12 *Egypt. J. Soil. Sci.* **Vol. 55**, No. 2, pp.185-195 (2015)

Availability of P, Fe, Mn, Zn and Cu as Affected by Waterlogging and Compost Addition in Some Soils of Egypt

Amel L. Abd El-Latif
Soil Science Department, Faculty of Agriculture, Cairo University,Cairo, Egypt.

UNDER conditions of waterlogging, a Laboratory experiment was conducted for studying the effect of period of soil water logging and compost addition on pH, Redox potential (Eh) and the availability of P, Fe, Mn, Zn and Cu in clay loam and sandy soils. The obtained results indicated that, waterlogging the sandy soil up to three weeks and the clay loam soil up to four weeks decreased their pH values thereafter these values tended to increase slightly, and the compost additions reduced soil pH.

In both soils, Eh showed a marked decline reaching a minimum value during the first week of waterlogging. The addition of the compost resulted in a greater decrease of Eh.

Waterlogging the investigated soils increased their availability of P, Fe and Mn, while the availability of Zn and Cu decreased. The addition of compost decreased the availability of the investigated elements. This trend may be due to the formation of insoluble organic complexes.

Keywords: Waterlogging, Compost, Redox potential, Phosphorus, Micronutrients.

There are about million feddan planted with rice annually in Egypt. In summer, it is quite common to see large areas of agriculture land flooding with water. When a soil is submerged, air is excluded and the soil quickly becomes anoxic and reduced. This phenomenon changes physical, biological and chemical properties of soil (Kirk, 2004). Soil pH is probably the most important chemical soil parameter (Bloom, 2000).

Organic matter is one of the main factors affecting soil Eh (Oglesby, 1997). Organic matter degradation rates are fastest under oxidizing conditions, in the presence of free O_2 (Macias and Camps Arbestain, 2010). Singh *et al.* (1981) mentioned that application of organic manures (fresh organic matter and compost) to flooded rice soils tended to increase their content of available P after 20 days.

The availability of several micronutrients such as Mn, Cu or Zn, is strongly influenced by soil Eh and pH. There is evidence for direct or indirect biological alterations in the availability, solubility, or oxidation-reduction state of Mn, Zn, Cu, Mo, Co, Si, Ni and various others (Reddy *et al.,* 1986).

The objective of this investigation was to monitor changes in redox potential, pH and availability of some essential nutrients as a result of waterlogged and compost additions.

Materials and Methods

A- Soil sampling

Two surface soil samples (0 – 30) variable in their texture were collected from different locations in Egypt. The first sample was a sandy soil taken from Agric. Res. Station, Ismailia Governorate. The second sample was a clay loam soil collected from Faculty of Agriculture Farm, Cairo Univeristy.

All the samples were air dried, crushed and sieved through a 2 mm sieve. Some of the initial soil properties are shown in Table 1.

TABLE 1. Some properties of the investigated soils .

No. of Soil	Particle size distribution					O.M %	$CaCO_3$ %	EC dS/m	pH (1:2.5)
	C.S %	F.S %	Silt %	Clay %	Texture class				
1	16.2	28.7	17.4	37.7	Clay loam	1.90	2.90	2.99	7.5
2	76.3	15.8	2.0	5.9	Sandy	0.42	0.24	0.45	7.4

B- Compost treatments

Some physical and chemical properties of the studied compost are shown in Table 2, compost used in this study was supplied from Arab Organization for Industrial at El-Khatara, Sharkia Governorate. The compost was mixed with the investigated soils in three rates : 1% (Level 1) ,2% (Level 2) and 3% (Level 3).

C- Experimental work

One hundred gram portions of each soil was uniformly packed in plastic cups. Each cup received the calculated quantity of the considered compost. The soil was thoroughly wetted with a quantity of tap water sufficient to maintain ahead of 3.0 cm above the soil.

The cups were covered and incubated at 28° ± 2° along the whole period of study which extended to 5 weeks. Each treatment was replicated three times and the cups were arranged in split plot design. Factors of the experiment were 4 different compost, two different soils and 6 period of waterlogging (*i.e* 4 x 2 x 6).Statistical analysis was done according to Snedecor and Cochran (1990).

