J. King Saud Univ., Vol. 4, Agric. Sci. (2), pp. 287-297 (A.H. 1412 / 1992).

Changes in Extractable Zn and P Applied as Organic and Inorganic Forms to a Certain Calcareous Saudi Arabian Soil

A.M. Falatah and M.S. Nadiem
Soil Science Department, College of Agriculture,
King Saud University, Riyadh, Saudi Arabia

Abstract. A greenhouse incubation study was conducted to investigate the extraction of Zn and P by Ammonium Biocarbonate – Diethylenetriaminepentaacetic Acid (AB-DTPA) from a calcareous sandy loam soil that had been treated with $ZnSO_4 \cdot 7H_2O$, KH_2PO_4 and/or poultry manure (PM). Extractable Zn from soil receiving Zn fertilizer increased rapidly within the first day of incubation, and decreased uniformly throughout the following 84-days. Extractable P from samples treated with P fertilizer showed the same pattern up to 54 days but increased thereafter indicating the release of a portion of the fixed P with elapsed time. Application of $ZnSO_4 \cdot 7H_2O$ decreased Fe and Cu and increased that of Mn. In contrast, addition of KH_2PO_4 increased extractable Fe and Mn, but decreased extractable Cu. Poultry manure (PM) addition decreased soil-pH and increased extractable Zn and P levels throughout the tested periods. The considerable increase in these nutrients was also attributed to the organic complexing agent in manure which most probably supplied chelating agents that kept nutrients in soluble and available form. Extractable Zn or P from soil amended with PM did not decline with time at the same rate as inorganic Zn and P which were added as fertilizers. The results obtained show that, poultry manure is a valuable source of nutrients with relatively long lasting effect on soil reaction and nutrients availability.

Introduction

Zinc and phosphorus deficiences have been reported to limit crop growth in calcareous soils, although the total content of Zn and P in these soils is not less than that of soils which supply adequate Zn or P to plants [1,2]. The addition of inorganic Zn and P fertilizers to calcareous soils probably will provide a temporary correction of their deficiency [3,4]. Organic matter (poultry manure) is usually added to calcareous soils as a soil amendment to improve their properties and fertility levels. The effective utilization of P and Zn present in poultry manure is evidence of the importance of organic matter in increasing the availability of these elements in soils [5,6].

Azevedo and Stout [7] reported that the P in poultry manure was equally available as inorganic sources, but other investigators [4] concluded that the effects of manure P are greater than the same amounts of inorganic P. The effect in all cases was attributed to the complexing agents in manure which is responsible for supplying chelating agents that aid in keeping nutrients soluble and more available to plants. The present study was planned to investigate the effect of inorganic Zn and P and poultry manure (PM) application on nutrients availability in a calcareous soil. Particular interest was focused on Zn and P, however, data were also collected for other elements such as Fe, Mn and cu to illustrate related effects on these nutrients. Also the role of poultry manure (PM) as a source of Zn, P and as a complexing agent that may increase the extractability of the inorganic Zn and P added to calcareous soil was investigated.

Materials and Methods

An incubation experiment was carried out using surface (0-30 cm) soil sample collected from King Saud University Farm (KSUF) at Dirab, Saudi Arabia. The soil was sandy loam (coarse loam, mixed calcareous hyperthermic, typic torriflovents), which has mechanical composition of 74% sand, 14% silt and 12% clay; a cation exchange capacity (CEC) of 5 Cmol(+)/kg;$CaCO_3$ of 28%; organic matter (OM) of 0.41%; and pH of 7.7 in 1:1 soil water mixture. AB-DTPA extractable Zn, Fe, Mn, Cu and P were 0.5, 4.2, 10.4, 0.5 and 5.1 mg/kg respectively. This experiment consisted of 27 treatment combinations with three replications. The treatments were as follows: manure at three levels 0, 1 and 2%, three levels of Zn: 0, 5 and 10 mg/kg as $ZnSO_4.7H_2O$ and three levels of P: O, 25 and 50 mg/kg as KH_2PO_4. The manure used was ground in a willey mill and passed through a 2 mm screen. It contained 0.22% Fe, 0.023% Zn, 0.038%Mn, 0.007% Cu, 1.36% P and 1.96% N. The above treatments were mixed with one kg of sandy loam soil. Treated and untreated samples were packed into plastic pots having a drainage hole at base. The soil moisture in each pot was brought to field capacity by weight and maintained at this level during the experimental period. The temperature in the greenhouse was controlled at 24 ± 2°C throughout the experiment. A subsample of each treatment was taken after 1, 28, 56, and 84 days, and analyzed for pH and AB-DTPA extractable nutrients.

