# EFFECT OF PHOSPHOROUS AND ZINC APPLICATION ON THE AVAILABILITY OF PHOSPHORUS AND SOME MICRONUTRIENTS IN THE SOILS OF EGYPT

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(Manuscript received 28 December 1991)

***Abstract***

Laboratory incubation experiments were conducted using alluvial and calcareous soils to evaluate the effect of applying three levels of phosphorus (0, 50 and 100 ppm) and zinc (0, 5 and 10 ppm) in all possible combinations, on the changes of both the available phosphorus and the EDTA-extractable zinc, iron, copper and manganese content in soil. The results showed that applying phosphorus significantly decreased the content of EDTA-extractable Zn, Fe, Cu and Mn in soils. However, the rate of decrease declined with the length of the incubation period. The depressive effect of P on extractable Zn content was found to be more obvious with respect to soil native Zn than that of the applied one. Application of Zn also depressed the content of extractable Fe, Cu and P but significantly increased that of extractable Mn.

## INTRODUCTION

The interaction between P and Zn has been studied by many investigators. Usually, the interaction is designated as a P-induced Zn deficiency. The reduction in the availability of Zn in soil due to the application of P has been reported by Ellis *et al.* (1964), Kalyansundaram and Mehta (1970), Badanur and Venkata Rao (1973) and Haldar and Mandal (1979). On the other hand, Marinbo and Lgue (1972) showed the application of P increased the amount of EDTA-extractable Zn and DTPA-extractable Fe and Mn in soil. However, application of Zn has been reported to cause a decrease in the availability of the Fe (Premi 1971, Venkata Subrahamanyam and Mehta 1975) and an increase in the availability of Mn in soil (Brar and Sekhon 1976, Venkata Subrahamanyam and Mehta 1975). Hulagur *et al.* (1975) and Mandal and Haldar (1980) reported that application of Zn or P lowered the availability of Fe and Cu.

Under the conditions of Egypt, El-Sherif (1973) studied the relationship between P-fertilization and Zn-application in highly calcareous soils of the North Western Coastal plain. He found that the interaction between P and Zn was not affected by the calcium carbonate content. Sarour (1981) found that the available Zn was only reduced through heavy application of P up to the 50 ppm level in the clay loam soil. He also added that available P showed tendencies to decrease with increasing rate of Zn application up to 5 ppm Zn or more. Dahdoh (1981) found that the high levels of P addition resulted in decreasing the amount of water soluble Zn and EDTA-extractable Zn. El-Mashadi (1981) found that P-application did not affect Zn availability in both alluvial and calcareous soils.

This work was carried out to investigate the effect of phosphorus and zinc application on the availability of phosphorus, zinc, copper, iron and manganese in both alluvial and calcareous soils.

## MATERIALS AND METHODS

Surface soil samples were collected from El-Kalubia Governorate and El-Tahrir District representing the alluvial and calcareous soils, respectively.

The particle size distribution was carried out by the Pipette method, Piper (1950). Organic matter content was determined according to Walkley and Black method, Jackson (1967). PH was determined in 1 : 2.5 soils : water suspention using Beckman pH-meter, Jackson (1967). Calcium carbonate was estimated volumetrically using the Collin's calcimeter according to Richards (1954). The electrical conductivity and soluble cations and anions were determined in soil paste according to the standard method, Jackson (1967). The main physical and chemical characteristics of the studied soil samples were presented in Table 1.

The soil samples were air-dried, ground and sieved to pass through a 2 mm sieve (1 kg) packed in polyethylene pots (2.5 L capacity). The treatments consisted-

Table 1. Some physical and chemical properties of the studied soil samples.

