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Evaluation of Different Plant Active Iron Extractants under Conditions of Egypt

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IRON status in sixty one soils of Egypt cultivated with corn was studied by determining their total and available (DTPA), iron content, and active iron in plant using different methods by determination of Fe in leaf below and opposites the ear collected at silking stage.

The amount of soil available iron extracted by the DTPA method ranged from 1.48 to 14.80 mg/kg Fe. According to the critical level of available iron in soil (4.5 mg Fe/kg), the data showed that 57% of the tested soils contain adequate quantities, while 23% are within the margin range, and only 20% are deficient.

As regards the concentration of Fe in the dry leaves collected during silking stage from corn plants ranged from 208 to 625 mg/kg Fe. The average values of active iron in leaves extracted by EDTA, DTPA, O-Ph., 2,2' Bip. and HCl were 33.78, 46.95, 65.07, 100.43, and 140.74 mg/kg Fe, respectively.

A highly significant positive correlation coefficient was obtained between the values of plant active iron extracted by any of the five extractants and DTPA-soil available Fe. These results clearly demonstrate that active iron extracted by the five solutions is favorable to be used for separating iron-deficient from non-deficient plants.

The critical values of active iron extracted by EDTA, DTPA, O-Ph., 2, 2'Bip. and HCl were 40.0, 55.00, 80.00, 120.00 and 180.00 mg/kg Fe, respectively. According to these values, 59, 65, 57, 46 and 62% of the soils studied are classified as deficient, respectively. Moreover applying the critical value of Fe soil-DTPA, less than 4.5 mg/kg proved that 43% of the studied soils are in the deficiency range, In this respect, it is obvious that such value coincides well with that obtained by the 2,2'Bip plant active iron (46%). On the other hand, the price of 2,2'Bip is so high (one Kg= 15000 L.E) that makes, from the economical point of view, the use of 2,2' Bip is excluded. Moreover, since the other extractants gave reliable results the EDTA is very suitable according to its low price(one Kg= 40 L.E).

Keywords: Active iron, Corn plant, Egyptian soils, Extractants.

Iron chlorosis is a very common disorder of crops grown in calcareous soils. It is well known that the total iron concentration in leaves is not a valid index for iron nutritional status of crops and that the total iron concentration in chlorotic leaves is often similar or even greater than in the green leaves (Neaman and Aguirre, 2007)

Soil tests provide an indication of nutrient level in the soil and together with plant analysis are important agronomic tools for determining crop nutrient needs. The concentration of an essential element in a field grown plant indicates the soil's ability to supply that nutrient. Nutrient concentrations in the plant are also related to the quantity of the available nutrient in the soil. For iron it is well recognized that soil and plant testing is not very reliable in predicting iron induced chlorosis. For example the concentration of total Fe in iron chlorotic leaves can be higher than in green leaves (Marschner,1995) and although the DTPA extractable soil iron amounts were over the critical concentration range, visual and analytical symptoms of iron chlorosis can be seen on the leaves (Katkat *et al.,* 1994 and Başar, 2000 & Başar, 2005).

It is well known that the total concentration of iron in plant leaves is not a valid index for iron nutritional status of crops and that the total concentration of iron in chlorotic leaves is often similar or even greater than in the green leaves. These discrepancies are related to the localization and binding state of iron in leaves, in which a proportion of iron might be precipitated in the apoplasm of leaves and might not be physiologically available (Römheld, 2000).

Plant analysis is one of the accepted tools for diagnosing deficiency disorders. Deficient plants, if analyzed at the right stage usually contain lower amount of the deficient element than the corresponding healthy checks. Perhaps, iron is the only essential element which often evades this most simple definition of deficiency, since instance is not uncommon when the total content of iron in the chlorotic plants was higher than in the green paints (Römheld, 2000).

Because of poor development of analytical methods for "active iron" analysis, diagnosis of iron deficiency is usually based on visual symptoms and/or positive response to application to iron chelates. However, in addition to iron deficiency, zinc (and in some cases manganese) deficiencies are very common in crops grown in calcareous soils .

Several techniques based on plant tissue analysis have been proposed for diagnosis of iron deficiency in plants **(**Mehrotra *et al.,* 1985**).** Various extractants have been proposed to extract the fraction of total iron, which is metabolically active and is related to occurrence of iron chlorosis. These extractants include water, dilute acids (hydrochloric acid, acetic acid, oxalic acid and citric acid), chelating agents such as EDTA, DTPA, tartaric acid and some organic solvents including 2, 2'Bipyridyi and its derivatives, o-phenanthroline and several other compounds.

1 *M* HCl and 1.5% o-phenanthroline in the fresh leaves and 1 *M* HCl in oven-dried leaves were well related to visual chlorosis ratings and chlorophyll content of the leaves as compared with other methods. The 1 *M* HCl method seemed to be the method of choice for producing a suitable index of Fe status of plants due to lower cost of analysis and ease in handling dry samples. Concentration of Fe determined by this method from green leaves at the midpoint position was generally ≥30 mg kg^{-1}, which may be accepted as the critical index value for Fe in peach trees. Active Fe in the midpoint leaves was markedly and significantly higher than extremity leaves. To sample midpoint leaves may be recommended in determination of active Fe (Başar, 2003).

Several methods for determination of extractable iron (Fe; or so-called "active Fe") have been proposed. Three methods of Fe extraction were tested: 1.5% phenanthroline (pH 3) and 1 M hydrochloric acid (HCl) from fresh leaves, and 1 M HCl from oven-dry leaves. Regressions between the extractable Fe concentrations and the leaf SPAD-color were statistically significant for phenanthroline method, while non-significant for HCl methods (Neaman and Aguirre, 2007).

The aims of the present work are to study the suitability of five chemical extractants to estimate the amount of iron, as an index of iron nutritional status in corn plant tissues which grown in newly reclaimed soils at different levels of available Fe.

Materials and Methods

Sixty one fields cultivated with corn were chosen to represent the most common types of cultivated areas, *i.e.*, the alluvial soils of Nile Delta and reclaimed sandy and calcareous soils Egyptian deserts adjacent to the Nile delta. Each type was represented with the most major texture classes. The studied soils comprised 34 noncalcareous and 27 calcareous soil samples. Plant and surface soil samples were collected from each site. Locations of these samples are given in Fig. 1.

Plant samples

Sixty one samples of the leaf below and opposite the ear just at silting stage of corn plants were collected form the different fields. Each sample included 25 corn plants grown on the same spot from which the composite sample of the soil was taken. The leaves of corn plants were washed in 0.1N HCl, and rinsed several times with redistilled water and then freed from the sticking water drops by sandwiching them between sheets of clean blotting papers. After that, the leaves were cut into small pieces with the help of stainless steel scissors. Two grams of the fresh-chopped subsample were used for active iron determination by using the five extraction solutions.

The rest of the leaf samples were dried in an aerated oven at 70°C to constant weight, ground in porcelain mortar, and preserved in glass containers for analysis of total Fe, K, Ca and P content.