Results and Discussion

Extractable Zn

The AB-DTPA extractable Zn was significantly affected by the period of incubation and rate of added Zn (Fig. 1). Extractable Zn increased with time for untreated soil samples. At the end of the studied periods there was an overall increase of 31% in extractable Zn which indicate that a portion of retained Zn in the soil which maintained under respective moisture condition was released gradually

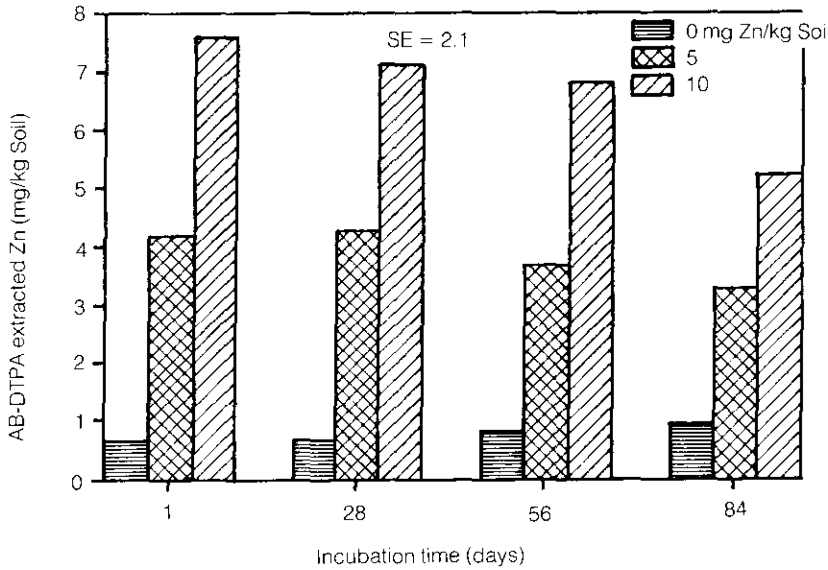

Fig. 1. Extractable Zn as affected by Zn rates ($Zn\ SO_4 . 7H_2O$) and incubation time

with lapse of time (Fig. 1) Although the increase was not significant, its trend agrees with the finding of Bauer [8] and Hulagur *et al.* [9].

As expected, extractable Zn values inceased when Zn fertilization rate increased regardless of incubation periods. It is presumed that portion of the added Zn fertilizers reacted with the soil components and become nonextractable. Ths is substantiated by the gradual decline of extractable Zn from incubated Zn treated samples. This observation is in general agreement with reported findings of Brown *et al.* [10] and Follett and Lindsay [11]. Approximately 47% of the lower level and 43% of the higher level of added Zn were recovered at the end of the incubation time.

Table 1 shows that extracted Zn values from soil samples treated with PM combined with Zn fertilizer were similar to those extracted from soil samples treated with PM only. The present data are not consistent with hypothesis that complexing properties of organic matter will increase the added inorganic nutrients availability as reported by many authors [5, 6, 12] but agrees with the concept that there is an interaction between the fertilizer and the manure which is important in the reversion of Zn to nonextractable form [13].

Table 1. Effect of Zn fertilizer ($ZnSO_4.7H_2O$) combined with poultry manure (PM) on extractable Zn.