D- Soil analysis

The physical and chemical properties of the studied soil were determined according to Page *et al.* (1982) and Klute (1986).

Samples of each soil were taken on 0, 1, 2, 3, 4 and 5 weeks after water logging. Soil pH was determined in 1:2.5 soil : water suspension using a pH meter from Jenway. Redox potential (Eh) was instantly measured at each period using platinum redox electrodes.

Available phosphorus was immediately extracted by 0.5 N $NaHCO_3$ and determined spectrophotometrically (Jackson, 1973). Available Fe, Mn, Zn and Cu were immediately extracted by DTPA (Lindsay and Norvell, 1978) and analyzed by atomic absorption spectrophotometry.

TABLE 2. Some physical and chemical properties of compost .

Property	Values
Bulk density (kg/m^3)	730
Moisture contents (%)	17
pH (1:10)	8.2
EC (1:10) dS m^{-1}	4.64
Ammonium Nitrogen ($mgkg^{-1}$)	330
Nitrate Nitrogen ($mgkg^{-1}$)	189
Total nitrogen (%)	1.16
Organic matter (%)	29.53
Organic carbon (%)	17.02
Ash (%)	70.65
C/N ratio	14.67
Total phosphorus (%)	0.50
Total potassium (%)	0.94
Total iron ($mgkg^{-1}$)	850
Total zinc ($mgkg^{-1}$)	650
Total cupper ($mgkg^{-1}$)	135
Total manganese ($mgkg^{-1}$)	425

Result and Discussion

Figure1 shows the pH changes with time of the two soils as affected by waterlogging and compost additions in the studied soils. The pH of the two waterlogged soils decreased significantly with time, following the expected pattern (Ponnamperuma, 1972) and reached slightly acidic values. The rate of pH decrease was more pronounced during the 1^{st} and 2^{nd} weeks of submergence. The subsequent changes in pH were very little.

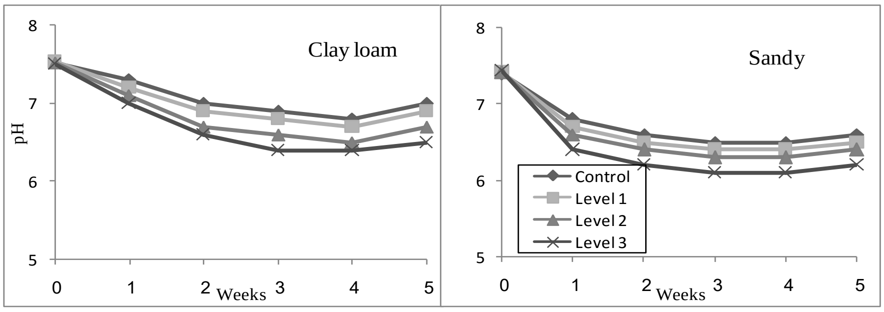

Fig. 1. The effect of waterlogging and compost additions on pH of the studied soils .

The rate of pH decrease is accelerated by the application of the compost. This may be due to the respiration of aerobic bacteria, and the production of organic acids, from the decomposition of organic matter. These organic acids dissociate and produce H^+ (Dakora & Phillips, 2002. and Carvalhais *et al.*, 2011). The release of CO_2 from carbonic acid that dissociates and produces H^+, decreased the pH in the submerged soil (Marschner, 1995 and Dakora & Phillips, 2002).

These results were in agreement with Brady and Weil (2010), who explained that organic matter contributes to soil acidfication through the formation of soluble complexes with free cations such as calcium or magnesium which could be easily lost by leaching. The present data showed that at the end of the flooding period (3rd and 4th weeks) the pH attained a fairly stable value of 6.4 in the clay loam soil and 6.1 in the sandy soil. These results are in close agreement with Taha (1980). It is worthy noticed that pH values in the sandy soil was significantly lower than those of the clay loam soil under the same treatments which could be rendered to the higher buffering capacity of the clay loam soil which consumed some of the produced acidity.

The effect of flooding time, with or without added compost, on the values of soil Eh of the two soils are illustrated in Fig. 2.