| Soil characters | Soils | |
|---|---|---|
| | El-Kalubia Governorate $S_1$ | El-Tahrir District $S_2$ |
| Practicle size: | | |
| Coarse sand % | 0.71 | 14.75 |
| Fine sand % | 15.14 | 63.34 |
| Slit % | 36.65 | 12.98 |
| Clay % | 47.50 | 9.95 |
| Texture | Clay | Sandy loam |
| Field capacity | 35.00 | 21.00 |
| $CaCO_3$ | 2.56 | 24.78 |
| E.C. mmhos/cm | 1.55 | 3.09 |
| pH | 7.70 | 7.70 |
| Ionic content of the soil paste in meq/L. | | |
| Calcium | 4.40 | 9.77 |
| Magnesium | 6.25 | 8.66 |
| Sodium | 4.85 | 11.58 |
| Potassium | 0.25 | 0.82 |
| Carbonate | ---- | ---- |
| Bicarbonate | 2.50 | 4.00 |
| Chloride | 4.50 | 10.50 |
| Sulphate | 8.75 | 16.33 |
| Available phosphorus as ppm | 13.50 | 4.20 |
| Available zinc as ppm | 4.70 | 5.40 |
| Available iron as ppm | 8.90 | 8.10 |
| Available copper as ppm | 1.33 | 1.13 |
| Available manganese as ppm | 5.67 | 5.27 |

of combinations of three levels of P (0, 50 and 100 ppm as $KH_2PO_4$) and three levels of Zn (0, 4 and 10 ppm as $ZnSO_4$) in three replicates. The soil samples were incubated in the laboratory at room temperature. Soil samples were drawn from each pot after 1, 7, 14, 28, 56 and 84 days. Available Zn, Fe, Cu and Mn were determined by an atomic absorption spectophotometer according to Lindsay and Norvell (1969). Available phosphorus was determined using Olsen's method (Jackson 1967).

The obtained results were statistically analysed according to Ceapoiu (1968).

## RESULTS AND DISCUSSION

### Available phosphorus:

Data in Table 2 reveal that the application of phosphorus significantly increased the available phosphorus amounts in soils. Only from 12-16% of the applied phosphorus remained in the available from after 24 hours of its application in calcareous soil, whereas in alluvial soil from 14-27% and from 11-21% of the applied phosphorus remained in the available from after 1 and 7 days of its application, respectively; the rest of the amounts have been transformed to some forms not extractable in Olsen's solution.

Concerning the effect of Zn application on the values of available P, data in Table 2 showed that the application of Zn significantly decreased the values of available phosphorus in soils. The decrease ranged from 14-34% within 7 days of incubation when Zn was applied at the rate of 10 ppm. A similar observation was made by Hulagur *et al.* (1975) and Mandal and Haldar (1980).

Regarding the effect of soil types on the available phosphorus content, data in Table 2 reveal that the available phosphorus content was significantly affected by soil types, the highest values were found in the alluvial soil whereas the lowest values were found in the calcareous ones (Fathi 1978, Megalah 1978, El-Mashadi 1981).

Data in Table 2 also show that the available phosphorus values were significantly increased with time of incubation, however, they began to decrease after 12 weeks. These re: are in agreement with those obtained by Mandal and Haldar

Table 2. Effect of phosphorus and zinc application on the changes in available phorphorus content (ppm) of soils.