Treatments Zn	PM	AB-DTPA extractable Zn
mg/kg	%	mg/kg
0	0	2.2
0	1	5.2
0	2	9.1
5	0	4.4
5	1	4.8
5	2	8.4
10	0	7.4
10	1	6.8
10	2	8.8

Effect of applied Zn on extractable Fe, Mn and Cu

AB-DTPA extractable Fe decreased with Zn application (Table 2). The reduction was significant between 0 and 10 mg Zn/kg levels. This phenomenon was reported by Premi [14] who stated that applied Zn fertilizer tended to decrease extractable soil-Fe. Conversely, application of Zn showed an increase in extractable Mn. Therefore, the decrease in extractable Fe may be attributed to the increase of extractable Mn as reported by Venkata and Mehta [15]. They illustrated the antagonistic relationship between Fe and Mn in soil. The Cu data follow a similar pattern to the Fe, showing a significant decrease at 5 and 10 mg Zn/kg in extractable Cu levels. This agrees with the observation of Hulagur *et al.* [9]. This can be plausibly explained as the result of failure of Cu to compete strongly with added Zn for the available chelation sites of the DTPA.

Table 2. Extractable Fe, Mn, and Cu as influenced by Zn ($ZnSO_4$. $7H_2O$) application.

Zn rates	AB-DTPA extractable		
	Fe	Mn	Cu
mg/kg		----mg/kg----	
0	8.2	14.2	1.3
5	7.5	14.6	1.1
10	7.1	15.8	0.95
LSD (0.05)	0.8	1.4	0.07

Extractable P

Extractable P by AB-DTPA was significantly affected by incubation time and P application (Fig. 2). Added P-fertilizer increased extractable P. As the incubation time increased the extractable P decreased and reached its minimum values after 56 days. This indicates that a portion of added P reacted with soil components and was therefore retained in nonextractable form. Similar trend was reported earlier by many investigators [16, 17, 18]. Extractable P, however, increased after 56 days of incubation with recoveries of added (25 and 50 mg/kg) P being 63% and 52% respectively. This suggests that a portion of the retained P was released with tim due to changes in the soil chemical environment such as the drop in pH values from 7.7 at day one to 7.3 at 56-day incubation. A recent study by Singh *et al.* [19] reported similar changes in extractable P with time in saline and sodic soils. They related such changes to varying pH during incubation.

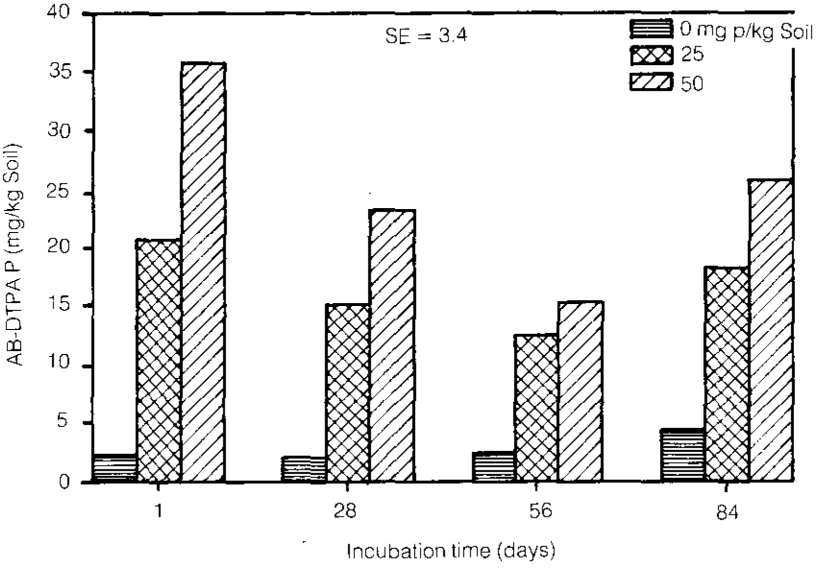

Fig. 2. Extractable P as affected by P rates (KH_2PO_4) and incubation time

Application of P fertilizer had a significant effect on soil micronutrients extractability (Table 3). Addition of 25 and 50 mg P/kg caused a noticeable increase in AB-DTPA extractable Fe and Mn. This indicates that soil Fe and Mn moved from less extractable to more extractable apparently due to changes pH during incubation. Shuman [20] observed similar trend which supports the present result. The data also

Table 3. Extractable Fe, Mn, and Cu as influenced by P (KH_2PO_4) addition.

