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ASSESSMENT OF THE EFFECTIVENESS OF TYPE AND LEVEL OF PHOSPHATIC FERTILIZER ON HEAVY METAL AND PHOSPHORUS CONTENT OF ALFALFA

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ABSTRACT: Phosphorus (P) is a major limiting factor for crop production from many tropical and subtropical soils. However, there is concern that this practice can increase the concentration of heavy metals in the soil. Greenhouse experiment using alfalfa (*Medicago sativa* L.) was carried out to evaluate the effects of different types of phosphatic fertilizers and P levels on the growth and the uptake of P, Zn, Mn, Pb and Cd by alfalfa. Surface soil samples of five locations were selected to represent soils cultivated for 10 and 50 years, irrigated with normal water and sewage effluent and uncultivated soil. Eighteen treatments were used. Treatments consisted of all combination of three types of phosphatic fertilizers and six P levels. Phosphorus was added to pots, containing 7 kg soil, as single superphosphate (SSP), triple superphosphate (TSP) and rock phosphate (RP) at levels of 0, 45, 90, 135, 180 and 450 kg P fed^{-1}. The TSP had higher total Zn compared with SPP and RP, while RP had higher total Mn compared with SSP and TSP. Low levels of Pb and Cd were detected in phosphorus fertilizers 13.6 ± 2.5 mg Pb kg^{-1} and 3.4 ± 0.7 mg Cd kg^{-1}. Dry matter production of alfalfa increased with application of phosphatic fertilizers. The total uptake of Zn, Mn, Pb, and Cd by alfalfa grown on the studied soils is closely related to the time of cultivation. In general, Zn, Mn, Pb and Cd uptake by alfalfa were reduced significantly by phosphorus fertilizers. The effectiveness of various phosphorus fertilizers in reducing the heavy metals generally followed this order at the equivalent P addition level: RP > SSP > TSP. Further study is needed in order to measure and predict the long-term availability of Cd and Pb in various soils which will be important in determining the acceptable loading limits of this metal in agricultural lands.

Key words : Phosphatic fertilizer, heavy metal, alfalfa.

INTRODUCTION

The continuous application of large amounts of fertilizers to agricultural lands has raised concern regarding the possible accumulation of toxic levels of their heavy metals and potential harm to the environment. Recent statistics show that about 18.9 million tonnes and 68000 tonnes P are applied annually to soils all over the world and in Egypt, respectively (FAO, 2004). Considering the concentrations of heavy metals in P fertilizers, substantial amounts are added to the soil every year. As an average, 9 kg of P is used for 1 feddan (0.42 ha) containing averages of 145, 481, 325 and 3.5 $mgKg^{-1}$ of Zn, Mn, Pb and Cd in a P fertilizer would result in 2.9, 9.6, 6.5 and 0.07 g fed^{-1} in a year of Zn, Mn, Pb and Cd, respectively.

Contamination levels of soils with heavy metals from various anthropogenic sources and their subsequent uptake by crops depend upon several factors. These factors include the total content, form and origin of the metal in the soil as well as the properties of the soils themselves. Soil pH, texture, organic matter content, cation exchange capacity, and other elements may be particularly important with respect to the form of the heavy metal that is present in the soil and its bioavailability for plants.

Heavy metals in the environment are a source of some hazards because of their potential reactivity, toxicity, and mobility in the soil. Some heavy metals (e.g., Zn and Mn) are essential for plant and animal health; however, at environmental concentrations above those necessary to sustain life, toxicity may occur. Other heavy metals (e.g. Pb and Cd) are not known to be essential to plants and animals. Toxicity may occur when these metals become concentrated in the environment above background levels.

Sells *et al.* (2003) found that the phosphorus fertilization significantly increased cadmium concentration in plants. However, Zwonitzer *et al.* (2003) pointed out that additions of phosphorus did not influence lead concentration in plant tissues but zinc concentration in plant tissues increased with increasing amount of P from KH_2PO_4 and decreased with increasing amounts of P from rock phosphate.

On the other hand, many researchers showed that phosphorus fertilizers significantly reduced plant Zn, Pb and Cd uptake (Prochnow *et al.*, 2001; Hettarachchi *et al.*, 2002; Knox *et al.*, 2003; Basta and McGowen, 2004 and Brown *et al.*, 2004). Basta and Gradwohl (1998) evaluated effect of rock phosphate (RP) in reducing the plant and oral bioavailability of Cd, Pb and Zn. They pointed out that the soil amended with RP reduced Zn toxicity and plant available Cd, Zn and Pb were also reduced by RP treatment, but the extent of reduction is uncertain. Ma and Rao (1997) investigated the feasibility of using Florida rock phosphate (RP) to immobilize aqueous Pb from Pb-contaminated soils. Rock phosphate effectively immobilized Pb from different Pb contaminated soils, but its effectiveness was affected by soil pH and extent of Pb contamination, with aqueous Pb reduction ranging from 21.8 to 100%.