| Soils | P-levels | Days of incubation 1 | | | | 7 | | | | 14 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean |
| $S_1$ | $P_0$ | 13.5 | 11.0 | 9.8 | 11.4 | 13.5 | 11.8 | 10.0 | 11.8 | 16.0 | 14.0 | 12.0 | 14.0 |
| | $P_{50}$ | 25.7 | 22.9 | 20.1 | 22.9 | 21.8 | 19.4 | 18.3 | 19.8 | 27.9 | 24.6 | 22.2 | 24.9 |
| | $P_{100}$ | 40.1 | 37.1 | 35.0 | 34.0 | 34.0 | 32.0 | 31.1 | 32.0 | 43.0 | 38.8 | 36.7 | 39.5 |
| | Mean | 26.4 | 23.7 | 21.6 | | 23.1 | 21.1 | 19.8 | | 28.9 | 25.8 | 23.6 | |
| $S_2$ | $P_0$ | 4.2 | 3.5 | 1.2 | 3.0 | 7.3 | 4.2 | 2.5 | 4.7 | 8.1 | 5.1 | 4.2 | 5.8 |
| | $P_{50}$ | 11.4 | 10.6 | 9.4 | 10.5 | 13.5 | 11.4 | 9.8 | 11.6 | 16.6 | 13.5 | 12.1 | 14.1 |
| | $P_{100}$ | 17.5 | 15.8 | 14.5 | 15.9 | 22.5 | 19.0 | 16.2 | 17.2 | 24.5 | 22.3 | 19.0 | 21.9 |
| | Mean | 11.0 | 10.0 | 8.4 | | 14.4 | 11.5 | 9.5 | | 16.4 | 13.6 | 11.8 | |
| | | 28 | | | | 56 | | | | 84 | | | |
| $S_1$ | $P_0$ | 17.5 | 15.0 | 13.0 | 15.2 | 19.0 | 17.3 | 14.0 | 16.8 | 14.0 | 11.5 | 10.0 | 11.8 |
| | $P_{50}$ | 31.2 | 27.5 | 25.2 | 28.0 | 32.5 | 29.1 | 27.2 | 29.6 | 26.3 | 22.8 | 17.3 | 22.2 |
| | $P_{100}$ | 46.1 | 41.1 | 38.7 | 42.0 | 27.2 | 43.0 | 40.0 | 43.4 | 30.9 | 28.4 | 28.0 | 29.1 |
| | Mean | 31.6 | 27.9 | 25.6 | | 32.9 | 29.8 | 27.1 | | 23.7 | 20.9 | 10.4 | |
| $S_2$ | $P_0$ | 8.9 | 7.1 | 5.5 | 7.2 | 10.1 | 8.6 | 6.7 | 8.4 | 6.0 | 4.3 | 3.5 | 4.1 |
| | $P_{50}$ | 18.1 | 14.5 | 13.3 | 15.3 | 20.1 | 17.0 | 15.3 | 17.5 | 13.0 | 12.0 | 8.3 | 11.1 |
| | $P_{100}$ | 28.1 | 24.8 | 22.3 | 25.1 | 29.3 | 26.5 | 23.8 | 26.6 | 23.3 | 18.6 | 15.3 | 19.1 |
| | Mean | 18.4 | 15.5 | 13.7 | | 19.8 | 17.4 | 14.9 | | 14.1 | 11.6 | 9.0 | |

| L.S.D. | at 5% | at 1% | L.S.D. | at 5% | at 1% | L.S.D. | at 5% | at 1% |
|---|---|---|---|---|---|---|---|---|
| Soils (S) | 0.57 | 2.83 | SxZn | 0.33 | 0.77 | SxPxZn | 0.37 | 0.62 |
| Phosphorus (P) | 0.23 | 0.54 | SxI | 0.28 | 0.44 | SxPxI | 0.42 | 0.60 |
| Zinc (Zn) | 0.23 | 0.54 | PxZn | 0.26 | 0.43 | SxZnxI | 0.42 | 0.60 |
| Intervals (I) | 0.20 | 0.31 | PxI | 0.30 | 0.42 | PxZnxI | 0.48 | 0.66 |
| SxP | 0.33 | 0.77 | ZnxI | 0.30 | 0.42 | SxPxZnxI | 0.68 | 0.93 |

(1980).

Concerning the effect of the interactions among different treatments, statistical analysis in Table 2 revealed that the trend of these interactions is quite similar to that found in the case of individual factors.

## Extractable zinc:

The results in Table 3 clearly show that phosphorus application significantly decreased the values of extractable Zn (Takkar *et al.* 1976, Mandal and Haldar 1980; Sarour 1981; Dahdoh 1981). The level of decrease, however, was found to decline gradually with the progress of incubation (Mandal and Haldar 1980; Sarour 1981).

Concerning the effect of Zn application on the extractable Zn values, data in Table 3 show that the application of Zn significantly increased the extractable Zn values in the two soil types. An increase to the extent of 50% was recorded in the alluvial soil as compared with 43% increase in the calcareous one due to the application of Zn at the rate of 10 ppm within 56 days of incubation. This indicate that in calcareous soil a considerable amount of the added Zn changed into some form not extractable by DTPA solution.