P rates	AB-DTPA extractable		
	Fe	Mn	Cu
mg/kg	----------	----mg/kg----	----------
0	5.4	12.5	0.65
25	5.8	12.8	0.61
50	6.7	14.5	0.58
LSD (0.05)	1.2	1.8	0.05

shows that extractable Cu decreased due to P fertilizer addition. This trend agrees with the findings of Badanur and Venkate Rao [21] who observed that application of P caused a decrease in extractable soil-Cu. They postulated that the increase of P in soil solution may lead to immobilization of Cu in the soil.

Effect of poultry manure (PM) amendment on soil-pH and nutrients extractability

Extracted Mn, Fe, Cu and soil-pH values for untreated and manure amended soil samples are shown in Table 4. One day after manure addition soil pH remained nearly the same as untreated soil samples, but thereafter, soil pH of manure amended samples continued to decrease throughout the incubation period. The pH decrease appeared proportional to the amounts of manure applied and increases in nutrients extractabilities.

Extractable Mn values increased as PM rates and incubation time increased. The amounts of Mn applied with 1.0 and 2.0% manure treatments were approximately 4 and 8 mg/kg respectively and therefore, most of this increase in extractable Mn from original soil as a result of PM addition could be due to chelation of solubilized soil Mn. The drop in pH values of the manure amended samples naturally contributed to the increase in extractable Mn.

AB-DTPA extracted more Fe from manure treated soil samples than from the corresponding untreated ones throughout the incubation periods. The remarkable increase in extractable Fe was attributed to the addition of 22 and 44 mg Fe/kg in the added manure. The extracted Fe increased with time but only 59 and 44% of added manure Fe was recovered at the end of the experiment. As with Mn extractable Cu from manure treated samples remained high relative to untreated samples throughout the incubation period.

Table 4. Extractable Mn, Fe and Cu and resulting pH from soil samples treated with poultry manure (PM).

Manure treatment	Days after manure addition			
	1	28	56	84
%			pH	
0	7.6	7.6	7.7	7.6
1	7.8	7.3	7.2	7.0
2	7.8	7.1	7.1	6.8
SE = 0.31				
			Mn	
			mg/kg	
0	9.4	10.5	9.8	11.3
1	12.5	18.5	21.4	23.5
2	14.2	21.6	24.5	28.7
SE = 3.5				
			Fe	
			mg/kg	
0	5.4	4.6	5.2	4.8
1	7.6	12.5	15.8	18.4
2	9.7	16.5	24.5	28.7
SE = 2.7				
			Cu	
			mg/kg	
0	0.5	0.5	0.4	0.5
1	0.9	1.4	1.6	1.8
2	1.3	1.5	1.9	2.3
SE = 0.07				

AB-DTPA extracted Cu was higher than the amounts of Cu applied in 1 and 2% manure which were about 0.7 and 1.4 mg/kg. Most of this increase in extractable Cu could be due to chelation of solublized soil Cu and the drop in pH of the manure amended samples which naturally caused such increase in extractable Cu.

Poultry manure was an effective source of P as illustrated by a marked increase in extractable P with time (Fig. 3). This is in close agreement with the finding of Elias Azar *et al.* [22] who reported that the increase in extractable P is typical to manure P. Their results also showed beneficial effect of manure on soil P solubility. Extract-

