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Nutrients Availability As Related to Heat Capacity and Other Desert Soil Conditions

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A LONG-TERM pot experiment was conducted in green house as to pursuit the availability of P, Fe, Mn and Zn nutrients in two deserts soils (sandy and calcareous). The main treatments of soil are made by addition of organic matter and salinity with four different levels and time of experiment by five periods. The results showed almost general increase in heat capacity of both soils as a results of relations between nutrients and organic matter content (positive effect). Mn and Zn showed in calcareous soil a negative effect due to the high $CaCO_3$ content. Time has almost negative relations with available nutrients due to a fixation by precipitation and other deformation reactions. Salinity has also negative relations with available nutrients in most cases due to competition of concentration with studied ions .

In this study, the derivated factor of heat capacity which changed through the experiment gives definite positive relations with three of the studied nutrients, namely P, Fe and Mn which indicate some thermophilic compounds and endothermic reactions. The reaction is negative with Zn and indicates some thermophobic compounds and exothermic reactions.

Keywords: Soil heat capacity, Available water, Organic matter, Salinity level, Time.

The available form of nutrients in soils is important for plant growth. Its presence in soils often varies with the variation of soil type and $CaCO_3$ content as it increased with the decrease in pH of soil and with the increase in the organic matter (Yang *et al.,* 1985). Rather than the chemical and mineralogical bonds on clay, there are two groups of compounds are responsible for the binding of elements in soil ; namely: I- biochemical type which is present in living organisms (like simple aliphatic acids, amino acids, sugar and polyphenols), II- humic substances, such as humic and fulvic acids. It was found that iron, manganese and zinc precipitated in soil and strongly bound to clay surfaces (Bear, 1976). Various investigators reported by Dahdoh and El-Hassanin (1994) had attempted to deduce the cumulative effect of green manure, crop residues or farmyard manure applied to field pots upon the availability of soil zinc and phosphorus. The concentration of available phosphorus was increased by addition of organic matter and by raising salinity levels in both sandy and calcareous soils (Kpomblekou and Tabatabai, 1997).

The soil solution chemistry of both iron and manganese is a complicated one due to their existence in more than one oxidation state in soil. Bear (1976) and Malcolm *et al.*(1993) found that the availability of iron, zinc and manganese was decreased by the increase of soil pH while it increased by the adition of organic matter and raising salinity levels, except zinc which decreased by raising salinity level. It was reported that the humifying straw favoured the availability of elements in calcareous soil, but the composted straw was generally better in the alluvial soil. The availability of zinc was increased by increasing sewage sludge rate addition on both calcareous and sandy soils (Kpomblekou and Tabatabai,1997; Malcolm *et al.*, 1993 and Negm *et al.*, 1996). Also, Iu *et al.* (1981b) concluded that the effect of organic matter addition on zinc availability was usually less than those for iron and manganese due to the less sensitivity of zinc to any redox changes.

Pandeya (1991) presented the interaction or adsorption of iron-fulvic acid complexes involves physical and metal ion coordinate bonding on clay surfaces. Also, the thermal properties were linear functions of adsorbed iron - fulvic acid complex by the soil. The negative values of enthalpy and free energy changes for the adsorption of zinc in soil (Prasad *et al.* 1991 and Prasad and Sarangthem, 1992) suggested that the adsorption of zinc was an exothermic reaction.

The aim of this article is to spot light on the effect of different factors like organic matter addition, salinity level and time of irrgation on the availability of some nutrients such as Zn, Mn, Fe and P, also, the relation between the heat capacity of sandy and calcareous soil samples and availability of the studied nutrients. This is because the availability of metal ions in soil and increase in soil heat capacity are two main factors controlling plant growth, especially in desert soils.