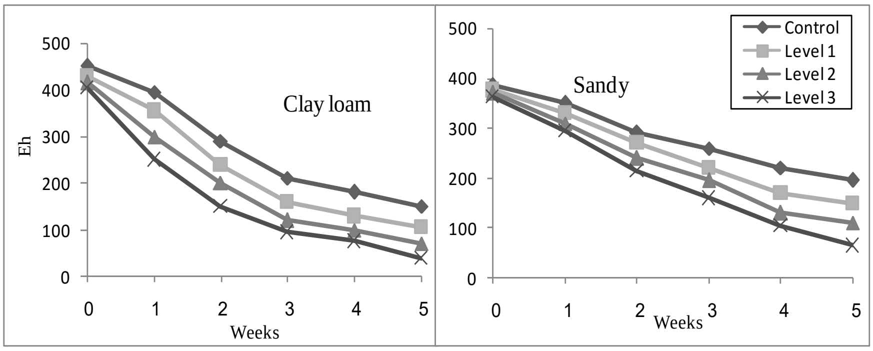

Fig. 2. The effect of waterlogging and compost additions on Eh of the studied soils.

The initial Eh values for the control soils were relatively high and varied between 385 mV (Sandy) and 450 mV (Clay loam). The results indicated that the Eh significantly decreased in the two types of waterlogged soils over a period of 5 weeks. For the two soil types, Eh showed a marked decline reaching a minimum value during the first week of submergence. The rapid initial decrease of Eh is apparently due to the release of reducing substances accompanying oxygen depletion before Mn^{+4} an Fe^{+3} hydrated oxides can mobilize their buffer capacity (Ponnamperuma, 1972). The decrease was greater in the clay loam soil (150 mv) than sandy soil (195 mV). This trend may be due to the higher organic matter content of clay loam soil (1.9 %) than sandy soil (0.42).

The addition of compost resulted in a greater decrease of Eh in the two soils, but the soils reached their minimum Eh after 5 weeks.With addition of 3% compost (3^{rd} level), the clay loam soil exhibited a greater decline (40 mV) than the sandy soils (52 mV). This trend may be attributed to the increased microbial respiration which stimulated by the organic matter (IU *et al.*, 1981). Organic matter can be partly and reversibly, reduced by microorganisims and it plays the role of electron shuttle, *i.e.* a mobile carrier of electrons (Lovley *et al.*, 1998).

Data presented in Fig. 3 revealed that P availability generally increased in both types of soil under waterlogging condition. This increase in available – P can be associated with the decrease in its soil pH during the same period. Statistical analysis reveals that the differences between effects of compost levels were significant in their effects on available P ($LSD_{0.05}$: 0.129 and 0.119 in clay loam soil and sandy soil, respectively).

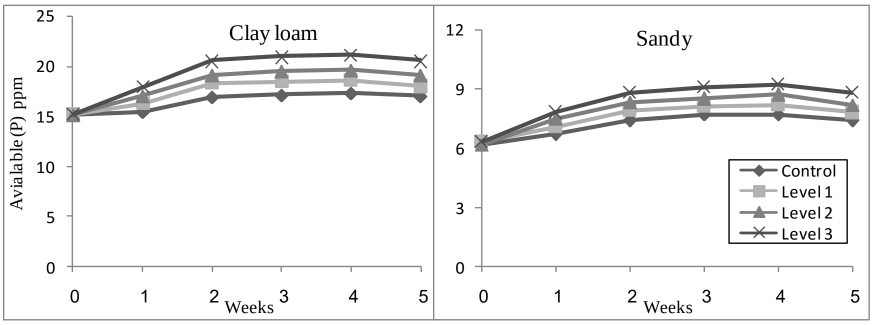

Fig. 3. The effect of waterlogging and compost additions on available P of the studied soils .