The content of Zn in the two soils significantly decreased with increasing the time of incubation, but the value always remained higher in the zn-treated soil than in the control. This decrease in the extractable Zn content in the soils with the progress of the period of incubation may be attributed to coprecipitation of both $ZnCO_3$ and $Zn(OH)_2$ (Sinha *et al.* 1975), or to competition of Fe resulting from chelating ligands (Giordano and Mortvedt 1972). According to Norvell (1972), Fe can compete more strongly than Zn for complex formation with DTPA. The results in Table 4 show that the extractable Fe content in the two soils increased with increasing incubation, the rate of increase is comparatively higher in calcareous soil than in alluvial one. The decrease in extractable Zn content in soils with the increased period of incubation may also be partially attributed to the increased concentration of extractable Fe. These findings are in agreement with those of Mandal and Haldar (1980).

Concerning the effect of different interactions between the studied factors, significant differences for all combinations can be observed except the triple interaction including Zn application or days of incubation and the tetra interaction which show significant effect on extractable Zn content (Table 3).

Table 3. Effect of phosphorus and zinc application on the extractable zinc in soils as ppm.

| Soils | P-levels | Days of incubation | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | | | | 28 | | | | 56 | | | | 84 | | | |
| | | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean |
| $S_1$ | $P_0$ | 4.7 | 5.8 | 8.7 | 6.4 | 3.0 | 4.1 | 5.9 | 4.4 | 2.7 | 3.7 | 5.5 | 4.0 | 3.1 | 3.8 | 6.0 | 4.3 |
| | $P_{50}$ | 3.8 | 4.6 | 5.7 | 4.7 | 2.8 | 3.4 | 4.6 | 3.6 | 2.3 | 3.3 | 4.4 | 3.3 | 2.4 | 3.3 | 4.5 | 3.4 |
| | $P_{100}$ | 3.1 | 3.5 | 5.3 | 4.0 | 2.1 | 2.3 | 4.0 | 2.8 | 1.8 | 2.2 | 3.8 | 2.6 | 1.8 | 2.3 | 3.9 | 2.6 |
| | Mean | 3.9 | 4.6 | 6.5 | | 2.3 | 3.0 | 4.6 | | 3.0 | 3.3 | 5.3 | | 2.4 | 3.1 | 4.8 | |
| | | | | | | | | | 4.8 | | | | | | | | |
| $S_2$ | $P_0$ | 5.4 | 5.9 | 8.3 | 6.5 | 3.7 | 4.1 | 6.5 | 4.5 | 3.4 | 3.9 | 6.3 | 4.5 | 3.4 | 3.9 | 6.3 | 4.5 |
| | $P_{50}$ | 4.8 | 5.6 | 7.5 | 6.0 | 3.9 | 3.6 | 6.1 | 3.1 | 3.4 | 3.5 | 5.6 | 4.2 | 3.2 | 3.3 | 5.5 | 4.0 |
| | $P_{100}$ | 3.9 | 4.8 | 5.7 | 4.8 | 2.7 | 2.7 | 3.9 | | 2.3 | 2.6 | 3.8 | 2.9 | 2.1 | 2.5 | 3.6 | 2.7 |
| | Mean | 4.7 | 5.4 | 7.1 | | 3.4 | 3.5 | 5.5 | | 3.0 | 3.3 | 5.3 | | 2.9 | 3.2 | 5.1 | |

| L.S.D. | at 1% | L.S.D. | at 1% |
|---|---|---|---|
| Soils (S) | 1.2 | S x I | 0.3 |
| Phosphorus (P) | 0.4 | P x Zn | 0.3 |
| Zinc (Zn) | 0.4 | P x I | 0.3 |
| Intervals (I) | 0.2 | S x P x Zn | 0.4 |
| S x P | 0.5 | S x P x I | 0.4 |
| S x Zn | 0.5 | | |

## Extractable iron:

Data in Table 4 reveal that the extractable Fe values ranged between 6.0-15.6 ppm and from 5.5-18.7 ppm in the alluvial and calcareous soils, respectively (Dubey *et al.* 1970, El-Galah and Hendawy 1972, El-Sikhry 1976; Abdallah 1977). The results in Table 4 also show that application of both Zn and P has significantly lowered the extractable Fe content in the two soils under investigation. The amounts always are lower in the Zn- and P-treated soil than that in the untreated ones (Pathak *et al.* 1975; Mandal and Haldar 1980). Venkata Subrahamanyam and Mehta (1975) postulated that colloidal Zn sulphate and Zn hydroxide form a coating on the absorbed Fe and thus make it less extractable. The decrease may also be due to the ionic competition between Zn and Fe for chelating ligands (Norvel 1972). The decrease due to P application may be attributed to the interaction of Fe and P resulting in the formation of iron phosphate. The concentration of extractable Fe was found to be lowest when both P and Zn were applied together.