Soil samples

The collected sixty one surface (0 - 30 cm) soil samples were air dried, crushed with wooden mallet, and sieved through a 2 mm stainless steel sieve. Precautions were taken to avoid any contamination. The soil samples were analyzed for total and available iron. Soil texture, total carbonates ($CaCO_3$), pH, EC and organic carbon, were determined in all studied samples.

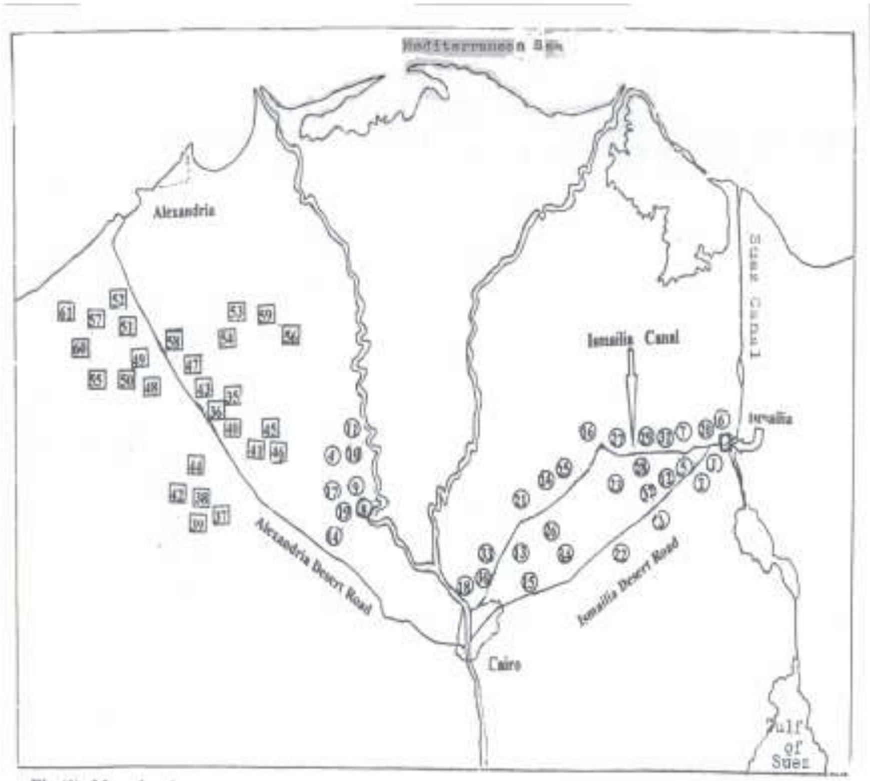

Fig. 1. Locations of the collected soil leaf samples of corn plants.

Active iron

Active iron in the fresh plant materials was determined with five specific reagents as follows:

- O-phenanthroline solution (1.5 %, pH 3.0) (O.Ph) according to the method described by Katyal and Sharma (1984).
- 2,2' Bipyridyl solution (1.5% , pH 7.0) (2,2'Bip.) according to the

method described by Abadia *et al.* (1984).

- 0.1N ethylendiamine tetraacetic acid pH 7.0 (EDTA) according to the method described by Mehrotra *et al.* (1985).
- 0.1N diethylen triamine pentaacetic acid pH 7.0 (DTPA) according to the method described by Mehrotra *et al.* (1985).
- 1.0N HCl according to the method described by Takkar and Kaur (1984).

The procedure involves extraction of 2 g of washed chopped fresh plant material by 20 ml of each of the five solution extractants and Fe^{2+} was determined using atomic absorption spectrophotometer (UNICAM 969 AA).

Total Fe, K, Ca and P

Portions of 0.5 gram of plant material were digested according to the method described by Page *et al.* (1982).Total Fe and Ca were determined in plant digest using atomic absorption Spectrophotometer (Unicam 969 AA). Potassium was determined in plant digest using Flame Photometer as described by Page *et al.* (1982). Phosphorus was determined in plant digest using ascorbic acid method described by Page *et al.* (1982).

Soil analysis

- Mechanical analysis was carried out according to the international pipette method as described by the Agricultural Education Association (Klute, 1986).
- Soil texture index (TI) was calculated using the equation of Sillanpaa (1982) as follows:

TI =1.0 x %clay fraction (>0.002 mm) + 0.3 x %silt fraction (0.002 - 02mm) + 0.1 x %sand fraction (>0.02 mm).

- Organic carbon was determined according to Page *et al.* (1982).
- Total carbonates were estimated according to Heanes (1981).
- pH values were measured in the saturated soil paste by glass electrodes using Beckman pH-meter.
- Electric conductivity of soil paste extract (ECe) was determined according to Page *et al.* (1982).
- Total iron in soil samples was determined Spectrophotometry according to Katyal and Sharma (1980 and 1984)
- Available iron was extracted by DTPA and determined using atomic absorption spectrophotometer according to Lindsay and Norvell (1978).

Results and Discussion

Iron nutritional status in some soils of Egypt was studied based on determination of total iron content, the level of its availability using soil test method and active iron in plant leaves under field conditions.

Since the status of soil iron is controlled by soil physico-chemical characteristics, the experimental materials handled were selected so as to differ as wide as possible. The sixty one soil samples were collected from different locations in Egypt (Fig.1), to represent calcareous and noncalcareous soils, the two abundant soil types in Egyptian soils, each type was represented with the most texture classes. The studied soils comprised 34 noncalcareous and 27 calcareous soil samples (Table1).

TABLE 1. Some characteristics of the studied soils.

Soil No.	Total carbonate content %	pH	O.M %	EC dS/m	Soil No.	$CaCO_3$ %	pH	O M %	EC dS/m
	Noncalcareous soils								
1	2.99	7.82	0.42	2.97	18	2.89	7.90	1.78	2.50
2	2.68	7.90	0.41	4.98	19	5.62	7.72	0.45	4.60
3	3.39	8.00	0.26	2.67	20	2.07	7.85	0.95	3.25
4	2.35	7.90	0.22	2.70	21	2.38	7.82	0.54	5.00
5	2.24	7.92	0.23	2.20	22	6.69	7.70	1.64	2.50
6	2.86	8.00	2.27	4.80	23	2.90	7.80	0.89	8.48
7	1.08	7.98	0.08	2.86	24	4.62	7.90	1.58	5.30
8	1.26	7.84	0.20	2.38	25	3.01	7.71	0.89	6.82
9	3.45	7.83	0.18	3.29	26	1.57	7.90	1.24	1.56
10	1.61	7.30	0.21	1.93	27	2.98	7.80	2.26	2.92
11	3.98	7.90	1.49	2.42	28	2.30	7.70	0.18	2.41
12	2.30	7.80	1.25	1.31	29	2.91	7.81	0.79	7.10
13	1.80	7.80	0.13	1.78	30	2.87	7.93	1.50	6.84
14	4.98	7.90	1.10	2.93	31	4.63	7.80	1.38	2.95
15	2.00	7.60	1.20	1.48	32	1.70	7.70	0.89	1.78
16	0.80	8.00	1.03	1.46	33	2.88	7.90	2.78	3.65
17	1.45	7.77	0.60	5.48	34	3.40	7.68	1.40	2.54
	Calcareous soils								
35	11.65	8.10	0.40	1.40	49	8.50	7.95	0.38	2.86
36	8.34	8.10	0.50	0.78	50	14.20	7.99	0.55	3.87
37	9.77	7.60	0.51	1.71	51	20.00	7.98	2.23	4.98
38	8.29	7.70	0.53	0.78	52	28.29	7.84	2.50	4.55
39	10.82	7.80	0.49	0.88	53	30.42	8.10	2.34	4.63
40	9.28	7.90	0.25	1.62	54	39.80	8.20	0.60	0.93
41	9.34	7.90	0.35	3.75	55	37.08	8.01	1.40	4.58
42	11.42	7.90	0.37	5.46	56	26.89	7.98	1.59	3.85
43	15.48	7.93	2.57	2.34	57	35.42	7.94	1.52	3.41
44	9.52	7.70	0.45	5.93	58	28.75	7.92	1.67	3.50
45	9.52	7.80	0.46	6.71	59	19.38	8.10	2.56	5.98
46	10.55	7.80	0.68	7.34	60	28.95	7.88	1.12	4.82
47	16.00	7.80	0.87	2.15	61	8.96	8.10	0.63	2.80
48	30.58	7.98	0.95	2.55					

