Diagnosis of Nutrient Status in Balady Mandarin Orchards of a Newly Reclaimed Area in Egypt

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Abstract: The present work aimed to determine the nutritional status of Balady mandarin orchards, through soil testing and leaf analysis, in order to work out a proper fertilization programs. A field study was conducted at El-Tall El-Kepeer, Ismailia governorate, covering 19 Balady mandarin orchards grown on sandy soils under drip irrigation. These soils are of poor fertility. However, fertilization of these orchards still depends upon the grower's inherited knowledge and in very small scale on the extension information. The trees were fifteen years old. The orchard soils had very high pH values, low to high level of EC and Na, and were low in total $CaCO_3$ and very low in O.M. The values for available nutrients in soil were found to be as very low of P, Fe, Mn, Zn and Cu. Values of K, Mg ranged between very low to medium levels, However values of Ca ranged between medium to high levels. The leaf macronutrient values were low in N, ranged between optimum to high in P and Mg, ranged between low to high in K, However values of Ca was ranged between low and optimum. The leaf micronutrient contents were as follow, Fe ranged from optimum to high; Mn, Zn and Cu were ranged from low to the beginning of optimum levels. The nutrient correlations of the leaves revealed some antagonisms between K and Ca, Mg and both of Mn and Zn. Also, the nutrient correlations of the leaves and fruits revealed some antagonisms between N in leaves and Zn in fruits, P and K in leaves and Mn in fruits, K in leaves and N, Cu in fruits, Ca in leaves and K in fruits.

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Introduction:

In the past, research has been mainly focused on relatively small orchards in clay soil in Nile Delta which was highest in nutrient supply. During the recent years, the programs of agricultural development in Egypt aim to increase the cultivated areas in sandy soil. Soils in El-Tall El-Kepeer area, Ismailia Governorate are highly sand, which contains about 90% to more than 95% sand. Citrus production comprises the largest fruit sector in Egypt. Egypt has a great potential for citrus production when its ecological and other characteristics were considered. According to, Static's of Agricultural Production Requirements (2007). Production of Egypt citrus is 3.181.000 t coming from 2,109,000 t of orange, 732,000 t mandarins, 297, 000 t lemon and 43,000 t grapefruit, Besides that, there are about 42.000 ha are in the beginning of production. However, about 30% of citrus orchards in Egypt became located on poor soils and newly reclaimed areas. Poor soil fertility and poor fertilization strategies are largely a result of insufficient information on the soil fertility and plant nutritional status of crops in these areas.

One of the major deficiencies in most of the sandy citrus soils of Egypt is an acute shortage of organic matter and is commonly low in both macro and micronutrients, which can limit tree function. In addition micronutrients deficiency occurs in trees growing in such alkaline soils (Amberger, 1982, El-Fouly and Fawzi, 1982 and El-Fouly *et al*. 1986).

Balady mandarin is extensively grown in these sandy soils which their inherited fertility is low and pH values in the range of 8.0 to 9.0, and proper nutrients management is required to grow mandarin successfully on such soils. In the past, research has been mainly focused on macronutrients such as N and P.

Mandarin trees do much better to their nutritional status through good nutrition and controlled nutrient supply during different seasons can produce higher yield. Average recommendation will result in high yielding or large trees in the grove receiving relatively less fertilizer than they require, and low yielding or small size tree areas receiving relatively more fertilizer than necessary (Schumann *et al*., 2003; Zaman *et al*., 2005). Local over fertilization may decrease ground water quality, reduce profit margins, induce deficiency of other elements and interfere with metabolic processes. Under unsuitable fertilization, may restrict citrus yield and quality and variable rate of application avoids these problems but requires knowledge of the scale of variability of soil and tree characteristics within each field (Mulla and Bhatti, 1997).

Soil and leaf analysis can be used to evaluate the nutritional status of the trees and nutrient availability in the soil to supply the trees with nutrients requirement (El-Fouly, 1985, Embleton *et al*., 1996). It is necessary to have information on nutrients removal for each variety grown in the region to determine proper fertilization management strategies, and make adjustments on their fertilization programs accordingly. The objective of this study was; therefore, to diagnosis nutrient status in Balady mandarin trees grown in sandy soils, to be used as a tool to optimize fertilizers use and helps in formulating the fertilization programs.