Material and Methods

The experimental work was conducted in pots in green house in order to pursuit carefully the changes in moisture, temperature and salinity of soil. Sandy soil samples were collected from El-Khattara (the northern fringe of El-Sharkia Governorate) and calcareous soil samples were collected from the surface layer of Maryut research station of Desert Research Center (D.R.C). Each pot experiment contained 500 g of soil sample, which mixed thoroughly with compost (as a source of organic matter). Compost was added with four doses namely; 0,1,2,4% (w/w). Some chemical and physical characteristics of both soil samples and compost are present in Table 1. Watering was applied with the selected saline levels to reach maximμm up to 50 % depletion from soil available moisture range to all pots by means of weighing pots every day. The first group of pots was irrigated by distilled water (as a control of salinity), The 2nd group was irrigated by tap water (salinity = 250ppm), the 3rd group was irrigated by 2000 ppm of NaCl solution and then the 4th group was irrigated by 4000 ppm of NaCl.

The experiment was extended up to ten months and soil samples were taken every two months. The pots were arranged in split - split design with three replications. After each period the samples were dried, crushed, sieved through 2.00mm sieve and kept dry. The heat capacity was measured using copper calorimeter method described by Partington (1963). Available phosphorus was extracted following Olsen method described by Collenie *et al.* (1982) using JASCO 7800 Spectrophotometer at wave length of 660mm. Available iron, manganese and zinc were extracted following Lindsay and Norvell (1978) method using Unicam 929 AA Atomic Absorption Spectrophotometer.

Results and Discussion

Statistical analysis of variance was undertaken using "Costat Program" based on performing the experiment as tri-split design; in which organic matter addition represented main plot; salinity levels represented sub - main plot and time of water cycle irrigation represented sub - sub main plot.

TABLE 1 . Some physical and chemical characteristics of soil samples and compost used in the present work.

Characters	Particle size distribution			Moisture retention			EC	pH	Availability of nutrients (ppm)			
	Sand%	Silt%	Clay%	F.C%	W.P%	AV.%			P	Fe	Mn	Zn
Sandy Soil	86.3	6.3	7.4	1.87	0.26	1.61	0.17	7.84	3.64	2.038	1.39	0.234
Calcareous Soil	48.16	19.94	31.85	22.12	9.40	12.72	4.36	7.78	7.00	3.65	4.52	0.309
Compost	-	-	-	26.2	10.28	15.92	1.93	7.04	15.58	26.36	13.07	4.516

F.C = is the filed capacity, W.P = is the welting point, AV. = is the available water and EC = is the electrical conductivity.

Relation between Soil Heat Capacity and Availability of Studied Nutrients

Heat capacity of soil defined by Hillel (1980) "the amount of heat required to raise the temperature of a unit mass of soil by 1C° (cal g-1 $C^{\circ -1}$)". The data in Table 2 and Fig . 1 and 2 A-D reveal that availability of P, Fe and Mn increased by increasing heat capacity of the soil. Therefore, it can be assumed that some endothermic reactions of P, Fe and Mn deformation or thermophobic, which are-supported with the energy existed by the increase of soil heat capacity either by organic matter or salinity or by time. Pandeya (1991); Fokin and Radzhabova (1996) and Maraghan (1985) in agreement with those obtained, where the regression equations of sandy (1-3) and calcareous soils (4-6) are given by;

$$P = -13.3 + 80.6\ Cp \quad (1) \qquad P = -9.1 + 113.16\ Cp \quad (4)$$

$$Fe = 12.7 + 68.61\ Cp \quad (2) \qquad Fe = -18.4 + 77.52\ Cp \quad (5)$$

$$Mn = -3.86 + 34.49\ Cp \quad (3) \qquad Mn = -39.9 + 182.05\ Cp \quad (6)$$

Where P, Fe and Mn are concentrated in ppm and Cp is heat capacity cal/g. This means that the availability of P, Fe and Mn increased by coefficients of 0.806, 0.686, 0.345, 1.132, 0.775 and 1.821 ppm for each (0.01 cal/g) change of heat capacity in both sandy and calcareous soils, respectively. It is clear that the availability of P, Fe and Mn in calcareous soil is greatly affected by soil heat capacity than sandy soil. On the other hand, the availability of Zn is decreased by increasing soil heat capacity in both sandy and calcareous soil. Therefore, it can be assumed that, some exothermic reactions or thermophobic compounds of Zn are created in both sandy and calcareous soils. These results are in agreement with those obtained by Prasad *et al.* (1991) and Prasad and Sarangthem (1992). Also, the regression equations of sandy (7) and calcarous soil (8) are given by;

$$Zn = 19.74 - 48.13\ Cp \quad (7) \qquad Zn = 18.74 - 33.99\ Cp \quad (8)$$

This means that availability of Zn in both soils decreased by coefficients of 0.481 and 0.340 ppm for each (0.01 cal/g) change of heat capacity. It is clear that the availability of Zn in sandy soils is greatly affected by soil heat capacity than calcareous soils as the presence of $CaCO_3$ in the latter impede Zn deformation.