Calcium carbonate content of the noncalcareous soils ranged from 0.80 to 6.69%, while that of the calcareous soils showed a range from 8.29 to 39.80% (Table1). All studied soil samples are alkaline with pH values ranged from 7.30 to 8.20.

Organic matter content of the studied soils varied widely and ranged from 0.08 to 2.78% (Table 1). The fine-textured soils showed relatively high values of organic matter content as compared with coarse-textured soils.

Most of the soils were nonsaline with EC values less than 4 dS/m at 25^{o}C. Only nine soil samples in the noncalcareous group and 10 soil samples in the calcareous group showed relatively higher EC values that ranged from 4 - 8 dS/m at 25^{o}C. One soil sample in noncalcareous group showed an EC value higher than 8dS/m at 25^{o}C.

Wide variations in texture were found among the studied soils of the same group (Table 2). Noncalcareous soils comprised of two clay, 8 sandy clay loam, 4 sandy loam, 5 loamy sand and 15 sandy soil samples. The calcareous soils included one loamy soil, 10 sandy clay loam, 5 sandy loam, 5 loamy sand and 6 sandy soil samples.

TABLE 2. Particle size distribution of the studied soil samples.

Soil No.	Coarse sand %	Fine sand %	Silt %	Clay %	Texture index (TI)	Texture class
Noncalcareous soils						
1	72.80	24.95	2.15	0.10	10.52	S.
2	60.00	38.95	0.55	0.50	10.56	S.
3	58.35	40.00	1.00	0.65	10.79	S.
4	50.85	47.25	1.30	0.60	10.80	S.
5	65.00	32.45	2.05	0.50	10.86	S.
6	68.00	29.40	2.10	0.50	10.87	S.
7	50.10	47.10	2.30	0.50	10.91	S.
8	55.30	42.10	2.00	0.60	10.94	S.
9	60.90	35.40	3.30	0.40	11.02	S.
10	63.46	34.30	1.40	0.84	11.04	S.
11	50.65	45.80	3.00	0.55	11.10	S.
12	74.92	22.52	1.56	1.00	11.21	S.
13	51.80	43.50	3.50	1.20	11.78	S.
14	48.85	42.84	5.66	2.65	13.52	S.
15	65.20	24.80	5.50	4.50	15.15	S.
16	54.60	26.00	15.20	4.20	16.82	L.S
17	71.24	18.59	2.56	7.61	17.36	L.S
18	69.92	12.80	9.74	7.54	18.73	L.S
19	57.98	24.97	8.60	8.45	19.33	L.S
20	66.09	19.46	5.02	9.43	19.49	L.S

TABLE 2. Cont.

Soil No.	Coarse sand %	Fine sand %	Silt %	Clay %	Texture index (TI)	Texture class
21	50.06	25.23	16.07	8.64	20.99	S.L
22	67.63	12.42	7.53	12.42	22.68	S.L
23	50.27	18.67	17.84	13.22	25.47	S.L
24	51.38	22.11	11.75	14.78	25.63	S.L
25	49.16	17.49	12.20	21.15	31.48	S.C.L
26	45.94	20.71	11.20	22.15	32.18	S.C.L
27	40.88	19.91	18.37	20.86	32.45	S.C.L
28	33.60	21.90	21.50	23.00	35.00	S.C.L
29	46.51	17.14	9.49	26.86	36.07	S.C.L
30	45.18	15.44	10.42	28.96	38.15	S.C.L
31	31.33	24.62	12.72	31.33	40.74	S.C.L
32	15.10	34.00	18.40	32.50	42.93	S.C.L
33	12.32	13.66	32.15	41.87	54.11	C.
34	17.70	18.06	12.61	51.63	58.99	C.
Calcareous soils						
35	60.30	36.90	2.20	0.60	10.98	S.
36	60.40	36.30	2.20	1.10	11.43	S.
37	67.50	27.80	3.90	0.80	11.50	S.
38	65.00	30.50	3.40	1.10	11.67	S.
39	51.90	41.60	5.80	0.70	11.79	S.
40	70.10	26.00	2.45	1.45	11.80	S.
41	50.70	33.50	11.50	4.30	16.17	L.S
42	57.40	24.50	11.90	6.20	17.96	L.S
43	52.72	32.46	7.16	7.66	18.33	L.S
44	50.20	29.50	10.20	10.10	21.13	L.S
45	53.80	17.60	20.20	8.40	21.60	L.S
46	41.80	33.90	13.50	10.80	22.42	S.L
47	21.43	49.34	13.93	15.30	26.56	S.L
48	28.44	41.89	12.68	16.99	27.83	S.L
49	25.95	30.00	30.05	14.00	28.61	S.L
50	34.80	25.80	23.60	15.80	28.94	S.L
51	7.72	46.11	26.84	19.33	32.77	S.C.L
52	9.33	47.83	20.19	22.65	34.42	S.C.L
53	17.14	37.87	22.79	22.20	34.54	S.C.L
54	22.18	39.35	13.85	24.62	34.93	S.C.L
55	18.28	32.62	26.62	22.48	35.56	S.C.L
56	16.76	37.28	22.25	23.71	35.79	S.C.L
57	7.70	44.20	24.65	23.45	36.04	S.C.L
58	5.94	46.96	20.16	26.94	38.28	S.C.L
59	15.85	36.42	19.97	27.76	38.98	S.C.L
60	5.97	43.90	22.40	27.73	39.44	S.C.L
61	21.55	17.20	36.25	25.00	39.75	L.

S. : Sandy
L.S : Loamy sand
S.L : Sandy loam
S.C.L : Sandy clay loam
L : Loamy
C. : Clay

Total iron in the studied soils

Values of total iron content in the 61 studied soil samples ranged from 0.18 to 4.88%, with an average value of 1.65% (Table 3). The highest values are recorded for the heavy textured soil, whereas the lowest ones belonged to the sandy soils. The calcareous soils lie in between, but they were closer to sandy than to the heavy soils. Almost similar range values of total iron were reported for Egyptian soils by El-Sayad (1983), El-Rais (1984) and Abou-Yossef (1988).