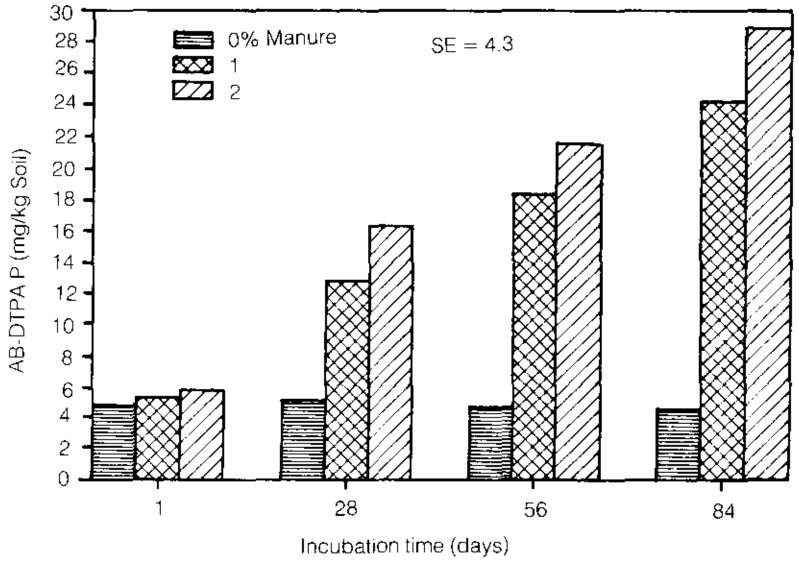

Fig. 3. Extractable P as affected by manure rates and incubation time

able P of samples treated with inorganic P ($KH_2 PO_4$) was initially high and gradually decreased with time. This is a typical behavior of phosphorus fertilizer as reported by many workers [23]. The present findings reaffirm their conclusions.

Similar to P, extractable Zn from PM amended soil increased consistently with time (Fig. 4). This increase was more a result of chelation of solubilized soil Zn due to manure appliction than to added manure Zn (2.5 and 4.6 mg/kg).

Conclusion

AB-DTPA extractable Zn increased with increasing amounts of $ZnSO_4$ $7H_2O$ added, and decreased with increasing incubation time. Similarly, inorganic P application led to higher extractable P, but reversion to less extractable form occurred with increasing incubation up to 56 days incubation. Thereafter, extractable P tended to increase with longer time (84 days). The increases in extractable forms of Fe, Mn, Cu, Zn and P as a result of PM application were substantial. This may have important implication in the management of calcareous soils amended with poultry manure. The works of Sims et al. [24]; Schwab and Lindsay, [25]; Thomas and Mathers, [5] showed that AB-DTPA extracted nutrients are considered to be available. Most probably the complexing agent and changes in soil chemical environment

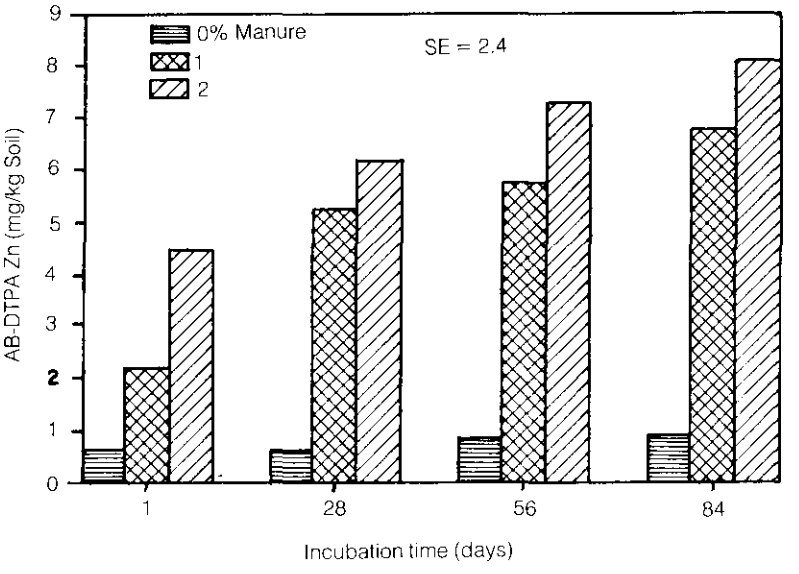

Fig. 4. Extractable Zn as affected by manure rates and incubation time

caused by manure amendment is responsible for increasing nutrients extractability. In conclusion, results show that poultry manure is valuable source of plant nutrients. Addition of poultry manure to calcareous soil affects soil properties and leads to increased availability of Zn, Mn, Fe and P in soils.