TABLE 2. Correlation and regression coefficients between organic matter, salinity, time and soil heat capacity with availability of some nutrients in both sandy and calcareous soils at n = (240).

Sandy Soil

Y	Available Phosphorus			Available Iron			Available Manganese			Available Zinc		
X	Corr. (r)	a	b	orr. (r)	a	b	Corr. (r)	a	b	Corr. (r)	a	b
O.M	0.8364***	4.43	1.39	0.4841***	3.04	0.789	0.3129***	3.95	0.466	0.2544***	7.26	0.259
S	-0.2808***	7.55	-4.31	-0.0637n.s	-	-	-0.4344***	55.7	-5.96 E-04	-0.1354*	7.91	-1.27 E-04
T	-0.4118***	9.02	-0.01	-0.4956***	6.96	-0.02	-0.1356*	4.14	-0.0035	0.5676***	5.89	0.01
Cp	0.3349***	-13.3	80.6	0.2912***	12.7	68.61	0.1603*	-3.86	34.49	-0.3263***	19.74	-48.13

Calcareous Soil

Y	Available Phosphorus			Available Iron			Available Manganese			Available Zinc		
X	Corr. (r)	a	b	orr. (r)	a	b	Corr. (r)	a	b	Corr. (r)	a	b
O.M	0.6206***	20.8	2.64	0.3445***	4.25	0.5375	0.0244n.s	-	-	0.0625 n.s	-	-
S	-0.1551*	26.3	6.0E-04	-0.2893***	5.85	-4.16E-04	-0.2039**	17.1	-9.189E-04	0.0014 n.s	-	-
T	-0.7122***	34.9	-0.0527	0.3503***	6.91	-0.0095	-0.7203***	26.6	-0.0613	0.7349***	6.300	0.0115
Cp	0.2708***	-9.1	113.16	0.5055***	-18.4	77.52	0.3789***	-39.9	182.05	-0.3836***	18.74	-33.99

n = number of samples, Y = dependent factor, X = independent factor, r = correlation coefficient, a = intercept, b = regresion coefficient, O.M = organic matter, S= salinity level, T = time, Cp = soil heat capacity.