TABLE 3. Total and available iron extracted by DTPA in the studied soils.

Soil Sample No.	Total Fe %	Available Fe (mg/kg)	Soil Sample No.	Total Fe %	Available Fe (mg/kg)
Noncalcareous Soils					
1	0.18	2.72	18	1.84	5.42
2	0.69	3.10	19	0.84	5.50
3	0.55	4.12	20	0.94	5.20
4	0.50	3.20	21	1.88	6.12
5	0.36	2.38	22	2.20	6.32
6	0.73	3.20	23	2.68	5.99
7	0.32	2.24	24	2.23	14.80
8	0.45	2.60	25	2.87	7.14
9	0.23	2.61	26	2.63	8.78
10	0.80	2.40	27	3.50	12.08
11	0.54	4.40	28	3.04	3.56
12	0.84	6.30	29	0.89	6.45
13	0.63	2.18	30	3.68	6.65
14	0.63	4.45	31	3.87	7.14
15	1.16	6.94	32	3.27	4.18
16	1.46	11.26	33	4.88	7.39
17	0.89	4.56	34	4.50	7.66
Calcareous Soils					
35	0.50	1.64	49	1.58	7.90
36	0.54	3.04	50	1.48	8.31
37	0.79	1.48	51	2.30	9.06
38	0.72	2.26	52	2.40	9.74
39	0.52	1.68	53	0.95	10.03
40	0.82	3.25	54	2.45	12.85
41	1.16	1.70	55	2.31	13.50
42	1.51	1.80	56	2.45	13.74
43	0.75	8.78	57	1.90	13.91
44	1.59	2.12	58	1.94	12.01
45	2.12	2.80	59	2.57	13.60
46	1.65	2.28	60	2.31	10.30
47	2.13	8.91	61	3.40	12.22
48	0.95	9.30			

It is well known that the total concentration of iron in plant leaves is not a valid index for iron nutritional status of crops and that the total concentration of iron in chlorotic leaves are often similar or even greater than in the green leaves. These discrepancies are related to the localization and binding state of iron in leaves, in which a proportion of iron might be precipitated in the apoplasm of leaves and might not be physiologically available (Römheld, 2000).

The range and average values of total iron and its correlation coefficients with soil characteristics in the different soil types are given in Table 4. The data showed that the variations in the total iron content of the studied soils were due to variations in soil texture and organic matter content. A highly significant correlation was found between total iron and both soil texture index (TI) and organic matter content (OM %). Based on correlation coefficient of simple effect of either texture index or organic matter on total iron content, it could be concluded that the former contributed by 76% and the latter by 34% of the variation in total iron content in the all soils. The texture has more influence than organic matter content on the total iron content of the soils (Fig. 2).

TABLE 4. Range and average of total soil Fe (%) and simple correlation coefficient with some soil characteristics in the different soil types.

	All soils (61)	**Noncalcareous soils (34)**	**Calcareous soils (27)**
Range	0.18 - 4.88	0.18 - 4.88	0.50 - 3.40
Average	1.65	1.67	1.62
Simple correlation coefficient (r)			
OM %	0.58**	0.70**	0.41*
Texture Index	0.87**	0.92**	0.82**
Clay %	0.87**	0.90**	0.80**
Silt %	0.68**	0.83**	0.78**
C.Sand %	-0.60**	-0.74**	-0.72**
F.Sand %	-0.39**	-0.57**	-0.04
$CaCO_3$ %	0.09	0.12	0.39*
EC	0.23	0.1`3	0.46*

* : significant at 5% level of probability.
** : significant at 1% level of probability

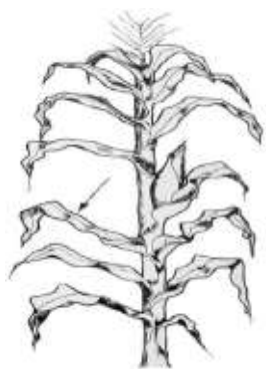

Fig .2. Corn leaves samples: leaf below and opposite ear were submit to analysis.

Multiple regression relating the total iron to texture index value (TI) and organic matter content (OM %) of all studied soils yielded the following equation :

Total Fe (%) = - 0.31 + 0.08(TI) + 0.007(OM %)

The multiple correlation coefficient (R=0.87**) was highly significant, this means that 75.69% of the variations in total iron content of the studied soils could be attributed to the variations in texture index value and organic matter content. The finer the texture and the higher the organic matter content, the higher the total iron content in studied soil samples.

Available iron in the studied soils

Data of DTPA-extractable available soil iron are given in Table 3. The range and average values of DTPA-Fe are given in Table 5. It was observed that the values of DTPA-extractable iron ranged from 1.48 to 14.80 mg/kg in all studied soils with an average value of 6.18 mg/kg. The amount of available Fe extracted by the DTPA solution increased with increasing the organic matter, clay or silt content in soils. A significant positive correlation was obtained between DTPA extractable iron and the organic matter, clay and silt contents in all soils (noncalcareous and calcareous soil) (Table 4).

TABLE 5. Range and average of available Fe (mg/kg) and simple correlation coefficient with some soil characteristics in the different soil types.

	All soils (61)	**Noncalcareous soils (34)**	**Calcareous soils (27)**
Range	**1.48 - 14.80**	**2.18 - 14.80**	**1.48 - 13.91**
Average	**6.18**	**5.56**	**7.34**
Simple correlation coefficient (r)			
OM %	0.59**	0.54**	0.66**
Texture Index	0.62**	0.41*	0.90**
Clay %	0.59**	0.39*	0.91**
Silt %	0.64**	0.48**	0.70**
C.Sand %	-0.63**	-0.16	-0.87**
F.Sand %	-0.03	-0.56**	-0.37
$CaCO_3$ %	-0.58**	0.20	-0.77**
EC	0.11	0.14	0.10
Fe %	0.34**	0.51**	0.67**

These soil characteristics are the main factors corresponding to the highly significant positive correlation between DTPA extractable iron and texture index (TI). The obtained correlation coefficient values in the present study mean that 40.96% of the variation in DTPA-extractable iron is due to the silt content, and only 34.81% to the clay content or organic matter in all studied soils. Similar results are reported by Abadia *et al.* (1980) and El-Sayad (1983), who found that a significant positive correlation between the DTPA-extractable Fe and either organic matter content or clay content. The most common extractants are, perhaps, 1.5% phenanthroline (pH 3) and/or 1 N hydrochloric acid (HCl) solutions used for analysis of fresh or dry leaves. (Sönmez and Kaplan, 2004).

There was a significant positive correlation coefficient between iron extracted by DTPA of all studied soils (noncalcareous and calcareous) and total iron content in soils.