References

[1] Throne, D.W. "Zinc Deficiency and Its Control." *Adv. Agron.*, 9 (1957), 31-65.

[2] Barrow, N.J. and Shaw, T.C. "The Slow Reaction Between Soil and Anion: Effect of Time and Temperature on the Decrease in Phosphate Concentration in the Soil Solution." *Soil Sci.*, 119 (1975), 167-177.

[3] Rehm, G.W., Wiese, R.A., and Hergert, G.W. "Response of Corn to Zinc Source and Rate of Zinc Band Applied with Ortho or Polyphosphate." *Soil Sci.*, 129 (1980), 36-44.

[4] Olsen, S.R. and Barber, S.A. Effect of Waste Application on Soil Phosphorus and Potassium. In: *Soils for Management of Organic Waste and Waste Water.* Elliott, L.F. and Stevenson F.J. (Eds.). Madison, Wisconsin: ASA, CSSA, SSSA, 1977.

[5] Thomas, J.D. and Mathers, A.C. "Manure and Iron Effects on Sorghum Growth on Iron Deficient Soil." *Agron. J.*, 71 (1979), 792-794.

[6] Prasad, B., Singh, A.P. and Sinha, M.K. "Effect of Poultry Manure as a Source of Zinc, Iron, and as Complexing Agent on Zinc and Iron Availability in Calcareous Soil." *J. Indian Soc. Soil Sci.*, 32 (1984), 519-521.

[7] Azevedo, J. and Stout, P.R. "Farm Animal Manure: A Review of Their Role in Agriculture Environment." *Division of Agric. Sci. University of California Manual*, 44 (1974).

[8] Bauer, A. "Distribution of Available Micronutrient Cations in Bunelkhand Soil." *Soil Fertil.*, 28 (1965), 2936-2939,

[9] Hulagur, B.F., Dangarwala, R.T., and Mehta, B.V. "Interrelationship among Available Zinc Copper and Phosphorus in Soil." *J. Indian Soc. Soil Sci.*, 23 (1975), 231-235.

[10] Brown, A.L., Krantz, B.A., and Martin, P.E. "The Residual Effect of Zinc Applied to Soils." *Soil Sci. Soc. Am. J.*, 28 (1964), 236-238.

[11] Follett, R.L. and Lindsay, W.L. "Changes in DTPA-Extractable Zinc, Iron, Manganese, and Copper in Soils Following Fertilization." *Soil Sci. Soc. Am. J.*, 35 (1971), 600-602.

[12] Miller, W.P., Martens, D.C. and Zelazny, L.W. "Effect of Manure Amendment on Soil Chemical Properties and Hydrous Oxide." *Soil Sci. Soc. Am. J.*, 49 (1985), 856-861.

[13] Sims, J.T. "Soil-pH Effect of Distribution and Plant Availability of Manganese, Copper, and Zinc." *Soil Sci. Soc. Am. J.*, 50 (1986), 367-373.

[14] Premi, P.R. "Available Fe as Affected by Different Levels of Zn." *Soil Fert.*, 34 (1971), 3620.

[15] Venkata, A.S. and Mehta, B.V. "Effect of Zn, Fe and Moisture on the Availability of Zn, Fe and Mn in Soil." *J. Indian Soc. Soil Sci.*, 23 No. 2 (1975), 236-241.

[16] Devine, J.R., Gunary, D. and Larsen, S. "Availability of Phosphate as Affected by Duration of Fertilizer Contact with Soil." *J. Agric. Sci.*, 71 (1968), 359-364.

[17] Hooker, M.L., Peterson, G.A., Sander, D.H., and Daigger, L.A. "Phosphate Fractions in Calcareous Soil as Affected by Time and Amounts of Added Phosphate. *Soil. Sci. Soc. Am. J.*, 44 (1980), 269-277.