2. Materials and Methods

Field practices

The study was conducted in Baladi mandarin of fifteen years old, grafted on folk mariana rootstock and established on sand soil, located in El-Tall El-Keeper, Ismailia governorate, Egypt as a newly reclaimed area, during two successive years (2008-2009). Extensive survey was conducted covering as many as 19 orchards represent area of 20000 ha. The trees were under drip irrigation system and were uniform in growth. The trees were subjected to the same management treatments. The trees were cultivated at 4 x 4 m distance (620 tree/ha^{-1}). The common fertilizer applications were used as following: 48 m^3/ ha of farmyard manure during January. NPK rates were 310 kg N ha^{-1}, as ammonium nitrate (33.5% N), 66 kg P_2O_5 ha^{-1}, as superphosphate (15.5% P_2O_5) and phosphoric acid (60% P_2O_5) and 215 kg K_2O ha^{-1}. as potassium sulfate (48-52% K_2O) kg ha^{-1} year) were applied as fertigation and distributed along the growing season. Foliar sprays of Mg nitrate were applied to the spring flush leaves.

The study were done on orchards considered to be low yielding (<22,000 kg/ha).

Soil sampling

Soil samples were randomly collected from the zone of the root tips of the trees under the end of canopy in November. Depth of the soil sampling was 0-60cm. The samples were air dried, ground to pass through a 2 mm sieve using a wooden grinding and stored in plastic bottles prior to the physical and chemical analysis.

Leaf sampling

The leaf samples were collected randomly around the tree from the fully mature leaves of spring flush. 4 to 7– month–old young shoots. Samples were washed with tap water, 0.001 N HCL and distilled water, respectively, then dried at 70^o C and ground in a stainless steel mill, then passed through a 40 mesh nylon sieve and stored in plastic bottles.

Fruit sampling

The mineral analysis was done in the total fruit including the peel, pulp, and the juice to estimate the total mineral nutrient contents in the harvested fruits.

Chemical analysis

Soil samples were analyzed for texture, pH and electrical conductivity (EC) using water extract (1:2.5) method, for total calcium carbonate ($CaCO_3$%): calcimeter method and for organic matter (O.M%) using potassium dichromate (Chapman and Pratt, 1978). Phosphorus was extracted using sodium bicarbonate (Olsen *et al*., 1954). Potassium (K), calcium (Ca) and Magnesium (Mg) and sodium (Na) were extracted using ammonium acetate (Jackson, 1973). Iron (Fe), Manganese (Mn), Zinc (Zn) and Copper (Cu) were extracted using DPTA (Lindsay and Norvell, 1978).

Plant material was digested using an acid mixture consisting of nitric, perchloric and sulfuric acids in the ratio of 8:1:1 (v/v), respectively (Chapman and Pratt, 1978). Nitrogen (N) was determined in the dry plant material using the boric acid modification described by Ma and Zuazage (1942), and distillation was done using a Buechi 320-N_2-distillation unit. Phosphorus was photometrically determined using the molybdate vanadate method according to Jackson (1973).

Potassium, calcium and sodium were determined using flame photometer (Genway). Mg, Fe, Mn, Zn and Cu were determined using the Atomic absorption spectrophotometer (Perkin Elemer 1100 B). The soil data were evaluated using the criteria published by Ankerman and Large (1974), Lindsay and Norvell (1978) and Peryea (2000), whereas the leaf analysis data were evaluated according to the criteria reported by (Jones *et al.*, 1991) in Plant Analysis Handbook. Data were subjected to statistical analyzed using Costate Statistical package, in order to calculate means, standard deviations (SD) and the possible correlations (r) (Anonymous, 1989).

3. Results and Discussion:

Soil properties and its nutrients status:

From Table 1. it can be noticed that soil texture is sandy, It's known that coarse-textured soils lack both nutrient and water holding capacities. Also, soil pH had high value, the range was between 8.30-9.10 and the average was 8.80$\pm$0.18. Under such high alkaline conditions, availability of some nutrients is expected to be low. The average of electric conductivity (EC) was in the medium level (0.30$\pm$0.18); however the range was between low and very high levels (0.14-0.76). The soil found to be low in $CaCO_3$; contained lower than 2% $CaCO_3$ which is expected to haven't effect on the nutrient availability

(Ankerman and Large, 1974). The soil of the orchards was very poor in organic matter content, the range was between 0.13-0.27 and the average was 0.20±0.03%. Soil organic matter is used as an indicator of soil fertility. It is well known that soil organic matter had a strong positive relationship with total N content in soil, thus it is also, expected to be low.