Concerning the effect of incubation on the extractable Fe values, data in Table 4 reveal that the extractable Fe values were significantly increased with incubation, the highest values were obtained after 28 days and then declined. The increase was due to the reduction of soluble ferric compounds to more soluble ferrous form. This finding is in agreement with that of Mandal and Haldar (1980).

Regarding the effect of soils on the extractable Fe, it is obvious that the studied soils have no significant effect on extractable Fe values (Dubey *et al.* 1980; Abdallah 1977).

Concerning the effect of different interactions between the studied factors, significant differences can be observed except the double interaction including soil and phosphorus application and all triple interaction whereas the tetra interaction shows a highly significant effect on the extractable Fe content.

## Extractable copper:

Data in Table 5 show that the application of Zn at.the rate of 10 ppm significantly decreased the extractable Cu content to the extent of 12.9 only after 7 days of incubation, followed by a gradual decrease as the period of incubation was lengthened in the two soil samples. Data in the same Table show that the application of

Table 4. Effect of phosphorus and zinc application on the extractable iron (ppm) in soils.

| Soils | P-levels | Days of incubation | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | | | | 28 | | | | 56 | | | | 84 | | | |
| | | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean |
| $S_1$ | $P_0$ | 8.9 | 1.7 | 7.6 | 8.1 | 15.6 | 14.3 | 14.0 | 16.4 | 13.1 | 13.0 | 11.7 | 12.6 | 8.6 | 8.4 | 8.1 | 8.4 |
| | $P_{50}$ | 7.3 | 7.2 | 6.7 | 7.0 | 14.8 | 14.2 | 13.7 | 14.2 | 13.1 | 11.2 | 9.2 | 11.2 | 8.5 | 8.0 | 7.7 | 8.0 |
| | $P_{100}$ | 6.8 | 6.5 | 6.0 | 6.4 | 14.3 | 13.0 | 12.0 | 13.0 | 12.5 | 10.4 | 8.5 | 10.5 | 7.6 | 7.5 | 6.9 | 7.3 |
| | Mean | 7.4 | 7.1 | 6.8 | | 14.8 | 13.8 | 13.2 | | 12.9 | 11.5 | 9.8 | | 8.2 | 8.0 | 7.6 | |
| $S_2$ | $P_0$ | 8.1 | 7.7 | 7.6 | 7.8 | 18.7 | 18.3 | 17.7 | 18.2 | 12.5 | 11.6 | 10.0 | 11.4 | 8.4 | 8.1 | 8.0 | 8.2 |
| | $P_{50}$ | 6.7 | 6.4 | 6.1 | 6.4 | 18.1 | 17.7 | 17.6 | 17.8 | 11.9 | 10.4 | 10.0 | 10.8 | 8.0 | 7.5 | 7.0 | 7.5 |
| | $P_{100}$ | 6.4 | 6.0 | 5.5 | 6.0 | 17.5 | 16.0 | 14.7 | 16.1 | 10.8 | 10.0 | 9.0 | 9.9 | 6.9 | 6.6 | 5.7 | 5.4 |
| | Mean | 7.1 | 6.4 | 6.4 | | 18.1 | 17.3 | 16.7 | | 11.7 | 10.7 | 9.7 | | 7.8 | 7.4 | 6.9 | |

| L.S.D. | at 1% | L.S.D. | at 1% |
|---|---|---|---|
| Phosphorus (P) | 0.5 | P x I | 0.4 |
| Zinc (Zn) | 0.5 | Zn x I | 0.4 |
| Intervals (I) | 0.3 | S x P x Zn x I | 0.8 |
| S x I | 0.4 | | |

Table 5. Effect of phosphorus and zinc application on the extractable copper (ppm) in soils.