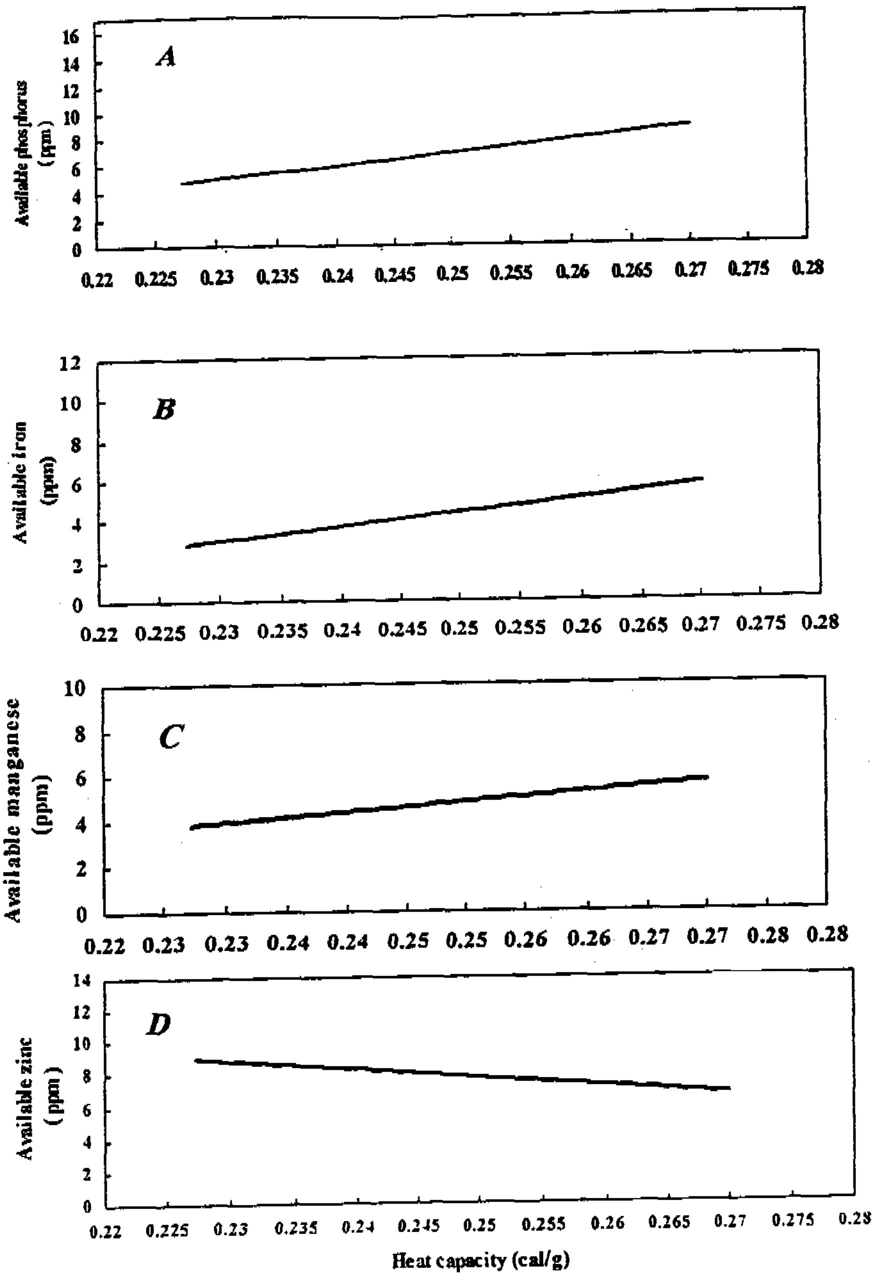

Fig. 1. Relation between heat capacity and availability of P (A), Fe (B), Mn (C) and Zn (D) under different organic matter percentage, salinity levels and time in sandy soil.