Table (1): Range, Mean±SD of physical-chemical characteristics of the soil

Character	Range	Mean±SD	Available nutrient content	Range	Mean±SD	Evaluation
Sand %	88 - 91	90±1	Macronutrients, (mg/100g)			
Silt %	02 - 04	03±1	P	00.22 - 00.55	00.40± 00.10	Very low
Clay %	05 - 09	07±2	K	11.50 - 38.00	25.00±12.59	Medium
Texture	Sandy		Mg	22.00 - 62.00	41.20±12.49	Medium
pH(1:2.5)	8.30 - 9.10	8.80±0.18	Ca	105.00 - 320.00	233± 52.05	High
E.C dS/m	0.14 - 0.76	0.30±0.18	Na	08.00 - 38.00	15.45 ± 06.75	Very low
$CaCO_3$ %	0.80 - 2.00	1.44±0.30	Micronutrients, (mg/Kg)			
O.M %	0.13 - 0.27	0.20±0.03	Fe	01.60 - 04.10	2.65± 0.73	Very low
			Mn	00.30 - 01.50	0.84± 0.34	Very low
			Zn	00.20 - 00.70	0.44± 0.19	Very low
			Cu	00.10 - 00.60	0.29± 0.12	Very low

Table 1. contains also, the range and the average values of the major nutrient availability in the soil samples, available P-content was ranged between 0.22-0.55 and the mean was 0.40±0.10 mg/100g soil. According to data mentioned by Ankerman and Large, 1974 in Table 2, P is considered very low where under the conditions of such soil (high pH), the availability of P is expected to be reduced, and plants might suffer from P- deficiency. The average of available potassium levels seem to be medium, (25.00±12.59), however the range was between very low and high levels (11.50-38.00) mg/100g soil. Therefore, potassium fertilizers must be added to compensate the K shortage in the deficient soil. The mean extractable Ca was high (233±52.05) mg/100g soil, however the range was between medium to high (105-320) mg/100 g soil. The mean extractable Mg was medium (41.20±12.49) however the range was between low to medium (22-62) mg/100g soil.

Table (2): Tentative rating values of soil fertility status

Element	Rating				
	Very low	Low	Medium	High	Very high
$CaCO_3$%	<0.5	0.5 -2	2.1-8	8.1-30	31-45
Organic matter (O.M),%	<1.0	1-2	2.1-3	3.1-5	>5.0
Electric conductivity (E.C.) dS/m	<0.1	0.1-0.2	0.3-0.4	0.5-0.7	>0.7
pH	<5.8	5.9-6.6	6.7-7.2	7.3-8.5	>8.5
Macronutrients (mg/100g)					
Phosphorus (P)	<00.5	0.5-1.1	1.2-2.7	2.8-4	>4
Potassium (K)	<11.7	11.8-20	21-30	31-47	>47
Calcium (Ca)	-	<100	100-200	>200	-
Magnesium (Mg)	<11	11-29	30-180	>180	-
Sodium (Na)	<20	20-25	26-30	>30	-
Micronutrients (ppm)					
Iron (Fe)	<5	5-10	11-16	17-25	>25
Manganese (Mn)	<5	5-8	9-12	13-30	>30
Zinc (Zn)	<0.5	0.5-1.5	1.6-3	3.1-6	> 6
Copper (Cu)	<0.3	0.3-0.8	0.9-1.2	1.3-2.5	>2.5

Source: Ankerman and Large (1974), Lindsay and Norvell (1978), Peryea (2000)

As it's known in most sandy soils, which contain inadequate levels of available micronutrients and according to data in Table 2, mentioned by Ankerman and Large, 1974, the extractable Fe, Mn, Zn and Cu levels of the present soil samples are in the very low levels.