Under Egyptian conditions, Tahoun and Abdel-Bary (2000) studied the efficiency of gypsum and superphosphate in suppressing Pb bioavailability. Additions of superphosphate or gypsum could reduce Pb uptake from polluted soils.

Normal metal values in alfalfa range from 25 to 70 mg Zn Kg^{-1} dry weight, 30 to 300 mg Mn Kg^{-1} dry weight, 0.72 to 1.0 mg Pb Kg^{-1} dry weight (Abdel-Bary, 1990 and Bergmann, 1992). Shacklette *et al.* (1978) found that the concentration of lead in alfalfa was 2.0 mg Pb Kg^{-1} dry weight. The background levels of Cd in alfalfa that are reported in various countries range from 0.02 to 0.28 mg Cd Kg^{-1} dry weight (Linzon, 1978). The critical toxicity levels in leaves of crop plants are: 100-400 mg Zn Kg^{-1}, 400-1000 mg Mn Kg^{-1}, 30-300 mg Pb Kg^{-1} and 5-30 mg Cd Kg^{-1} (Jones, 1972; Davis *et al.*, 1978; Gough *et al.*, 1979; Kitagishi and Yamane, 1981; Adriano, 1986; Mengel and Kirkby, 1995 and Kabata – Pendias and Pendias, 2001).

The objectives of this study were to evaluate effects of different types of phosphatic fertilizers and P levels on the growth and the uptake of P, Zn, Mn, Pb and Cd by alfalfa.

MATERIALS AND METHODS

Surface soil samples (0-30 cm) from five different localities in Egypt were collected to be used in this work. The localities included El-Kattara Experimental Farm, a marginal area between the Nile Delta and the Eastern Desert (uncultivated sandy soil). El-Zani, El-Hessinia EL-Sharkia Governorate (cultivated vertisols for 10 and 50 years) and El-Gabal Al-Asfar (where the soils were subjected to Cairo sewage effluent irrigation for 10 and 50 years).

The soil samples were air dried, crushed and passed through a 2.0 mm sieve before being subjected to determinations of relevant physical and chemical properties. Seven kilograms of each soil sample were placed in plastic pots of 25 cm-diameter and 23 cm-height. The experiment was conducted in a randomized complete block design with three replications, under green house conditions at the Experimental station of the Faculty of Agriculture, El-Zagazig University. Treatments consisted of all combinations of three types of phosphatic (P) fertilizer (single superphosphate, SSP, triple superphosphate, TSP, and rock phosphate, RP) and six application levels of P (0, 45, 90, 135, 180 and 450 Kg P fed^{-1}) were added to the soil samples in the pots. Ammonium sulfate was added as an aqueous solution in two equal doses at a level of 60 kg N fed^{-1}., the first immediately after planting and the second after 3 weeks. Alfalfa seeds were sown on November 1, 2002 to give about 80 plants pot^{-1}. The seeds were covered with a thin layer of soil. Tap water was used for irrigation to maintain the soil moisture contents when required close to 80% of field capacity. The tap water used for irrigation had a pH value of 7.8 and an average electrical conductivity of 0.7 dSm^{-1}. It contained undetectable quantities of P (<0.06 mgL^{-1}) and minimal N (<10 mg total kjeldahl NL^{-1}). Sixty days after planting, the plants in each pot were harvested to yield the first cut. The pots were watered again to allow a second cut which was harvested after 45 days from the first cut. The plant material was dried to 70°C in a forced air oven for 48 hours to obtain the dry matter weight and then was ground to pass through 40 mesh-sieves prior to storing in plastic bags for subsequent analysis. Samples of the dry matter were digested in sulfuric and percholric acids and then Zn, Mn, Pb and Cd was determined in the digests using atomic absorption spectrophotometer, whereas P was determined colorimetrically using the method of Schouwenburg and

Walinga (1967). Particles-size distribution were determined according to Piper (1950). Organic matter, pH, EC, cations and anions in the soil were estimated according to standard method of Jackson (1958).

All data were statistically analyzed according to the technique of analysis of variance (ANOVA) and the least significant difference between the treatment means was obtained using the Statistical Analysis System (SAS) computer package (SAS Institute, 1989).

RESULTS AND DISCUSSION

General properties of soils :

The general properties of the soils of the five locations under study are shown in Table 1. The clay content of the investigated soils ranged from 5.1% in the El-Khattara soil to 50.1% in El-Zani I soil. With the exception of the El-Gabal El-Asfar soils sample, the organic matter content is closely related to the clay content, increasing from 0.32% in El-khattara to 2.60% in El-Zani I. The organic matter content was relatively high in the El-Gabal El-Asfar soil (5.16% and 3.12%) as a result of the irrigation with sewage effluent. The cation exchange capacity values were closely related to the clay content, ranging from 5.0 to 32.7 cmol kg^{-1} soil. The EC values ranged from 0.35 to 1.02 dSm^{-1} Magnesium and calcium were the dominant cations in the soil extract. The pH value of the studied soils was very high ranging from 8.2 to 8.8, except that of the El-Gabal El-Asfar (7.0 ± 0.2). The complete data concerning these soils are given by Mohsen (2005).