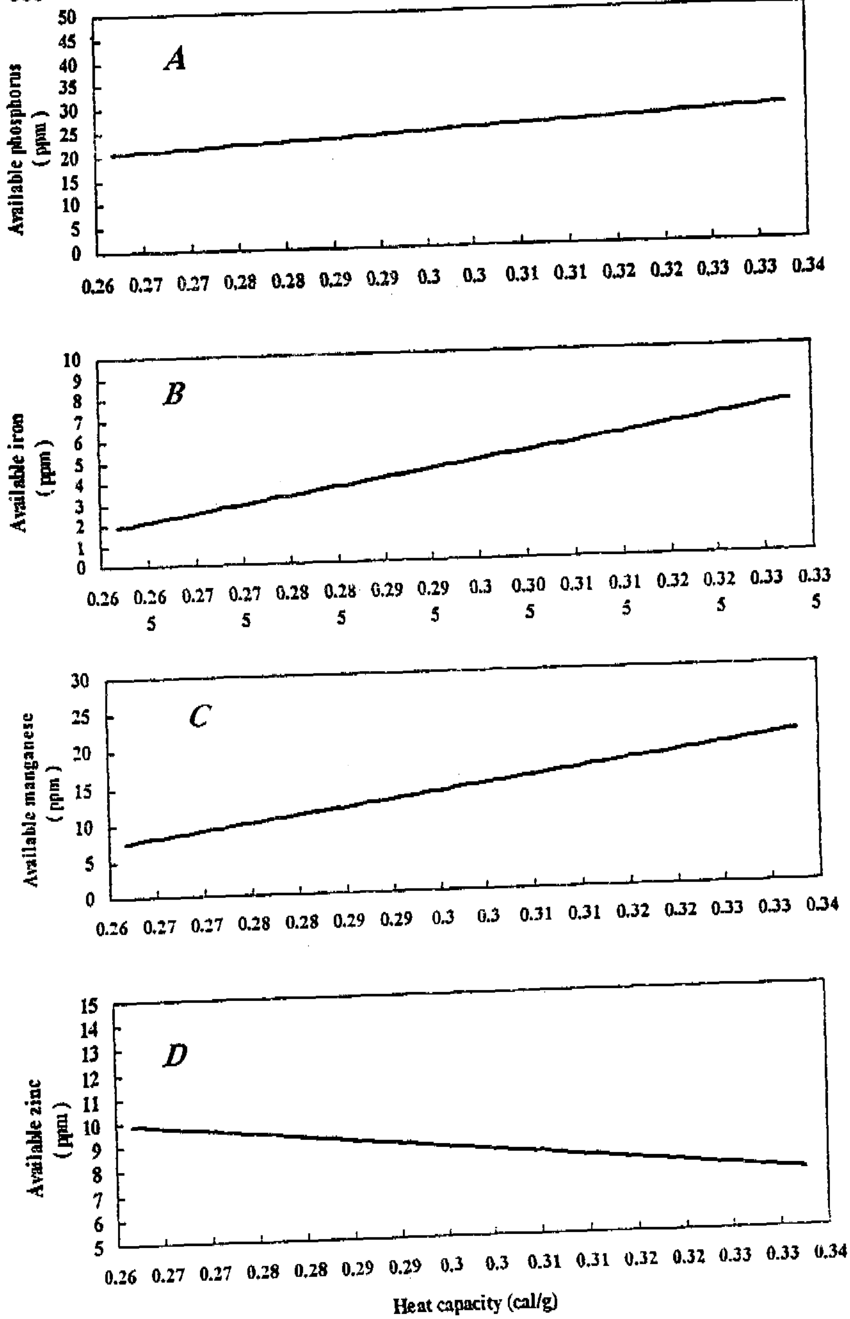

Fig. 2. Relation between heat capacity and availability of P (A), Fe (B), Mn (C) and Zn (D) under different organic matter percentage, salinity levels and time in calcareous soil.

The data in Table 2 show that the addition of compost increased availability of nutrients studied in both sandy and calcareous soils, which is due to the production of humates that exchanged with the adsorbed anion, such as phosphates, iron, manganese and zinc (Kpomblekou and Tabatabai, 1997 and Negm *et al.*, 1996). Also, Bear (1976) concluded that the increase in the availability of some nutrients could be resulted from solubilization and mobilization by short chain of organic acids, amino acids and bases. The effect of each 1% organic matter caused changing in the availability of P, Fe, Mn and Zn by factors of 1.39, 0.789, 0.466 and 0.259ppm, respectively in sandy soil, but it affects two nutrients only P and Fe by factors of 2.64 and 0.537ppm, respectively in calcareous soil. However, organic matter percentage has no effect on the availability of Mn and Zn in calcareous soils.

The data in Table 3 reveal that the best percent of compost addition in sandy soil is 4%, while the best percent of compost addition in calcareous soil is 2% where it gives high availability of some nutrients in both soil samples.

Effect of Salinity Levels

The data in Table 2 show that the availability of nutrients studied in both sandy and calcareous soils decreased by increasing salinity levels. This may be explained by the competition between chloride ion and some nutrient elements in soil. These results are in agreement with those obtained by Dahdoh and El-Hassanin (1994), exception being the available form of Fe in sandy soils and Zn in calcareous soil which are not affected by increasing of salinity levels. In addition, Table 2 reveals that the availability of P, Mn and Zn in sandy soil decreased by 0.431, 0.596 and 0.127 ppm/1000ppm change of salinity, while P, Fe and Mn in calcareous soil decreased by 0.60, 0.416 and 0.919 ppm/1000ppm change in salinity, respectively. Table 4 shows that the best salinity levels are distilled and tap water in both sandy and calcareous soils.

Effect of Time

It is shown from Table 4 that the availability of P, Mn and Fe decreased by increasing time of irrigation in both sandy and calcareous soil samples. This may be due to two experimental factors; one of them is the successive irrigation which lead to an increase in accumulated salts. The second one is the decaying of organic matter which will result in decreasing the availability of phosphorus. In addition, Table 2 shows that, the availability of, P, Fe and Mn decreased by factors

TABLE 3. Effect of organic matter addition (%) on availability of phosphorus, iron, manganese and zinc in both sandy and calcareous soils.