| Soils | P-levels | Days of incubation | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | | | | 28 | | | | 56 | | | | 84 | | | |
| | | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean |
| $S_1$ | $P_0$ | 1.33 | 1.27 | 1.23 | 1.28 | 1.00 | 0.93 | 0.87 | 0.93 | 0.93 | 0.83 | 0.77 | 0.84 | 0.67 | 0.60 | 0.53 | 0.60 |
| | $P_{50}$ | 1.27 | 1.20 | 1.13 | 1.20 | 0.93 | 0.87 | 0.83 | 0.88 | 0.80 | 0.73 | 0.63 | 0.72 | 0.63 | 0.57 | 0.50 | 0.57 |
| | $P_{100}$ | 1.13 | 1.07 | 1.00 | 1.07 | 0.83 | 0.77 | 0.67 | 0.76 | 0.70 | 0.63 | 0.57 | 0.63 | 0.57 | 0.50 | 0.43 | 0.50 |
| | Mean | 1.24 | 1.18 | 1.12 | | 0.92 | 0.86 | 0.79 | | 0.81 | 0.73 | 0.66 | | 0.62 | 0.56 | 0.49 | |
| $S_2$ | $P_0$ | 1.13 | 1.10 | 1.03 | 1.09 | 0.87 | 0.80 | 0.73 | 0.80 | 0.70 | 0.60 | 0.53 | 0.61 | 0.30 | 0.27 | 0.23 | 0.27 |
| | $P_{50}$ | 1.07 | 1.00 | 0.97 | 1.01 | 0.83 | 0.77 | 0.70 | 0.77 | 0.60 | 0.53 | 0.47 | 0.53 | 0.27 | 0.25 | 0.20 | 0.23 |
| | $P_{100}$ | 1.00 | 0.97 | 0.93 | 0.79 | 0.80 | 0.70 | 0.63 | 0.71 | 0.53 | 0.43 | 0.37 | 0.44 | 0.27 | 0.23 | 0.23 | 0.24 |
| | Mean | 1.07 | 1.02 | 0.98 | | 0.83 | 0.76 | 0.69 | | 0.61 | 0.52 | 0.46 | | 0.28 | 0.24 | 0.23 | |

| L.S.D. | at 1% | L.S.D. | at 1% |
|---|---|---|---|
| Soils (S) | 0.21 | S x I | 0.06 |
| Phosphorus (P) | 0.07 | P x I | 0.05 |
| Zinc (Zn) | 0.07 | S x P x I | 0.08 |
| Intervals (I) | 0.04 | S x Zn x I | 0.08 |

phosphorus was also found to cause a considerable decrease in the content of extractable Cu in the two soil samples. Bingham (1963) attributed this depressive effect to the immobilization of Cu within the soil system.

Concerning the effect of different factors on the extractable Cu values, it can be noticed that the individual effect of these factors significantly affected the extractable Cu values, whereas both of the double and triple interactions including days of incubation and soils, significantly affected the extractable Cu values. No significant differences for the other combinations can be observed (Table 5).

## Extractable manganese:

Data in Table 6 show that application of Zn significantly increased the extractable Mn content in soils. This favorable effect of Zn application on extractable Mn content in the soil continued more or less uniformly throughout the period of incubation. The higher oxidation potential of Mn, $Mn^{++}$ (+1.08) as compared with that of Zn, $Zn^{++}$ (+0.76) favour the oxidation of Mn to $Mn^{+2}$ in the soil due to the following reaction:

$$Soil\text{-}Mn + Zn^{++} \text{------>} Soil\text{-}Zn + Mn^{++}$$

which may explain the decrease in Mn availability resulting from Zn application. This finding is in agreement with that of Mandal and Haldar (1980).

On the other hand, the application of P significantly decreased the extractable Mn-values, which may be due to its precipitation as manganese phosphate.

Concerning the effect of incubation period on the extractable Mn values, data in Table 6 also show that, the extractable Mn values like that of Fe, significantly increased with the incubation period. A maximum value existed after 56 days and, thereafter declined. The increase was due to the reduction of higher oxides of Mn, e.g. $MnO_2$, $Mn_2O_3$ and $Mn_3O_4$.