Multiple regressions relating the DTPA-extractable Fe to the organic matter content and texture index value of 61 studied soils yielded the following equation:

DTPA-extractable Fe (mg/kg) = 0.85 +1.95(O.M. %) + 0.14(TI)

The multiple correlation coefficient ($R= 0.72^{**}$) was highly significant. This mean that 52% of the variations in the extractable Fe by DTPA of the studied soils cloud be accounted for variations in organic matter content and texture index value.

According to the critical levels reported by Lindsay and Norvell (1978), the data in Table 3 and Fig. 4 of DTPA-available Fe levels showed that 57% (35 samples out of the 61 tested samples) are adequate (containing > 4.5 ppm DTPA-extractable Fe), while only 23% (14 samples) are within the margin range (containing 2.5 - 4.5 mg/kg DTPA-extractable Fe), and only 20% (12 samples) are deficient (containing < 2.5 mg/kg DTPA-extractable Fe). The deficient soils are those sandy in texture and poor in organic matter of either calcareous or noncalcareous soil type. Similar results were reported by Abou-Yossef (1988).

Total iron in plant

The concentration of Fe in dry leaf below and opposite the ear collected during silking stage from corn plants grown on the same soils from which soil samples were taken is presented in Table 6. The iron concentration in the leaves ranged from 208 to 625 mg/kg with an average of 339.69 mg/kg for all the studied soils.

The plants grown on noncalcareous soils had iron concentration in the leaves that ranged from 228 to 570 mg/kg with an average of 348.9 mg/kg, being in the same magnitude to those plants grown on calcareous ones which showed concentrations ranged from 208 to 625 mg/kg with an average of 328.1 mg Fe /kg.

Correlation coefficients relating the available iron in soil samples with total iron concentration in the leaves are often used as a criterion by which Fe soil test is evaluated. In this respect, the present study indicated that there was no relation between total iron content of the leaves and the available iron of the soil. Correlation coefficients obtained in this study failed to correlate with total Fe in leaves (Table 7).

TABLE 6. Total Contents of Fe, K, Ca and P and K/Ca ratio in the leaves below and opposite the ear collected at silking stage from corn plants in the different soil types.

sample No.	Fe (mg/kg)	K %	Ca %	P %	K/Ca ratio	sample No.	Fe (mg/kg)	K %	Ca %	P %	K/Ca ratio
Noncalcareous soils											
1	310.00	3.03	0.36	1.39	8.50	18	365.00	2.57	0.56	0.97	4.57
2	229.00	3.20	0.30	1.31	10.86	19	328.00	2.28	0.61	1.44	3.74
3	230.00	2.54	0.56	1.37	4.57	20	320.00	2.97	0.48	1.32	6.18
4	228.00	3.74	0.38	1.37	9.75	21	345.00	2.71	0.67	1.25	4.07
5	340.00	2.86	0.31	1.40	9.12	22	365.00	2.63	0.46	1.00	5.76
6	320.00	3.17	0.21	0.98	15.45	23	329.00	2.19	0.58	1.14	3.76
7	290.00	2.93	0.33	1.44	9.02	24	328.00	2.10	0.53	1.11	4.00
8	330.00	2.85	0.21	1.37	13.33	25	412.00	2.08	0.46	1.20	4.50
9	390.00	2.02	0.24	1.44	8.60	26	379.00	2.37	0.44	1.14	5.38
10	570.00	2.19	0.39	1.42	5.65	27	319.00	2.37	0.47	0.82	5.05
11	229.00	2.49	0.45	1.32	5.53	28	303.00	2.41	0.35	1.25	6.89
12	460.00	1.90	0.55	1.00	3.48	29	370.00	3.33	0.36	1.74	9.17
13	502.00	2.59	0.22	1.43	11.82	30	372.00	2.08	0.40	1.10	5.20
14	310.00	2.48	0.55	1.44	4.51	31	422.00	2.49	0.50	1.09	5.03
15	441.00	2.35	0.44	0.87	5.31	32	262.00	2.30	0.44	1.10	5.18
16	330.00	2.28	0.45	1.05	5.10	33	450.00	2.36	0.61	0.92	3.86
17	360.00	3.09	0.67	1.36	4.62	34	424.00	2.68	0.55	1.31	4.87

TABLE 6. Cont.

sample No.	Fe (mg/kg)	K %	Ca %	P %	K/Ca ratio	sample No.	Fe (mg/kg)	K %	Ca %	P %	K/Ca ratio
Calcareous soils											
35	448.00	2.66	0.26	0.92	10.43	49	225.00	2.84	0.71	1.53	3.98
36	227.00	3.06	0.35	1.53	8.83	50	208.00	3.31	0.60	1.57	5.49
37	235.00	2.85	0.20	1.29	14.04	51	298.00	3.33	0.51	1.22	6.50
38	286.00	2.80	0.18	1.58	15.48	52	340.00	2.56	0.41	1.20	6.20
39	240.00	3.81	0.19	1.56	19.83	53	408.00	3.16	0.77	1.58	4.11
40	230.00	2.29	0.45	1.21	5.13	54	338.00	2.48	0.30	1.18	8.38
41	481.00	2.20	0.18	1.29	12.23	55	264.00	3.79	0.69	1.51	5.47
42	315.00	2.93	0.29	1.96	10.13	56	460.00	3.46	0.33	1.39	10.52
43	365.00	2.02	0.60	1.39	3.36	57	347.00	3.80	0.41	1.56	9.24
44	278.00	3.61	0.33	1.14	10.98	58	380.00	3.64	0.51	1.53	7.18
45	625.00	3.16	0.24	1.46	13.47	59	425.00	3.10	0.61	1.25	5.12
46	239.00	3.00	0.23	1.00	13.08	60	316.00	3.33	0.46	1.59	7.22
47	238.00	2.92	0.44	1.30	6.64	61	323.00	1.95	0.69	1.37	2.83
48	320.00	2.86	0.55	1.66	5.24						

TABLE 7. Range and average of total Fe content (mg/kg) in the leaves below and opposite the ear collected at silking stage from corn plants, and simple correlation coefficient with some soil characteristics, K, Ca, P and K/Ca ratio in the different soil types.

	All soils (61)	**Noncalcareous soils (34)**	**Calcareous soils (27)**
Range	208 - 625	228 - 570	208 - 625
Average	339.69	348.88	328.11
Simple correlation coefficient (r)			
Available Fe	0.07	0.08	0.11
O M	0.22	0.22	0.22
Texture Index	0.24	0.35*	0.16
Clay	0.25*	0.36*	0.16
Silt	0.11	0.36*	0.13
$CaCO_3$	-0.02	0.22	0.14
K	0.25*	0.41*	0.14
Ca	0.07	0.04	0.08
P	0.12	0.08	0.08
K/Ca	-0.04	-0.12	0.07

The contradiction between the soil test method and plant analysis results can explain the effect of some soil factors which enhanced Fe content by plants. Aydin *et al.* (1989) reported that antagonistic and synergistic relationships between nutrients should be considered in interpreting plant analysis. Allen and David, (2007) stated that the high nutrient content in plants may result primarily from the optimum uptake conditions and to a lesser degree from the high nutrient content of soil. Iron concentration in plant was not a good reliable index of iron deficiency in soils. Therefore, in the present work calibration of the soil testing method and estimation of critical levels of either soil test method or plant analysis were taken in consideration (Allen and David, 2007).