Eh also indirectly affected P availability by affecting the solubility of metal ions as Mn, Al and Fe oxides and hydroxides or of $CaCO_3$, these bind to or adsorb phosphate ions and make them unavailable to plants (Phillips, 1998 and Brady & Weil 2010). The results also indicated that the rate of increase of available P is accelerated by the application of compost. This may be due to the organic acids dissociate and produce organic anions that exchange with sorbed P and the more available forms $H_2PO_4^-$/ HPO_4^{2-} were released to soil solution

(Zhang *et al.,* 2003). These organic anions form could chelate metal ions including Al, Ca, Fe that would immobilize Al-P, Fe-P and Ca-P; and as a result P concentration in soil solution is increased (Dakora & Phillips, 2002 and Kirk, 2004). At the end of the flooding period, phosphate ions decreased after reaching a peak value, this could be due to resorption by clay and hydrous oxides.

The obtained data revealed on Fig. 4 and 5 indicate a significant effect of applied compost on available Fe and Mn of the waterlogged soils. The data indicated that waterlogging was accompanied by a significant reduction in soil Eh and pH and an increase in available of Fe and Mn. These findings are in close conformity with those of Yaduvanshi *et al.* (2010). There is evidence for direct or indirect biological alterations in the availability, solubility, or oxidation – reduction state of Fe and Mn (Reddy *et al.,* 1986). In both soils, Fe and Mn concentration increased with time, reached a peak and then declined. In the clay loam soil, the peak of available Fe and Mn was high and reached 13.5 and 9.3 mg/kg on the 4th week of incubation, respectively. With the sandy soil the concentration ranges between (2.8 to 6 mg/kg)for Fe and (1.4 to 3.4 mg/kg) for Mn.These concentrations were lower than those for the clay loam soil, *i.e.* (7 to 15.9 mg/kg) and (4.9 to 12.5 mg/kg)for Fe and Mn , respectively. This seems to be reasonable and is due to the original low level of organic matter, Fe and Mn in sandy soil as compared to the clay loam one.

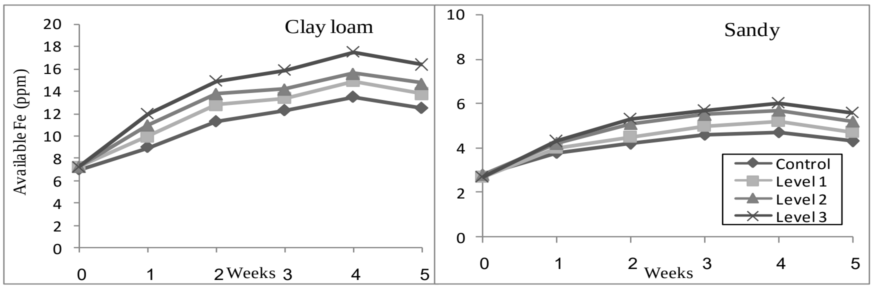

Fig. 4. The effect of waterlogging and compost additions on available Fe of the studied soils.

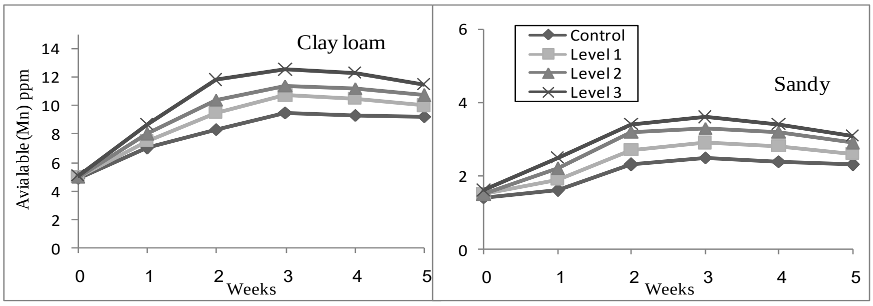

Fig. 5. The effect of waterlogging and compost additions on available Mn of the studied soils.

It is interesting to emphasize that manganese is always reduced at much higher Eh values than iron, and therefore is the first to be mobilized when the soil gets wet, and the last to oxidize (and thus become immobile) when it becomes dry. Mn is thus the most mobile (Dorronsoro *et al.,* 2002).

