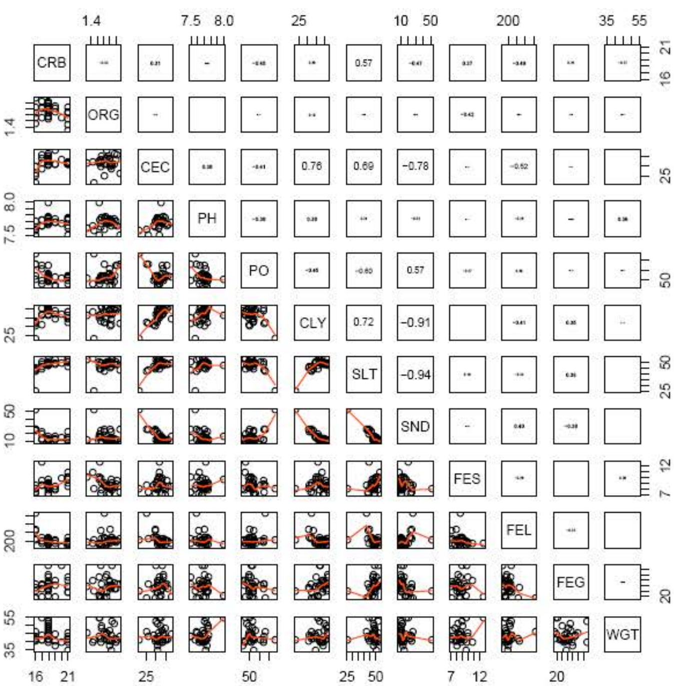

Fig. 3: Correlations between some soil properties and iron contents in 2006 according to statistics analysis

by fitin acid that is a storage form of P_2O_5 in grain. Similar results were observed in other samples and when the utilisable P_2O_5 content of soils increases, zinc content of grain decreases and vise verse. It can be stated that there is a inverse correlation between utilisable P_2O_5 content of soil and zinc content of grain (Fig. 2).

Iron content of the grain samples in 2006 were changed between 11.50 and 134.01 ppm in 2006 was relatively lower compared with values of 2005 (Table 4). Sample number 5 contained the lowest amount of iron and sample number 12 contained the highest amount of iron. While there was a direct relation between iron content of leaves and soil samples, there was a inverse relation between iron content of grain and iron content of leaf in 2006 (Table 4, Fig. 3).

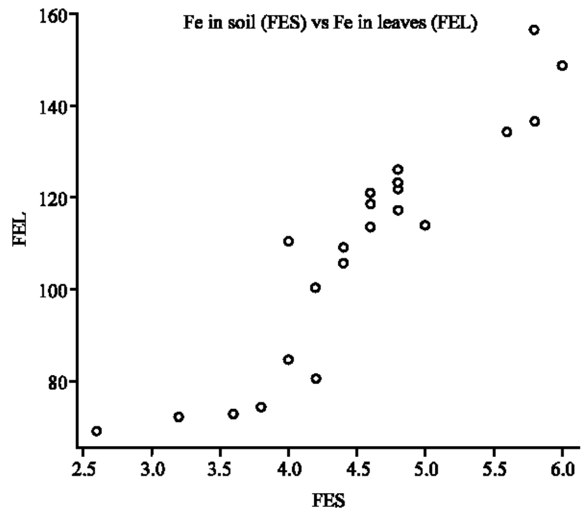

Fig. 4: Correlations between Fe in soil and Fe contents of leaves in 2005

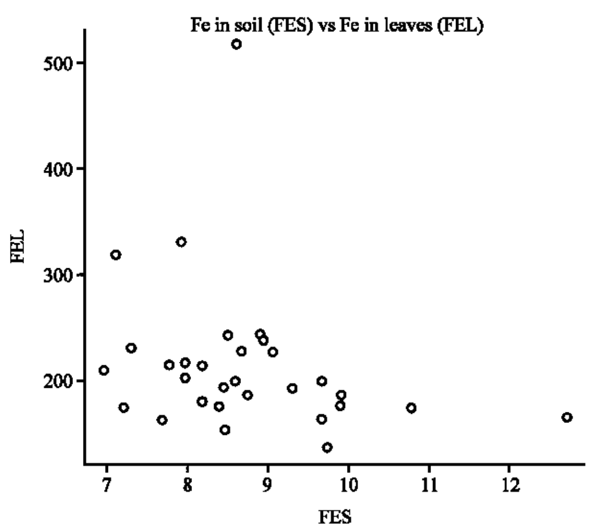

Fig. 5: Correlations between Fe in soil and Fe contents of leaves in 2006

Table 6: Correlations between Iron content of soil, leaf and grain according to statistics analysis 2006

		Descriptive statics		
		Mean	SD	N
Fe in soil		8.7033	1.18759	30
Fe in leaf		215.6467	71.13161	30
Fe in grain		58.4107	30.68698	30
		Correlations		
		Fe in soil	Fe in leaf	Fe in grain
Fe in soil	Pearson correlations	1.00	0.260	0.00
	Sig. (2-tailed)	0.00	0.166	0.999
	N	30.00	30.00	30.00
Fe in leaf	Pearson correlations	-0.26	1.00	-0.332
	Sig. (2-tailed)	0.166	0.00	0.073
	N	30.00	30.00	30.00
Fe in grain	Pearson correlations	0.00	-0.332	1.00
	Sig. (2-tailed)	0.999	0.073	0.00
	N	30.00	30.00	30.00

Correlation between zinc content of grain and P content of grain is significant at the 0.05 level according to statical analysis (Table 6).