Active iron

Active iron estimation methods mentioned above were used to extr iron in plant leaf samples. Active iron technique was carried out to evaluate the ability of the plant analysis to separate Fe deficient from non-defic

Data of extractable active iron in the five above mentioned methods are given in Table 8. The range and average values of the active iron of each extractant solution are given in Table 9. The EDTA solution extracts the lowest amount, while the hydrochloric acid solution extracted the highest one. According to the extractability power of the extractant solutions, the five solutions have the ascending order; EDTA < DTPA < O.Ph, <2,2'Bip. < HCl.

TABLE 8. Active iron (mg/kg) extracted by different methods from the leaf below and opposite the ear collected at silking stage of corn plants grown in different soil type.

Soil No.	Active iron (mg/kg)				
	EDTA	DTPA	O-Ph.	2,2Bip	HCl
	Noncalcareous soils				
1	25.86	45.18	50.45	57.61	79.73
2	32.62	42.13	44.88	60.63	99.94
3	38.45	47.35	60.00	92.40	123.15
4	29.62	43.67	45.25	78.26	78.61
5	20.57	30.20	15.02	44.67	72.93
6	35.60	48.00	45.87	76.19	109.45
7	20.53	28.29	25.09	39.87	5.84
8	28.08	40.51	45.91	64.68	77.42
9	29.99	38.68	44.93	8.08	71.20
10	24.20	29.00	22.25	42.68	68.00
11	38.81	50.35	79.00	100.32	154.50
12	40.00	55.00	88.32	114.40	167.00
13	16.17	25.00	23.50	31.24	60.00
14	35.18	50.53	75.01	105.30	140.50
15	38.50	52.50	80.27	127.68	178.00
16	43.55	65.28	84.23	136.84	183.00
17	39.33	50.98	76.51	110.26	130.57
18	41.97	55.59	83.63	114.17	166.08
19	39.24	54.24	79.63	121.74	160.90
20	38.20	53.94	84.58	117.21	153.74
21	39.05	50.56	79.68	122.43	170.55
22	39.87	59.07	85.00	125.76	184.86
23	38.84	53.84	78.36	126.16	182.75
24	45.44	53.71	84.80	118.66	213.57
25	35.26	52.11	83.65	124.99	183.15
26	37.20	62.72	77.00	127.78	165.20
27	37.85	55.92	79.50	133.02	221.47
28	37.54	45.54	58.00	102.96	119.54
29	41.27	52.41	75.51	131.45	180.07
30	39.86	57.91	83.61	123.75	190.87
31	38.26	56.11	83.30	119.14	192.15
32	35.50	51.50	70.20	101.52	133.50
33	42.96	58.69	80.30	127.38	174.26
34	39.64	54.31	2.00	125.51	186.47
35	7.65	9.00	13.00	16.80	31.00
36	29.50	38.00	38.00	47.96	85.50
37	8.29	8.49	17.00	19.44	45.00
38	18.00	22.17	34.00	35.20	45.00
39	8.59	10.23	15.00	17.44	37.00

TABLE 8. Cont.

Soil No.	Active iron (mg/kg)	Soil No.	Active iron (mg/kg)	Soil No.	Active iron (mg/kg)
Calcareous soils					
40	31.50	48.00	50.50	87.84	120.19
41	10.49	11.19	16.00	19.76	52.00
42	12.17	11.89	18.00	20.64	45.50
43	40.45	60.55	90.50	120.12	200.00
44	13.96	16.24	42.50	40.92	48.50
45	32.00	33.50	38.50	46.60	86.00
46	23.05	36.00	32.00	23.76	76.00
47	42.84	52.84	86.00	123.63	206.16
48	40.77	60.29	79.15	125.74	209.01
49	38.32	57.85	93.44	135.69	198.41
50	43.48	58.74	84.80	127.13	173.60
51	38.20	54.99	79.36	122.05	237.27
52	41.79	63.63	95.00	131.11	182.13
53	42.44	53.44	100.00	128.35	194.14
54	40.00	55.00	82.50	132.56	170.00
55	42.50	64.69	80.10	132.56	200.03
56	41.79	61.35	88.40	135.19	192.13
57	39.38	58.68	90.05	128.19	182.55
58	44.62	62.18	88.58	132.78	197.07
59	44.47	60.77	87.91	147.49	181.15
60	38.04	59.04	88.23	119.24	179.94
61	41.14	53.55	85.33	135.11	180.92

TABLE 9. Range and average values of extractable active iron (mg/kg) extracted in different methods from the leaf below and opposite the ear collected at silking stage from corn plants grown in different soil type.

Extractant	Soil type	Rang	Average
EDTA			
	AS	7.65 - 45.44	33.78
	NCS	16.17 - 45.44	35.44
	CS	7.65 - 44.62	31.68
DTPA			
	AS	8.49 - 65.28	46.95
	NCS	25.00 - 65.28	49.17
	CS	8.49 - 64.69	44.16
		13.00 - 100.00	65.07
	AS		
	NCS	15.02 - 88.32	59.48
	CS	13.00 - 100.00	63.48
	AS	16.80 - 147.49	100.43
	NCS	31.24 - 136.84	89.25
	CS	16.80 - 147.49	90.86
HCl			
	AS	31.00 - 237.27	140.74
	NCS	55.84 - 221.47	142.03
	CS	31.00 - 237.27	139.12

AS : All soils (61 samples).
NCS : Noncalcareous soils (34 samples).
CS : Calcareous soils (27 samples).

The values of leaf EDTA active iron ranged from 7.65 to 45.44 mg/kg with an average value of 33.78 mg/kg. Those of the DTPA ranged from 8.49 to 65.28 mg/kg with an average value of 46.95 mg/kg. The amount extracted in O-Ph ranged from 13.00 to 100.00 mg/kg with an average value of 65.07 mg/kg. Corresponding range for 2,2'Bip was from 16.80 to 147.49 with an average value of 100.43 mg/kg. While, that of HCl extractant was from 31.00 to 237.27 mg/kg with an average value of 140.74 mg/kg.

It is of interest to mention that the average values of each extractant were similar in both noncalcareous and the calcareous soils.

From the statistical point of view, high significant correlations were obtained between plant active iron extracted using the five extractant solutions and each of DTPA-soil available Fe, total iron, organic matter, clay and silt contents of the soil (Table 10). Noncalcareous and calcareous soils behaved the same in this connection.

Regarding to the relations between leaf active iron and both leaf Ca content and K/Ca ratio, highly positive correlation was obtained for former and a negative one for the latter (Table 11). However, no relation was obtained between leaf-active iron and either its total iron and potassium content.

No positive correlation coefficients were obtained between plant active iron extracted using of the five methods and each other's (Table 12).