The addition of 3% compost to the clay loam soil increased the DTPA extracted Fe concentrations at the 4^{th} week from 13.5 to 17.5 mg/kg while it increased from 9.3 to 12.3 for Mn. The same treatment for sandy soil resulted in much less increases in the DTPA Fe and Mn concentrations (4.7 to 6.0 and 2.4 to 3.4 mg/kg, respectively).

Applications of the compost to soil proved capable of significant increasing Fe and Mn availability as a consequence of the reduction of high valence forms of Fe and Mn to the divalent one. ($LSD_{0.05}$: 0.116 and 0.136 for Fe and Mn, respectively in clay loam soil and 0.112 and 0.77 in sandy soil).The rapid effect of added compost increasing the level of available Fe and Mn resulted mainly from the increased production of CO_2 and the great reduction in pH and redox potential of the soils. However, the effect of organic materials varied with the rate of the compost applied. Organic matter degradation rates are faster under oxidizing conditions, in the presence of free O_2 (Macias and Camps Arbestain, 2010). In the absence of free O_2 or inorganic oxidants as Fe^{3+} and Mn $^{4+}$, fermentation processes take place in which organic molecules are utilized as electron acceptors (Ugwuegbu *et al.,* 2001).

In both soils, Fe and Mn concentrations increased with time of flooding reaching a peak at the 4^{th} week, then declined at the 5^{th} week. This low final level of available Fe and Mn in the studied soils could be attributed to the precipitation of available Fe and Mn as Mn CO_3 and ferrous bicarbonate which then partly entered into changeable complex and was partly precipitated as sulfide , adsorption by clay surfaces and formation of insoluble organic complexes, (Taha,1980).

Data presented in Fig. 6 and 7 clearly, show the availability of Zn and Cu by the addition of the compost in the two types of soil under waterlogging conditions.

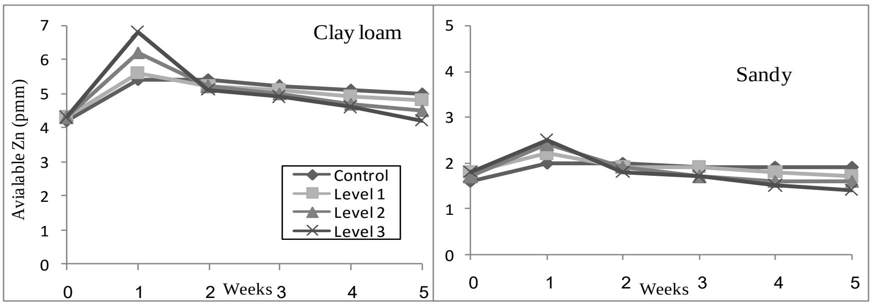

Fig. 6. The effect of waterlogging and compost additions on available Zn of the studied soils .

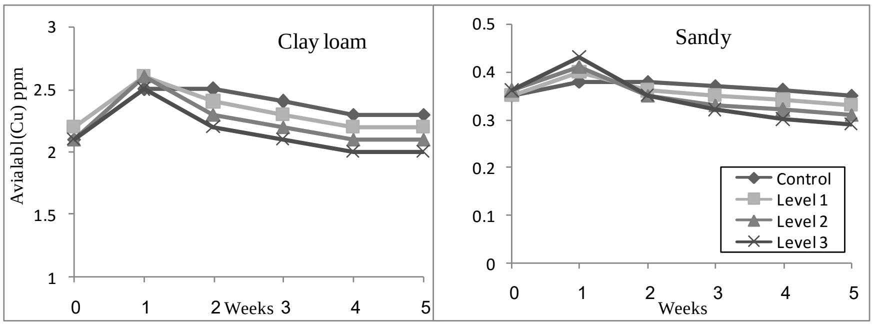

Fig. 7. The effect of waterlogging and compost additions on available Cu of the studied soils.