Nutrient concentrations in leaves:

It is well known that mandarin trees are very sensitive of nutrient deficiencies in the soil. Data of ranges and mean of nutrient leaves content in Table 3 and according to critical values mentioned by Jones *et al*. (1991), Reuter and Robinson (1986, 1997) in Table 4. Nitrogen concentration in the leaves ranged between 1.51-2.99 and the mean was 2.16±0.366%, on dry matter basis, which tends to be low. This may be due to high leaching of ammonium nitrate in such soil with 90% sand. It is recommended to add nitrogen as ammonium sulphate, which is less leaching and more efficient at sandy and high pH conditions. In this respect, Johnston (2004) reported that when ammonium sulphate is applied one pH unit can be decreased and this pH change is important for P availability supply and may be also for micronutrient availability supply. P-concentrations in the mature leaves ranged between 0.16-0.32%, and the mean is 0.23±0.044, which is ranged between sufficient and high levels and with sufficient mean. Potassium concentrations in the leaves ranged between low and high levels (0.65-1.39%), and the mean is sufficient (1.06±0.189). Magnesium concentrations in the mandarin leaves ranged between sufficient to high (0.56-0.73%), and the mean is 0.65±0.048 which, is in high level, while, Mengel and Kirkby, 1987, mentioned that Mg uptake by plants can be restricted by the high levels of Ca in the root medium, which might led to Mg deficiency in plants, in spite of its high levels in the soil. The high level of Mg in leaves may be resulted from the magnesium foliar application.

In spite of high levels of Ca in the root medium, calcium concentrations in the leaves ranged between low to sufficient (1.20-3.30%), and the mean is (2.42±0.49) which, is in low level, that is may be because the movement of calcium in the soil is slowly. Fe concentrations can be higher than, equal to, those in normal trees. Fe-concentrations were ranged from sufficient to high (99.0-375.0 ppm) and the mean is sufficient (185.0±79). Concentrations of Mn were ranged between low and sufficient (21.5-56.0 ppm) and the mean is (28±8.6) which is at the beginning of the sufficient levels. In this respect Bergman (1972) mentioned that the nutrient element contents should lie as far as possible in the middle or even better in the upper half of the satisfactory or optimal range. As a result of factors described above most Zn concentrations in this study were low in most cases, where Zn concentration was ranged between low and beginning of the sufficient level, (13.0-39.0 ppm) and the mean is low level (18.0±6).

Zinc deficiency is widespread in citrus trees in Egypt (El-Fouly, 1985). Marshner, 1993, mentioned that in soils with very high pH and very low in organic matter, availability of Zn to plant roots is extremely low. In addition, Boaretto *et al*., 2002; Sanchez and Righetti, 2002, found that when severe Zn deficiency symptoms appear, early spring foliar sprays could increase the micronutrient concentration in the targeted organs. Also, it could stimulate vegetative growth (Swietlik, 2002). Similar results were also, found by Shaaban and El-Fouly, 2005. In this study, Cu-concentration was found to be less than the adequate range in most samples, which ranged from low to sufficient level (2.0-15.0 ppm), with mean at the beginning of sufficient level (5.5±3.2 ppm). It is well known in sandy soil that Cu-availability and consequently its concentration in leaves of grown plant are expected to be low. Deficiencies of Cu can reduce Zn uptake through root injury. It could be concluded that nutrient concentration in Balady mandarin leaves is greatly affected by soil characteristics as well as farm management, thus soil and plant analysis, crop requirement should be considered when preparing a fertilizer recommendations.

Table (3): Range, mean±SD of leaf nutrient contents.

Element content	Range	Mean+SD	Evaluation	Element content	Range	Mean+SD	Evaluation
Macronutrients, (%)				Micronutrients, (ppm)			
N	1.51 - 2.99	2.16±0.366	Low	Fe	99.0 - 375.0	185.0±79	Sufficient
P	0.16 - 0.32	0.23±0.044	Sufficient	Mn	21.5 - 56.0	28±8.6	Sufficient
K	0.65 - 1.39	1.06±0.189	Sufficient	Zn	13.0 - 39.0	18.0±6	Low
Mg	0.56 - 0.73	0.65±0.048	High	Cu	2.0 - 15.0	5.5±3.2	Sufficient
Ca	1.20 - 3.30	2.42±0.491	Low				
Na	0.09 - 0.15	0.12±0.018	Sufficient				

Table (4): Values level of leaf nutrients content of Balady mandarin trees

Nutrient	Low	Sufficient	High
		%	
N	<3.00	3.00 – 3.40	>3.40
P	0.11 – 0.14	0.15 – 0.25	>0.25
K	0.47 – 0.89	0.90 – 1.10	>1.10
Mg	<0.30	0.30-0.60	>0.60
Ca	<3	3 - 6	>6
		ppm	
Fe	<60	60-150	>150
Mn	<25	25-200	>200
Zn	<25	25-100	>100
Cu	<5	5-15	>15