Sandy Soil					Calcareous Soil			
Rank	%	P (ppm)	d.l 0.01	d.l 0.05	%	P (ppm)	d.l 0.01	d.l 0.05
1	4	9.99	a	a	4	31.71	a	a
2	2	7.405	b	b	2	25.54	b	b
3	1	5.504	c	c	1	23.10	c	c
4	0	4.595	d	d	0	21.35	d	d
Rank	%	Fe (ppm)	d.l 0.01	d.l 0.05	%	Fe (ppm)	d.l 0.01	d.l 0.05
1	4	6.057	a	a	2	6.085	a	a
2	2	4.608	b	b	4	5.909	a	a
3	1	4.446	b	c	1	5.302	b	b
4	0	2.599	c	d	0	3.502	c	c
Rank	%	Mn (ppm)	d.l 0.01	d.l 0.05	%	Mn (ppm)	d.l 0.01	d.l 0.05
1	2	5.748	a	a	2	16.15	a	a
2	4	5.401	b	b	4	15.62	b	b
3	1	4.373	c	c	1	15.57	b	b
4	0	3.568	d	d	0	15.12	c	c
Rank	%	Zn (ppm)	d.l 0.01	d.l 0.05	%	Zn (ppm)	d.l 0.01	d.l 0.05
1	4	8.294	a	a	4	8.490	a	a
2	2	7.845	b	b	2	8.442	a	a
3	1	7.458	c	c	0	8.297	b	b
4	0	7.279	c	c	1	8.269	b	b

Rank= is arrange of treatments, n= is the number of samples, d.l= Are ordered letters (a>b>c>d>e) significantly different at the less significant levels (0.01 and 0.05).

of 1.00, 2.00, 0.35, 5.27, 0.95 and 6.13 ppm for each change of 100 days of time of irrigation in both sandy and calcareous soil samples, respectively. While the availability of Zn increased by increasing time of irrigation from 60 to 300 days. Table 2 also reveals that the availability of Zn increased by a factor 1.0 and 1.15 ppm for each 100 days change of time of irrigation.

The data in Table 5 reveal that the maximum availability of P, O, Fe and Zn in both kinds of studied soils are related to the time of irrigation, which found to be 60, 120 and 300 days for these elements, respectively. The maximum availability of Mn is found after irrigation for 180 days in sandy soil and 60 days for calcareous ones.

TABLE 4. Effect of salinity (ppm) on availability of phosphorus, iron, manganese and zinc in both sandy and calcareous soils.

Sandy Soil					Calcareous Soil			
Rank	*ppm*	*P (ppm)*	*d.l 0.01*	*d.l 0.05*	*ppm*	*P (ppm)*	*d.l 0.01*	*d.l 0.05*
1	12	7.844	a	a	12	26.96	a	a
2	250	7.183	b	b	2000	25.87	b	b
3	2000	6.570	c	c	250	25.23	c	c
4	4000	5.896	d	d	4000	23.66	d	d
Rank	*ppm*	*Fe (ppm)*	*d.l 0.01*	*d.l 0.05*	*ppm*	*Fe (ppm)*	*d.l 0.01*	*d.l 0.05*
1	12	4.693	a	a	250	5.834	a	a
2	250	4.453	b	b	12	5.683	a	a
3	2000	4.380	bc	b	2000	5.188	b	b
4	4000	4.205	c	c	4000	4.100	c	c
Rank	*ppm*	*Mn (ppm)*	*d.l 0.01*	*d.l 0.05*	*ppm*	*Mn (ppm)*	*d.l 0.01*	*d.l 0.05*
1	12	6.044	a	a	12	18.38	a	a
2	250	5.267	b	b	250	15.60	b	b
3	2000	4.366	c	c	2000	14.84	c	c
4	4000	3.409	d	d	4000	13.63	d	d
Rank	*ppm*	*Zn (ppm)*	*d.l 0.01*	*d.l 0.05*	*ppm*	*Zn (ppm)*	*d.l 0.01*	*d.l 0.05*
1	2000	8.212	a	a	2000	8.501	a	a
2	12	7.923	b	b	12	8.346	b	b
3	250	7.566	c	c	250	8.334	b	b
4	4000	7.175	d	d	4000	8.316	b	b

Rank= is arrange of treatments, n= is the number of samples, d.l= Are ordered letters (a>b>c>d>e) significantly different at the less significant levels (0.01 and 0.05).