The multiple regression equations between the different extractants and some soil properties and chemical composition of the leaves were calculated. The multiple correlation coefficients are presented in Table 13. These data illustrate that 70.60, 72.25, 79.21, 82.80, and 84.60% of the variations in the values of leaf extractable active iron by EDTA, DTPA, O-Ph, 2,2' Bip. and HCl, respectively, could be accounted for variations in organic matter, available soil Fe, texture index value, pH, EC, $CaCO_3$, K, Ca, P and Fe concentration in leaf.

The values of DTPA - extractable soil iron (available) are calibrated against the values of the plant leaves active iron content extracted by the different extractants to find out the critical concentration of plant active iron. The ability of the different active iron extractants to separate Fe deficient from non-deficient plants according to DTPA-soil test is illustrated in equations (1- 5).

TABLE 10. Correlation coefficients between active iron extracted in the leaf below and opposite the ear collected at silking stage from corn plants by different methods as well as some soil characteristics.

Soil type	Soil characteristic						
	Available Fe (mg/kg)	**Total**	**O.M.%**	**$CaCO_3$%**	**Clay%**	**Silt%**	**TI**
EDTA extractable active Fe							
AS	0.73**	0.43*	0.51*	0.21	0.51**	.0.44**	0.52**
NC	0.69**	0.44**	0.50**	0.34	0.38*	0.43**	0.39*
CS	0.87**	0.57**	0.59**	0.59**	0.79**	0.66**	0.79**
DTPA extractable active Fe							
AS	0.76**	0.43**	0.50**	0.24	0.51**	0.46**	0.53**
NC	0.71**	0.48**	0.51**	0.30	0.39*	0.42**	0.40*
CS	0.88**	0.58**	0.58**	0.61**	0.80**	0.66**	0.80**
O-Ph. extractable active Fe							
AS	0.79**	0.46**	0.52**	0.30*	0.55**	0.50**	0.56**
NC	0.69**	0.46**	0.40*	0.36*	0.39*	0.39*	0.40*
CS	0.90**	0.56**	0.64**	0.64**	0.84**	0.69**	0.84**
2,2'Bip extractable active Fe							
AS	0.81**	0.50**	0.53**	0.59**	0.52**	0.60**	0.60**
NC	0.74**	0.54**	0.48**	0.30	0.48**	0.52**	0.50**
CS	0.93**	0.59**	0.61**	0.65**	0.84**	0.69**	0.84**
HCl extractable active Fe							
AS	0.84**	0.53**	0.59**	0.33**	0.59**	0.55**	0.61**
NC	0.85**	0.60**	0.57**	0.38*	0.50**	0.51**	0.52**
NC	0.88**	0.54**	0.63**	0.63**	0.80**	0.79**	0.80**

TABLE 11. Correlation coefficient between extractable active iron in the leaf below and opposite the ear collected at silking stage from corn plants by different methods and each of total iron (mg/kg), K (%), Ca(%), P (%) and K/Ca ratio in the ear leaf of corn plant at silking stage.

	Simple Correlation Coefficient (r)				
Soil type	**Total Fe (mg/kg)**	**K (%)**	**Ca (%)**	**P (%)**	**K/Ca ratio**
EDTA extractable active Fe					
AS	-0.01	-0.12	0.71**	-0.14	-0.71**
NCS	-0.14	-0.28	0.65**	-0.48**	-0.60**
CS	0.04	0.05	0.75**	0.14	-0.76**
DTPA extractable active Fe					
AS	-0.03	-0.12	0.70**	-0.17	-0.71**
NCS	-0.11	-0.27	0.59**	-0.55**	-0.58**
CS	-0.03	0.03	0.76**	0.10	-0.78**
O-Ph. extractable active Fe					
AS	-0.01	-0.14	0.76**	-0.15	-0.73**
NCS	-0.04	-0.36*	0.70**	-0.48**	-0.67**
CS	-0.01	0.07	0.79**	0.12	-0.77**
2,2'Bip extractable active Fe					
AS	-0.04	-0.13	0.75**	-0.16	-0.75**
NCS	-0.01	-0.33*	0.67**	-0.46*	-0.67**
CS	-0.01	0.05	0.79**	0.11	-0.79**
HCl extractable active Fe					
AS	0.01	-0.13	0.72**	-0.17	-0.71**
NCS	0.05	-0.40*	0.63**	-0.56**	-0.67**
NC	-0.02	0.06	0.78**	0.12	-0.78**

TABLE 12. Correlation coefficient between active iron extracted by different methods in leaf below and opposite the ear collected at silking stage from corn plants in the different soil types.

Simple correlation coefficient				
	EDTA	**DTPA**	**O-Ph.**	**2,2'Bip**
All soils (61)				
HCl	0.89**	0.90**	0.93**	0.94**
2,2'Bip	0.93**	0.94**	0.96**	
O-Ph.	0.91**	0.92**		
DTPA	0.96**			
Noncalcareous soils (34)				
HCl	0.86**	0.87**	0.91**	0.93**
2,2'Bip	0.91**	0.93**	0.93**	
O-Ph.	0.90**	0.93**		
DTPA	0.90**			
Calcareous soils (27)				
HCl	0.93**	0.94**	0.95**	0.96**
2,2'Bip	0.94**	0.95**	0.97**	
O-Ph.	0.94**	0.94**		
DTPA	0.97**			

TABLE 13. Multiple regression equation and correlation coefficient (R) of all extractants as related to some soil properties and chemical composition of the leaves.

Method of active iron	Multiple Correlation Coefficient	
	Multiple regression equation	R
EDTA	y = 1.87 +1.08OM% +1.49available Fe + 0.15 Texture Index +2.52pH + 0.40EC -0.18$CaCO_3$% -1.70K in leaves % +23.11 Ca in leaves % -1.54 in leaves P% - 0.01total Fe in leaves (ppm)	0.84**
DTPA	y = 0.27 + 0.36 OM% + 2.37 available Fe + 0.37 Texture Index + 5.11 pH + 0.22 EC - 0.21 CaCO3% - 2.88 K in leaves %+ 30.84 Ca in leaves % -7.61 P in leaves % - 0.02 total Fe in leaves (ppm)	0.85**
O-Ph.	y = 145.67 + 1.15 OM% + 3.68 available Fe + 0.51 Texture Index - 12.23 pH + 0.92 EC - 0.02 CaCO3% - 4.82 K in leaves % + 68.90 Ca in leaves % -17.23 P in leaves % - 0.02 total Fein leaves (ppm)	0.89**
2,2’Bip.	y = 86.29 + 1.68 OM% + 6.74 available Fe + 0.83 Texture Index - 4.14 pH + 0.52 EC - 0.54 CaCO3% - 5.52 K in leaves % + 95.67 Ca in leaves % -16..55 P in leaves % - 0.04 total Fe in leaves (ppm)	0.91**
HCl	y = 205.91 + 4.58 OM% +9.27 available Fe + 0.87 Texture Index - 13.95 pH + 0.2.35 EC - 0.27 CaCO3% - 13.38 K in leaves %+ 116.57 Ca in leaves % -21.13 P in leaves % - 0.07 total Fe in leaves (ppm)	0.92**

The critical value of plant active iron of each extractant was worked out by fitting the regression of active iron content (y) against DTPA-soil available iron (x). The functional relations between y and x were as follows:

$$y = 8.79 + 7.40 x - 0.36 x^2 \quad (1)$$
$$y = 5.27 + 11.46 x - 0.56 x^2 \quad (2)$$
$$y = - 7.56 + 19.98 x - 0.98 x^2 \quad (3)$$
$$y = -16.72 + 30.64 x - 1.48 x^2 \quad (4)$$
$$y = -19.27 + 42.76 x - 2.02 x^2 \quad (5)$$

for EDTA, DTPA, O-Ph., 2,2'Bip. and HCl , respectively.