Even though these elements are not involved in oxidation-reduction reactions, their behavior in soils is influenced by flooding. Unlike the redox elements Fe and Mn, the concentrations of Zn and Cu in soil solution generally decrease after flooding. This decrease may be due to the metals formed sparingly soluble precipitated with sulfide which were not available (Connell and Patrick, 1968). These elements may undergo a temporary increase immediately after flooding (Mikkelsen and Kuo, 1976). This increase may be explained by the decrease in the pH soil in the first and second weeks. These results were in agreement with Frohne *et al.* (2011) who reported that deficiency is more likely at a high pH for Zn and Cu. The data also showed that the addition of the compost further decreased the DTPA-extracted Zn and Cu. Statistical analysis showed that there were significant differences between the effect of compost levels for Cu ($LSD_{0.05}$: 0.081 and .011 in clay loam soil and sandy soil ,respectively).On the other hand ,there were no significant differences between compost levels for Zn. These results were confirmed with Sim and Patrick (1978) who indicated that under reducing conditions, Zn and Cu were complexed by organic matter and also got adsorbed on exchange and organic sites .

References

Bloom, P.R. (2000) Soil pH and pH buffering. In: Summer ME (Ed.) *Handbook of Soil Science.* CRC Press, Boca Raton, FL.

Brady, N.C. and Weil, R.R. (2010) *Elements of Nature and Properties of Soils*. Pearson Education International, New Jersey.

Carvalhais, L.C., Dennis, P.G., Fedoseyenko, D., Hajirezaei, M.R., Borriss, R. and Wiren, N. (2011) Root exudation of sugars, amino acids and organic acids by maize as affected by nitrogen, phosphorus, potassium and iron deficiency. *J. Plant Nutr. Soil Sci.* **174**, 3-11.

Connell, W.E. and Patrick, W.H. (1968) Sulfate reductions in soil: effect of redox potential and pH. *Science*, **159**, 86-87.

Dakora, F.D. and Phillips, D.A. (2002) Root exudates as mediators of mineral acquisition in Low-nutrient environments. *Plant Soil*, **245**, 35-47.

Dorronsoro, B., Aguilar, J., Dorronsoro-Díaz, C., Stoops, G., Sierra, M., Fernández, J. and Dorronsoro-Fdez, C. (2002) *HydroSols, Hydromorphy in Soils.* Departament of Pedology. Faculty of Sciences. University of Granada. Spain.

Frohne, T., Rinklebe, J., Diaz-Bone, R.A. and Du Laing, G. (2011) Controlled variation of redox conditions in a floodplain soil: Impact on metal mobilization and biomethylation of arsenic and antimony. *Geoderma***, 160**, 414-424.

Iu, K.L., Pulford, I.D. and Duncan, H.J. (1981) Influence of water logging and lime or organic matter addition on the distribution of trace metals in and acid soil. I-Manganese and Iron. *Plant and Soil*, **59**, 317.

Jackson, M.L. (1973) *Soil Chemical Analysis*. Prentice Hall of India Private Limited, New Diehl, pp. 111-134.

Kirk, G.J.D. (2004) *The Biogeochemistry of Submerged Soils.* John Wiley & Sons Ltd., England.

Klute, A. (1986) *Methods of Analysis. Part I. Physical and Mineralogical Properties*. 2nd ed. *Agron. Madison*, Wisconsin, U.S.A.

Lovely, D.R., Fraga, J. L., B-HEL, Hayes, L.A., Phillips, EJP and Coates, J.D. (1998) Humic substances as a mediator for microbially catalyzed metal reduction. *Acta Hydrochim Hydrobiol* **26**, 152-157.

Lindsay, W.L. and Norvell, W.A. (1978) Development of a DTPA soil test for zinc, iron. Managenes and Copper. *Soil Science Society of America Journal*, **42**, 421-428.

Macias, F. and Camps Arbestain M. (2010) Soil carbon sequestration in a changing global environment. *Mitig Adapt Strateg Glob Change* **15**, 511-529.

Marschner, P. (1995) *Mineral Nutrition of Higher Plants*, 2nd ed. Academic, London.

Mikkelsen ,D.S. and Kuo,S. (1976) Zinc fertilization and behavior in flooded soils and fertilizer application for rice. Food and Fertilizer Technology Center, Taiwan.

Oglesby, JP (1997) Redox buffering by soil organic matter. *Abst. Pap. Am. Chem. S*. **213**, 147- GEOC.

Page, A.L., Miller, R. and Keeny, D. (1982) *Methods of Soil Analysis. Part II Chemical and Microbiological Properties*. 2nd ed. Agron. Madison, Wisconsin, U.S.A.