Conclusions

From the previous study and discussion of data obtained on sandy and calcareous soil samples it can be conclude the following:

In both sandy and calcareous soils, availability of P, Fe and Mn have similar trends with heat capacity. This indicates some thermophilic compounds and endothermic reactions. While with Zn the reaction is negative which indicate some thermophobic compounds and exothermic reactions.

TABLE 5. Effect of time (days) on availability of phosphorus, iron, manganese and zinc in both sandy and calcareous soils.

Sandy Soil					Calcareous Soil			
Rank	*days*	*P (ppm)*	*d.l 0.01*	*d.l 0.05*	*days*	*P (ppm)*	*d.l 0.01*	*d.l 0.05*
1	60	8.347	a	a	60	31.39	a	a
2	120	7.529	b	b	120	28.90	b	b
3	180	6.884	c	c	180	25.68	c	c
4	240	6.148	d	d	240	22.26	d	d
5	300	5.458	e	e	300	18.91	e	e
Rank	*days*	*Fe (ppm)*	*d.l 0.01*	*d.l 0.05*	*days*	*Fe (ppm)*	*d.l 0.01*	*d.l 0.05*
1	120	6.749	a	a	120	6.374	a	a
2	180	5.525	b	b	240	5.897	b	b
3	60	4.614	c	c	60	5.378	c	c
4	240	2.955	d	d	180	4.845	d	d
5	300	2.294	e	e	300	3.014	e	e
Rank	*days*	*Mn (ppm)*	*d.l 0.01*	*d.l 0.05*	*Days*	*Mn (ppm)*	*d.l 0.01*	*d.l 0.05*
1	180	6.28	a	a	60	25.72	a	a
2	120	5.50	b	b	180	17.8	b	b
3	300	4.56	c	c	240	15.04	c	c
4	240	4.50	c	c	120	13.13	d	d
5	60	3.02	d	d	300	6.394	e	e
Rank	*Days*	*Zn (ppm)*	*d.l 0.01*	*d.l 0.05*	*Days*	*Zn (ppm)*	*d.l 0.01*	*d.l 0.05*
1	300	9.346	a	a	300	10.63	a	a
2	180	8.027	b	b	120	8.257	b	b
3	120	7.823	b	b	180	8.158	b	b
4	240	7.241	c	c	240	7.863	c	c
5	60	6.157	d	d	60	6.970	d	d

Rank= is arrange of treatments, n= is the number of samples, d.l= Are ordered letters (a>b>c>d>e) significantly different at the less significant levels (0.01 and 0.05).

In sandy soil, both organic matter addition and salinity levels lead to an increase in the studied nutrients availability while time of water irrigation cycle leads to a decrease in the P, Fe and Mn availability but an increase in the availability of Zn. However, in calcareous soils, the organic matter addition causes a decrease on the availability of P and Fe while time of irrigation causes a decrease in the availability of P and Mn. The effect of time results in a decrease in the availability of all studied nutrients. The best treatments of organic matter additions and salinity levels are 4%, 2% and 2000ppm, respectively in both sandy and calcareous soils.Finally, renewing of organic addition is physically defined by approximately one year, which is commonly advised.

References

Bear, F.E. (1976) *"Chemistry of the Soil:"* Editor in Chief. Soil Sci. Former Chairman Department of Soils. Rutgers, The State University of New Jersy

Collenie, A., Verloo, M., Kiekens, L., Velghe, G. and Camerlynck, R. (1982)" *Chemical Analysis of Plants and Soil."*

Dahdoh, M.S.A. and El-Hassanin, A.S. (1994) Combined effects of organic source irrigation- water salinity and moisture level on the growth and mineral composition of Barley grown on Calcareous soil. *Desert Inst. Bull.*, Egypt, **44**(2), 247.