Source: Jones *et al.* (1991), Reuter and Robinson (1986, 1997)

Frequency distribution (%):

Table 5 showed frequency distribution (%) of soil nutrients, as well as the leaf concentrations of these nutrients. The data showed that 100% of the soil samples contained low N, P, Fe, Mn, Zn and Cu whereas 53% contained low K and Mg, 5% contained low Ca, while, 95%, 47%, 47% of Ca, K, Mg respectively, had optimum level. Leaf samples analysis showed that 89% of N and Ca, 84% of Zn, 53% of Cu, 37% of Mn and 10% of K from leave samples had low levels, while 89% of P, 84% of Mg, 74% of K and Fe, 63% of Mn, 47% of Cu from leave samples had optimum levels. In addition, 11%, 16%, 16%, 26% of leave samples showed high level of P, K, Mg and Fe, respectively. Therefore, we can, conclude that Balady mandarin trees have the ability to accumulate nutrients in higher concentrations in their leaves relative to their soils

Table (5): Frequency distribution (%) of available nutrient through analysis of soil fertility and leaf nutrient composition

Nutrient	Soil fertility constraints			Leaf nutrient constraints		
	Low	Optimum	High	Low	Optimum	High
N	100	-	-	89	11	-
P	100	-	-	-	89	11
K	53	47	-	10	74	16
Ca	5	95	-	89	11	-
Mg	53	47	-	-	84	16
Fe	100	-	-	-	74	26
Mn	100	-	-	37	63	-
Zn	100	-	-	84	16	--
Cu	100	-	-	53	47	-

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As for correlation between leaf nutrient contents of the mandarin trees, data of Table 6., showed that there is a significant positive correlation between content of P and both of Fe, Mn, Zn and between Fe and Cu and between Mn and Cu. As well as highly significant positive correlation were found between Fe and both Mn and Zn and between Mn and Zn. On the other hand, significant negative correlation was found between Mg and Mn and highly significant negative correlation was recorded between K and Ca and between Mg and Zn. Table 6, pointed out to the importance of the balance fertilization.

Table 6. Correlation coefficient between leaf nutrient contents of the mandarin

Nutrient	P%	K%	Ca%	Mg%	Na%	Fe ppm	Mn ppm	Zn ppm	Cu ppm
N%	0.397	-0.062	0.207	0.102	0.008	0.358	0.163	0.103	0.283
P%		0.187	-0.154	-0.216	0.317	0.558*	0.490*	0.549*	0.265
K%			-0.616**	0.158	0.095	0.092	0.073	0.066	-0.055
Ca%				-0.146	-0.054	0.218	0.230	0.207	0.220
Mg%					0.016	-0.277	-0.490*	-0.576**	-0.362
Na%						-0.031	-0.003	-0.031	-0.039
Fe ppm							0.773**	0.745**	0.556*
Mn ppm								0.900**	0.477*
Zn ppm									0.384

r* 0.05 = 0.456 (significant at 5% level) r** 0.01 = 0. 575 (significant at 1% level)

Nutrient concentrations and removal by fruits:

Tables 7 and 8 showed that Balady mandarin fruit removed the largest amount of potassium (K), followed by Calcium (Ca), nitrogen (N) phosphorus (P) and magnesium (Mg), respectively. Where a ton of fruit removed 2.06, 1.43, 1.33, 0.41 and 0.35 kg of K_2O, CaO, N, P_2O_5 and MgO, respectively. Also, Balady mandarin fruit removed the largest amount of iron (Fe), followed by manganese (Mn), zinc (Zn) and copper (Cu), respectively. Results suggest it reasonable to expect that potassium was the highest nutrient removed by Balady mandarin fruit.

Beside the nutrient removal, the behavior of each nutrient and soil properties must be take in consideration at preparing fertilization program. Fertilizing based solely on nutrient removal could lead to deficiencies or overuse of some nutrients. Leaching and denitrification of fertilizer nitrates may result in as much as 50% fertilizer nitrogen lost. Some nitrogen may be supplied from organic matter in the soil, but this amount is usually small in sandy soils. Yield nutrients removal is not a good indicator of phosphorus needs. Suitable- soil fertilized has an abundant reserve of soil phosphorus which is available to trees. Since phosphorus does not leach, it can build up to high levels in suitable-fertilized trees. Fertilization based on yield nutrients removal is better for potassium fertilization than the other nutrient. In sandy soils, potassium is not enough for high-yielding fruits. If fruits removal of potassium is greater than fertilizer applied, deficiencies can be occurring. It is worthy to mention that applying potassium as foliar spray on citrus trees gives better growth, high fruit-set and yield, (Ibrahiem *et al*., 1993). On the other hand, the uptake of some nutrients is dependent on their ratio in soil solution, for example much K reduces Mg availability in soil solution (Laegreid e*t al*.,1999). Calcium and magnesium must be considered because of the special needs for high fruit quality. The availability of iron, manganese, zinc and copper is little to do with yield removal.