Regarding the effect of soil on the extractable Mn, data in Table 6 reveal that the highest values were found in alluvial soil and the lowest were found in the calcareous one.

Concerning the effect of different interactions between the studied factors, no significant differences between all combinations can be observed except the double interaction including the days of incubation.

Table 6. Effect of phosphorus and zinc application on the extractable manganese (ppm) in soils.

| Soils | P-levels | Days of incubation | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | | | | 28 | | | | 56 | | | | 84 | | | |
| | | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean | $Zn_0$ | $Zn_5$ | $Zn_{10}$ | Mean |
| $S_1$ | $P_0$ | 5.67 | 6.00 | 6.80 | 6.16 | 8.27 | 8.53 | 9.60 | 8.80 | 9.80 | 10.7 | 11.3 | 10.6 | 6.07 | 6.83 | 7.70 | 6.87 |
| | $P_{50}$ | 5.47 | 5.67 | 6.13 | 5.76 | 7.43 | 8.13 | 8.67 | 8.08 | 8.33 | 9.40 | 10.4 | 9.37 | 5.20 | 5.67 | 6.60 | 5.82 |
| | $P_{100}$ | 5.33 | 5.53 | 5.67 | 5.51 | 6.87 | 7.33 | 8.00 | 7.40 | 7.73 | 8.37 | 9.20 | 8.48 | 4.40 | 5.27 | 6.33 | 5.33 |
| | Mean | 5.49 | 5.73 | 6.20 | | 7.52 | 8.00 | 8.76 | | 8.62 | 9.48 | 10.3 | | 5.22 | 5.92 | 6.88 | |
| $S_2$ | $P_0$ | 5.27 | 5.93 | 6.20 | 5.80 | 7.20 | 7.70 | 8.80 | 7.90 | 8.07 | 8.80 | 9.50 | 8.97 | 5.60 | 6.47 | 7.20 | 6.42 |
| | $P_{50}$ | 5.20 | 5.53 | 5.93 | 5.56 | 6.33 | 7.00 | 8.13 | 7.16 | 7.43 | 8.00 | 8.50 | 7.98 | 4.67 | 5.50 | 6.07 | 5.41 |
| | $P_{100}$ | 4.27 | 4.33 | 5.20 | 4.60 | 5.60 | 6.47 | 7.07 | 6.38 | 6.60 | 7.33 | 8.03 | 7.32 | 3.77 | 4.40 | 5.37 | 4.51 |
| | Mean | 4.91 | 5.27 | 5.78 | | 8.38 | 7.06 | 8.00 | | 7.37 | 8.04 | 8.68 | | 4.68 | 5.46 | 6.21 | |

| L.S.D. | at 1% | L.S.D. | at 1% |
|---|---|---|---|
| Soils (S) | 2.04 | Intervals (I) | 0.39 |
| Phosphorus (P) | 0.68 | S x I | 0.55 |
| Zinc (Zn) | 0.68 | P x I | 0.73 |

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# تأثير اضافة الفوسفور والزنك على تيسر الفوسفور وبعض العناصر الغذائية الصغرى فى أراضى مصر

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فى تجربة تحضين معملية على أرض رسوبية وأخرى جيرية لدراسة تأثير اضافة ثلاثة مستويات من الفوسفور (صفر ، ٥٠ ، ١٠٠ جزء فى المليون) وثلاثة مستويات من الزنك (صفر ، ٥ ، ١٠ جزء فى المليون) وكذلك جميع التفاعلات بينهما على كل من صور الفوسفور والزنك والحديد والنحاس والمنجنيز الميسرة وكذلك دراسة تأثير فترة التحضين على هذه الصور.

وقد أوضحت النتائج مايلى:

١ - أن اضافة الفوسفور أدت الى نقص معنوى لكل من صور الزنك والحديد والنحاس الميسرة وأن معدل النقص يقل تدريجيا بزيادة فترة التحضين.

٢ - أن اضافة الزنك أدت الى نقص معنوى لكل من صور الحديد والنحاس والفوسفور الميسرة في حين أنها أدت الى زيادة معنوية لعنصر المنجنيز.