Fokin, A.D., Radzhabova, P.A. (1996) Phosphate availability of soils as a function of organic matter status and transformation. *Pochvovedenie*, **11**, 1303 (Russ). Maik Nauka

Hillel, D. (1980) *"Fundamentals of Soil Physics"*, Academic Press, New York, London, Jovanovick Publishers.

Iu, K.L., Pulford, L.D. and Dunean, H. J. (1981b) Influence of water logging and lime or organic matter additions on the distribution of trace metals in an acid soil. *Plant Soil*, **59**, 327.

Kpomblekou, A.K. and Tabatabai, M.A. (1997) Effect of cropping systems on quantity / intensity relationships of soil phosphorus. *Soil Sci.* **162** (1), 56.

Lindsay, W.L. and Norvell, W.A. (1978) Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.* **42**, 421.

Malcolm Cressfr; Ken Killham and Tony Edwards (1993)*"Soil Chemistry and Its Applications"*. Cambridge University Press, England

Maraghan, J.T. (1985) Manganese deficiency in soybeans as affected by Fe EDDHA and low soil temperature. *Soil Sci. Soc. Am.* **49** (6), 1584.

Negm, A.Y., Awad, S.S. and El-Mailah, M.I. (1996) Wheat growth and some soil chemical characteristics of sludge soil under moisture content. *Egypt. J. Appl. Sci.* **11**(10), 240.

Pandeya, S.B. (1991) Thermodynamics of adsorption of iron - fulvic acid complexes on soils. *Indian Soc. Soil Sci.* **39** (4), 650.

Partington, J.R. (1963) *"An Advanced Treatise on Physical Chemistry*, Vol. III. *The Properties of Solids"*. John Wiley and Sons Inc., New York.

Prasad, B., Agarwal, A.D. and Kusum (1991) Adsorption and desorption of zinc on calcareous soils. *Indian Soc. Soil Sci.* 39(4), 662.

Prasad, B. and Sarangthem, I. (1992) Thermodynamics of zinc- chalets adsorption in calcareous soils. *Indian Soc. Soil Sci.* **40** (3), 458.

Yang, Dinggvo, Cheng, Yanao; Wen, Yanmao and Jin, Aizhem (1985) Content distribution and availability of trace elements in soils of Sichuan Basin (China). *Turang Xuebao,* **22** (2), 157.

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العناصر الميسرة وعلاقتها بالسعة الحرارية وبعض ظروف الاراضى الصحراوية

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أقيمت تجربة فى الصوبة بهدف دراسة تيسير بعض العناصر ومنها الفوسفور ، الحديد ، المنجنيز والزنك فى نوعين من الأراضى الصحراوية المصرية (الرملية والجيرية). المعاملات الرئيسية للأراضى هى إضافة المادة العضوية والملوحة بأربعة مستويات مختلفة ووقت التجربة لتحقيق خمس فترات زمنية .

واظهرت النتائج أنه يوجد علاقة معنوية موجبة بين تركيز العناصر الميسرة وكل من السعة الحرارية ونسبة المادة العضوية فى كلا التربتين فيما عدا عنصرى المنجنيز والزنك فلهما علاقة معنوية سالبة فى الأراضى الجيرية ويعزى هذا لاحتوائها على نسبة عالية من كربونات الكالسيوم ، كما وجدت علاقة معنوية سالبة فى معظم الحالات نتيجة لتراكم الأملاح. كذلك وجدت علاقة معنوية سالبة مع عامل الوقت نتيجة للتثبيت بواسطة الترسيب وبعض تفاعلات الإحلال.

وجد فى هذه الدراسة أنه يوجد علاقة معنوية موجبة بين السعة الحرارية وتفاعلات الفوسفور ، الحديد والمنجنيز وهذا يدل على أنها عناصر محبة للحرارة أو تفاعلاتها ماصة للحرارة بينما تفاعلات عنصر الزنك لها علاقة معنوية سالبة مع السعة الحرارية وهذا يدل على عنصر الزنك كاره للحرارة أو تفاعلات العنصر طاردة للحرارة.