The (y) values for maximum active iron content were: 40.00, 55.00, 80.00, 120.00, and 180.00 (mg/kg) active iron for EDTA, DTPA, O-Ph, 2,2'Bip. and HCl, in the same order.

According to the abovementioned active iron content values, 59, 65, 57, 46 and 62% of the soils studied are classified as deficient. Moreover applying the value of less than 4.5 (mg/kg) Fe soil-DTPA as the critical level reported by Lindsay and Norvell (1978) proved that 43% of the studied soils are in the deficiency range, In this respect, it is obvious that such value coincides well with that obtained by the 2,2'Bip plant active iron (46%). However, the price of such material is so high (one Kg = 6500 L.E) that makes, from the economical point of view, the use of 2,2'Bip is excluded. Moreover, since the other extractants gave reliable results, the EDTA is very suitable according to its low price (1 Kg cost 185 - 200 L.E.).

It could be concluded that to determine how well a fertilizer program is meeting the needs of corn crop, leaf plant sample must be analyzed at an early stage of growth throughout the growing season, then comparing the active iron analysis of these samples to the critical values. Therefore one could detect and correct impending nutrient deficiency before it occurs, and to change the timing or method of fertilization to make sure that fertilizer needs of the crop are fully met.

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تقييم طرق مختلفة لاستخلاص الحديد النشط في النبات تحت ظروف الأراضي المصرية

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تهدف الدراسة الى تقييم طرق تقدير الحديد النشط المستخلص باستخدام مستخلصات مختلفة اضافة الى تقدير الحديد الميسر في التربة من خلال عمل دراسة ميدانية على نباتات الذرة النامية تحت ظروف الأراضي المصرية. اضافة الى دراسة مدى ملائمة المستخلصات السابقة في استخلاص الحديد النشط المستخلص من أوراق نباتات الذرة النامية في الأراضي الحديثة الاستصلاح وعلاقة تلك الكمية بمحتوى الأرض من الحديد الميسر.

تم اجراء الدراسة الميدانية على 61 عينة أرض (34 غير جيرية – 27 جيرية) منزرعة بالذرة حيث تم تقدير كمية الحديد الكلى و الحديد الميسر (بطريقة الـ DTPA) في التربة. وكذلك تقدير تركيز كل من الحديد الكلى و الحديد النشط (باستخدام خمسة مستخلصات كيماوية) في الورقة أسفل الكوز و المقابلة له في نبات الذرة عند بدء طرد الحريرة و ذلك في نفس موقع عينة التربة. و يمكن تلخيص أهم النتائج المتحصل عليها فيما يلي:

أظهرت نتائج الحديد الميسر في التربة و المستخلص بطريقة الـ DTPA إن قيمه تراوحت بين 1,48 - 14,80 جزء في المليون حديد ، وارتبطت معنويا مع كل من محتوى التربة من المادة العضوية و قيم texture index و الطين و السلت و محتوى الحديد الكلى في التربة في جميع الأراضي سواء مع الأراضي الغير جيرية أو الجيرية.

وطبقا لمستوى الحديد الميسر في التربة وجد أن 57% من الأراضي تحت الدراسة كان الحديد الميسر بها في مجال الكفاية أو المرتفع ، بينما 23% فقط من تلك الأراضي كانت في المجال المنخفض و 20% فقط منها كانت في مجال النقص. وكانت الأراضي التي تعانى من نقص الحديد هي الأراضي ذات القوام الرملي و الفقيرة في المادة العضوية سواء فى الأراضي الغير جيرية أو الأراضي الجيرية ومن المتوقع أن تعانى النباتات النامية فى هذه الأراضي من نقص الحديد ومن الضروري تكرار تسميدها بالحديد.

تراوح تركيز الحديد الكلى فى الورقة أسفل الكوزو المقابلة له فى نبات الذرة عند بدأ طرد الحريرة بين 208 - 625 جزء فى المليون حديد. و قد أوضح التحليل الأحصائى أن الارتباط بين الحديد الميسر فى التربة و محتوى الأوراق من الحديد الكلى غير معنوي. وهذا يدل على أن التركيز الكلى للحديد فى النبات لايعتبر مدلول جيد يمكن ان يعتمد عليه فى تقييم حالة نقص الحديد فى النبات و التربة.

وقد أظهرت نتائج الحديد النشط فى الأوراق أن متوسط قيم الحديد النشط المستخلصة بـ : EDTA ، DTPA ، O-Ph ، 2,2’Bip. و HCl كانت 33,78 ، 46,95 ، 65,07 100,43 و 140,74 جزء فى المليون حديد نشط على التوالي.

أوضح التحليل الأحصائى أن هناك ارتباط عالي المعنوية بين المستخلصات الكيماوية المختلفة لاستخلاص الحديد النشط من الأوراق و الحديد الميسر فى التربة. وهذا يوضح فاعلية طرق استخلاص الحديد النشط الخمسة فى تمييز النباتات التي تعانى من نقص فى الحديد و تلك التي تحتوى على كمية كافية منه و يمكن أن تعتبر مدلول جيد يعتمد علية فى تقييم حالة الحديد فى النبات تحت ظروف الأراضي المصرية.

كانت الحدود الحرجة للحديد النشط المستخلص من الأوراق بالمستخلصات المختلفة التي تصفه طبيعة مع منحنى الاستجابة للحديد النشط بدلالة الحديد الميسر فى التربة هو : 40,00 ، 55,00 ، 80,00 ، 120,00 و 180,00 جزء فى المليون حديد نشط مستخلص بـ EDTA ، DTPA ، O-Ph ، 2,2'Bip. و HCl على التوالي.

طبقا لأرقام المستوى الحرج للحديد النشط المستخلص بـ EDTA ، DTPA ، O-Ph ، 2,2'Bip. و HCl أن 59 ، 65 ، 57 ، 46 و 62 % (على التوالي) من الأراضي المدروسة تصنف فى مستوى نقص الحديد. علاوة على ذلك طبقا للمستوى الحرج للحديد الميسر فى التربة (4,5 جزء فى المليون حديد) نجد أن 43% من الأراضي تصنف فى مستوى نقص الحديد و فى هذا الخصوص نلاحظ توافقه مع المستخلص 2,2'Bip (46%) من الناحية الاقتصادية نجد أن المستخلص 2,2'Bip مرتفع الثمن (ثمن الكيلو الواحد = 6500 جنيه) بينما مستخلص الـ EDTA الذي يمكن أن نثق فى نتائجه أيضا رخيص التكلفة (ثمن الكيلو الواحد 185 - 200 جنية).