Table 7. Range, mean±SD of fruit nutrient contents.

Nutrient content	Range	Mean±SD	Nutrient content	Range	Mean±SD
Macronutrients, (%)			Micronutrients, (ppm)		
N	0.47 - 1.27	0.75±0.16	Fe	11 - 87	39±25
P	0.02 - 0.26	0.08±0.06	Mn	4 - 9.5	7.2±1.4
K	0.48 - 1.34	0.98±0.21	Zn	4 - 9.0	6.1±1.4
Mg	0.10 - 0.15	0.12±0.02	Cu	0.5 - 2.5	1.2± 0.5
Ca	0.35 - 0.85	0.58±0.13			
Na	0.02 - 0.04	0.03±0.01			

Table 8. Nutrients removed by fruits

Macronutrients removed (Kg/ton fruit)				
N	P_2O_5	K_2O	CaO	MgO
1.33	0.41	2.06	1.43	0.35
Micronutrients removed (g/ton fruit)				
Fe	Mn	Zn	Cu	
70	13	11	2	

As shown in Table 9, a positive significant correlation was found between the content of K, Cu in both of leaves and fruits. However, highly significant negative correlation was found between the following nutrients, N in leaves and Zn in fruits and K in leaves and Mn in fruits. In addition, significant negative correlation was found between P in leaves and Mn in fruit, K in leaves and both N and Cu in fruit, Ca in leaves and K in fruits, as well as between Mg in leaves and Cu in fruits and between Cu in leaves and N in fruits. We can, therefore, conclude that when we want to improve the quality of fruits we must considering leave nutrients content.

Conclusion:

In our study we showed that there is nutrient deficiency and imbalance nutrition in Balady mandarin orchards. Nutrients concentration in mandarin leaves is greatly affected by soil characteristics. Balady mandarin trees have the ability to accumulate nutrients in higher concentrations in their leaves relative to their soils. Crop nutrient requirement should be considered when preparing a fertilizer recommendation. Leave nutrient contents and their effect on the fruit nutrients should be consider, to improving fruit quality.

Table 9. Correlation coefficient between leaves and fruit nutrient contents of the mandarin

Fruit / Leaf	N%	P%	K%	Ca%	Mg%	Na%	Fe ppm	Mn ppm	Zn ppm	Cu ppm
N%	-0.354	-0.292	-0.377	-0.446	-0.071	-0.247	0.339	-0.001	-0.608**	0.044
P%	-0.290	-0.082	0.001	0.051	-0.018	-0.119	0.047	-0.469*	-0.166	-0.059
K%	-0.464*	-0.160	0.494*	0.032	0.037	-0.336	-0.058	-0.651**	0.296	-0.485*
Ca%	0.102	0.269	-0.467*	-0.249	-0.136	0.079	0.007	0.190	-0.325	0.356
Mg%	-0.105	0.075	0.221	0.053	-0.238	0.201	0.117	0.176	-0.406	-0.458*
Na%	-0.105	0.304	0.143	-0.079	-0.210	-0.202	-0.084	-0.112	0.073	-0.328
Fe ppm	-0.418	-0.040	-0.161	-0.284	-0.095	-0.140	-0.081	-0.392	-0.140	0.218
Mn ppm	-0.321	0.205	-0.035	-0.237	-0.222	-0.127	-0.292	-0.329	-0.065	0.214
Zn ppm	-0.215	0.225	0.058	-0.066	0.058	-0.118	-0.212	-0.433	0.085	0.187
Cu ppm	-0.530*	-0.139	-0.305	-0.271	0.218	-0.157	-0.125	-0.061	-0.046	0.465*

r* 0.05 = 0.456 (significant at 5% level) r** 0.01 = 0. 575 (significant at 1% level)

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