REFERENCES

Beebe, S., A.V. Gonzalez and J. Rengifo, 2000. Research on trace minerals in the common bean. Food Nutr. Bull., 21: 387-391.

Black, C.A., 1965. Methods of Soil Analysis. 1st Edn., American Society Agronomy, Madison.

Brown, J.C., J.E. Ambler, R.L. Chaney and C.D. Foy, 1972. Differential Responses of Plantgenotypes to Micronutrients. In: Micronutrients in Agriculture, Mortvedt, J.J. P.M. Giordano and W.L. Lindsay, (Eds.). Soil Science Society, Madison, America, pp: 389-415.

Burton, J.W., C. Harlow and E.C. Theil, 1998. Evidence for reutilization of nodule iron in soybean seed development. J. Plant Nutr., 21: 913-927.

Cakmak, I., H. Ekiz, A. Yilmaz, B. Torun, N. Köleli, I. Gültekin, A. Alkan and S. Eker, 1997. Differential Response of Rye, Triticale, Bread and Durum Wheats to Zinc Deficiency in Calcareous Soils. 1st Edn., Kluwer Academic Publishers, Netherlands.

Charlson, D.V., T.B. Bailey, S.R. Cianzio and R.C. Shoemaker, 2005. Molecular marker satt481 is associated with iron-deficiency chlorosis resistance in a soybean breeding population. Crop Sci., 45: 2394-2399.

Fageria, N.K., V.C. Baligar and R.B. Clark, 2002. Micronutrients in crop production. Adv. Agron., 77: 185-268.

Godsey, C.B., P.S. John, J.S. Alan, K.T. Randal, R.T. Curtis and J.G. Ronald, 2003. Gehl correcting Iron deficiency in corn with seed row-applied Iron sulfate. Agron. J., 95: 160-166.

Goos, R.J. and B. Johnson, 2001. Seed treatment, seeding rate and cultivar effects on iron deficiency chlorosis of soybean. J. Plant Nutr., 24: 1255-1268.

Gregorio, G.B., D. Senadhira, H. Htut and R.D. Graham, 2000. Breeding for trace mineral density in rice. Food Nutr. Bull., 21: 382-386.

Hercberg, S., P. Galan and H. Dupin, 1987. Iron deficiency in Africa. World Rev. Nutr. Diet, 54: 201-236.

Irmak, S., Y. Kasap and A. Surucu, 2007. Effects of town waste on the heavy metal contents and plant nutrient element contents of soils in Harran plain. Turk. Fresenius Environ. Bull., 16-3: 285-289.

Kick, H., H. Burger and K. Sommer, 1980. Gesamt gehalte on Pb, Zn, Sn, As, Hg, Cu, Ni, Cr and Co in landwirtschaftlich and gardnerisch genutzten Böden. Nordrhein-Westfalens. Land. Forschung, 33: 12-22.

Kochian, L.V., 2000. Molecular Physiology of Mineral Nutrient Acquisition, Transport and Utilization. In: Biochemistry and Molecular Biology of Plants, Buchanan, B.B., W. Gruissem and R.L. Jones, (Eds.). Am. Society of Plant Biology, Rockville, pp: 1204-1249.

Long, J.K., M. Bänziger and M. E. Smith, 2004. Diallel analysis of grain iron and zinc density in Southern African-Adapted maize inbreds. Crop Sci., 44: 2019-2026.

McKeague, J.A., 1978. Manual of Soil Sampling and Methods of Analysis. 2nd Edn., Canada Society Soil Science, Ottawa, Canada.

Monasterio, I. and R.D. Graham, 2000. Breeding for trace minerals in wheat. Food Nutr. Bull., 21: 392-396.

Motta, A., B. Basso, M. Dell'Orto, J.F. Briat and C. Soave, 2001. Ferritin synthesis in response to iron in the Fe-inefficient maize mutant years 3. Plant Physiol. Biochem., 39: 461-465.

Nair, K.M., 2001. Alternate strategies for improving iron nutrition: Lessons from recent research. Br. J. Nutr., 85: S187-S191.

Nelson, D.W. and L.E. Sommers, 1996. Total Carbon, Orgnanic Carbon and Organic Matter. In: Methods of Soil Analysis, Sparks, D.L. (Ed.). American Society Agronomy, Madison, pp: 961-1010.

Niebur, W.S. and W.R. Fehr, 1981. Agronomic evaluation of soybean genotypes resistant to iron deficiency chlorosis. Crop Sci., 21: 551-554.

Olsen, S.R., V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of available phosphorus in soils, US Department of Agriculture Circular 939, Washington DC, of Soils in Harran Plain, Turkey. Fresenius Environ. Bull., 16: 285-289.

Romheld, V., 1987. Different strategies for iron acquisition in higher plants. Physiol. Plant., 70: 231-234.

Ronaghy, H.A., 1987. The role of zinc in human nutrition. World Rev. Nutr. Diet, 54: 237-254.

Vempati, R.K. and R.H. Loeppert, 1986. Synthetic ferrihydrite as a potential iron amendment in calcareous soils. J. Plant Nutr., 9: 1039-1052.

Welch, R.M., 2001. Micronutrients, Agriculture and Nutrition: Linkages for Improved Health and Well-being. In: Perspectives on the Micronutrient Nutrition of Crops, Singh, K. (Ed.). Scientific Publishers, Jodhpur, India.

Zhang, C., V. Romheld and H. Marschner, 1996. Remobilization of iron from primary leaves of bean plants grown at various iron levels. J. Plant Nutr., 19: 1017-1028.