Phillips, I.R. (1998) Phosphorus availability and sorption under alternating waterlogged and drying conditions. *Commun Soil Sci. Plant*. **29**, 3045-3059.

Ponnamperuma, F.N. (1972) The chemistry of submerged soils. *Adv. Agron*., **24**, 29-96.

Sim, J.L. and Patrick, W.H., Jr. (1978) The distribution of micronutrient cations in soil under conditions of varying redox potential and pH. *Soil. Sci. Soc. Am. J.* **42**, 256-262.

Reddy, K.R., Feijtel T.C. and Patrick. W.H.J. (1986) Effect of soil redox condition on microbial oxidation of organic matter. In: Chen Y, Avnimelech Y (Ed.). *The Role of Organic Matter in Modern Agriculture.* Kluwer Academic Publishers, Dordrecht, pp 117-160.

Singh, P.K., Panigrahi, B.C. and Satapathy, K.B. (1981) Comparative efficiency of Azolla, blue green algae and other organic manures in relation to N and P availability in flooded rice soil.

Snedecor,G. W. and Cochran, W.G. (1990) *Statistical Methods*. The Lowa state Univ. 7*th* ed. Pp. 507

Taha, S.A. (1980) Studies on manganese in some soils of Egypt. *Ph.D. Thesis, Fac. Agric* Cairo. Univ., Egypt.

Ugwuegbu, B.U., Prasher, S.O., Ahmed, D. and Dutilleul, P. (2001) Bioremediation of residual fertilizer nitrate: II. Soil redox potential and soluble iron as indicators of soil health during treatment. *J. Environ. Qual*. **30**, 11-18.

Yaduvanish, N.P.S., Setter, T.L., Sharma, S.K., Singh, K.N. and Kulshreshtha, N. (2010) Waterlogging effects on wheat yield, redox potential, manganese and iron in different soils of India. 19*th* *World Congress of Soil Science*, *Soil Solution* for a Changing World 1-6 August 2010, Brisbane, Australia.

Zhang,Y., Lin, X. and Werner, W. (2003) The effect of soil flooding on the transformation of Fe oxides and the adsorption/desorption behavior of phosphate. *J. Plant Nutrition Soil Sci.***166**, 68-75.

(*Received* 31/8/2014;
accepted 25/12/2014)

الغمر وتاثير اضافة الكمبوست على تيسر الفوسفور والحديد والمنجنيز والزنك والنحاس فى بعض الاراضى المصرية

أمل لطفى عبد اللطيف
قسم الاراضى – كلية الزراعة – جامعة القاهرة – القاهرة – مصر .

أقيمت تجربة تحت ظروف الغمر لدراسة تأثير فترة الغمر واضافة الكمبوست على كل من رقم ال pH و جهد الاكسدة والاختزال (Eh) وتيسر الفوسفور والحديد والمنجنيز والزنك والنحاس وذلك فى تربة طينية طميية وأخرى رملية .

وأوضحت النتائج ، أن غمر الاراضى الرملية أدى الى انخفاض رقم الـ pH فى الاراضى الرملية حتى الاسبوع الثالث وفى الاراضى الطينية الطميية حتى الاسبوع الرابع من الغمر ، وبعد ذلك حدث زيادة قليلة فى قيم الـ pH .كما أدى اضافة الكمبوست الى انخفاض رقم الـ pH .

وأوضحت النتائج ، أن قيم الـ Eh انخفضت انخفاضاً واضحاً فى كلا نوعى التربة المستخدمة ووصلت أقل قيمة خلال الاسبوع الاول من الغمر. كما أدى اضافة الكمبوست الى انخفاض أكبر فى قيم الـ Eh .

وبينت النتائج أن غمر التربة أدى الى زيادة تيسر كل من الفوسفور والحديد و المنحنيز ،بينما انخفض تيسر كل من الزنك والنحاس . وأن اضافة الكمبوست أدت الى انخفاض فى تيسر هذه العناصر . وهذا الاتجاه ربما يعزى الى تكوين مركبات غير ذائبة .