[18] Ryan, J., Curtin, D., and Cheema, M.A. "Significant of Iron Oxides and Calcium Carbonate Particle Size in Phosphate Sorption by Calcareous Soils." *Soil Sci. Soc. Am. J.*, 49 (1985), 74-76.

[19] Singh, R.K., Sengupta, M.B., Goswami, N.N., and Sastry, T.G. "Phosphate Absorption in Salt Affected Soils at Field Capacity." *J. Indian Soc. Soil Sci.*, 34 (1990), 434-437.

[20] Shuman, L.M. "Effect of Phosphorus Level on Extractable Micronutrients and Their Distribution Among Soil Fractions." *Soil Sci. Soc. Am. J.*, 52 (1988), 136-141.

[21] Badanur, V.P. and Venkata Rao, B.V. "Influence of Phosphorus Buildup on Availability of Micronutrients in Red Soils of Bangalore." *Soil Sci.*, 116 (1973), 292-294.

[22] Elias Azar, Laag K.A.E. and Pratt, P.F. "Biocarbonate Extractable Phosphorus in Fresh and Composed Dearly Manure." *Soil Sci. Am. J.*, 44 (1980), 435-437.

[23] Bar-Yosef, E. and Akiri, B. "Sodium Biocarbonate Extraction to Estimate Nitrogen, Phosphorus, and Potassium Availability in Soils." *Soil Sci. Soc. Am. J.*, 42 (1978), 319-323.

[24] Sims, J.L., Piya Duangpatra, Ellis, J.H., and Phillips, R.E. "Distribution of Available Manganese in Kentucky Soils." *Soil Sci.*, 127 (1979), 270-273.

[25] Schwab, A.P. and Lindway, W.L. "Effect of Redox on the Solubility and Availability of Iron." *Soil Sci. Soc. Am. J.*, 4 (1983), 201-205.

استخـلاص الزنك والفوسفور المضافان في صورة عضوية وغير عضوية إلى تربة جيرية

عبدالرزاق محمد فلاته و محمود السيد علي نديم

قسم علوم التربة، كلية الزراعة، جامعة الملك سعود

الرياض، المملكة العربية السعودية

ملخص البحث. أجريت تجربة لدراسة استخلاص عنصري الزنك والفوسفور بواسطة AB-DTPA من تربة جيرية (رملية سلتية) بعد معاملتها بكبريتات الزنك ($ZnSO_4 . 7H_2O$) وفوسفات البوتاسيوم (KH_2PO_4) وسماد عضوي (زرق الدواجن) وتركها في الصوبة الزجاجية لمدة ١، ٢٨، ٥٦، ٨٤ يومًا.

وقد أوضحت النتائج الآتي:

زاد الزنك المستخلص من التربة المعاملة بكبريتات الزنك في اليوم الأول بعد الإضافة ولكنه انخفض معنويًا بعد ذلك واستمر في الانخفاض حتى نهاية التجربة.

انخفض الفوسفور المستخلص من التربة المعاملة بفوسفات البوتاسيوم بعد الإضافة وحتى ٤٥ يومًا من بداية التجربة، ولكنه ارتفع نسبيًا بعد ذلك مشيرًا إلى انطلاق جزء من الفوسفور المثبت بعد هذه الفترة.

أدت إضافة الزنك للتربة إلى انخفاض كل من الحديد والنحاس وزيادة المنجنيز المستخلص من التربة في حين أدت إضافة الفوسفور إلى زيادة استخلاص الحديد والمنجنيز وانخفاض استخلاص النحاس.

انخفض الـ pH في التربة المعاملة بسماد عضوي (زرق الدواجن) وزاد استخلاص الزنك والفوسفور خلال فترة التجربة، وعزى ذلك إلى تأثير السماد على حموضة التربة وإلى الخواص المخلبية لمركباته العضوية مما يساعد على تيسير هذه العناصر.