Characteristics of phosphatic fertilizers :

The heavy metal content of the studied phosphatic fertilizers is shown in Table 2. Triple superphosphate (TSP) had the highest total content of Zn, while rock phosphate (RP) had the highest total content of Mn. Low levels of Pb and Cd were detected in the studied phosphatic fertilizers (13.6 ± 2.5 mg Pb kg^{-1} and 3.4 ± 0.7 mg Cd kg^{-1}). The results obtained for phosphatic fertilizer agree with those obtained by Webber *et al.* (1984) and Alloway *et al.* (1988). El-Sokkary (1993) found metal levels in phosphatic fertilizers ranged from 50 to 1450 $mgkg^{-1}$ for Zn, 40 to 2000 $mgkg^{-1}$ for Mn, 7 to 225 $mgkg^{-1}$ Pb and 0.1 to 170 $mgkg^{-1}$ for Cd.

Table 1. Some physical and chemical properties of the investigated soils

Soil parameter	Investigated soils				
	El-Zani I (50 year cultivated)	El-Zani II (10 year cultivated)	El Asfar I (50 year cultivated)	El Asfar II (10 year cultivated)	El-Khattara (uncultivated)
Sand (%)	34.80	37.70	77.60	85.20	90.00
Silt (%)	15.10	17.80	10.30	6.90	4.90
Clay (%)	50.10	44.50	12.10	7.90	5.10
Textural Class	Clay	Clay	Sandy loam	Sand	Sand
$CaCO_3$ (%)	1.95	1.64	1.40	0.10	0.37
O.M. (%)	2.60	1.40	5.16	3.12	0.30
pH*	8.80	8.80	7.20	6.80	8.20
EC* (dSm^{-1})	1.02	0.97	0.42	0.35	0.70
Soluble ions * (me L^{-1})					
Ca^{+2}	2.24	2.10	1.82	1.40	1.82
Mg^{+2}	4.90	5.04	2.80	2.94	3.64
Na^{+}	1.12	1.40	0.39	0.28	0.84
K^{+}	0.70	0.70	0.14	0.28	0.42
HCO_3^{-}	2.10	2.66	2.10	1.26	1.54
Cl^{-}	2.10	1.96	0.45	0.70	1.40
SO_4^{-2}	4.76	4.62	2.60	2.94	3.78
C.E.C, cmol kg^{-1}	32.70	27.80	14.00	12.30	5.00

* Soil to water extract of 1: 2.5

Table 2. Concentrations of heavy metals ($mgkg^{-1}$) in phosphatic fertilizers.

Fertilizer	Total heavy metal, $mgkg^{-1}$			
	Zn	Mn	Pb	Cd
SSP*	122.5	34.9	17.9	3.0
TSP	346.4	698.8	12.8	2.7
RP	194.1	980.0	10.1	4.5

* SSP = Single super phosphate TSP = Triple super phosphate

RP = Rock phosphate

Plant growth and biomass production :

Table 3 shows the amount of dry matter produced by alfalfa in two cuts and their total as affected by the different treatments. The maximum yield concept of Mitscherlich, as reported by Millar (1955), was used as a further basis for comparison. The dry matter of each treatment is given as a percentage of the total yield of treatment which gave the highest dry matter production.

It is interesting to note that there is much difference between the yield of the first and second cutting. These results correspond with the findings of Khaliefa (1995) and Tahoun *et al.* (2004) who reported that the dry matter yield of alfalfa declined as a function of progressing cuts but it was not in a linear trend.

There was a great increase in dry matter production of alfalfa as a result of phosphorus fertilization to different soils. The response of soils to phosphorus fertilizers could be descending arranged as follows: El-Zani II > El-Zani I > El-Asfar II > El-Khattara > El-Asfar I. The effect of P fertilizer types on the dry matter under the investigated soils presents somewhat complicated relations. Superiority of SSP over TSP and RP was in the El-Zani I and El-Asfar I soils; superiority of RP over SSP and TSP was in the El-Zani II and El-Khattara; TSP in El-Asfar II soil produced the highest biomass.

Addition of different levels of phosphorus has induced a marked increase in dry matter production. This effect was highly significant at the different levels of application to surpass the yield of the control by a 27%, 32%, 8.5%, 20.2% and 14.6% in El-Zani I, El-Zani II, El-Asfar I, El-Asfar II and El-Khattara soils, respectively.

El-Zani I soil had the greatest yield of alfalfa. The total dry matter was found to be proportional to the clay content of soils. Statistical analysis verified this relationship, as it showed that the correlation coefficient between the dry matter yield and the clay content was 0.60. It should be added, however, that the potential for a soil to store nutrients depends upon its texture (particularly clay content) and its organic matter content. This result is in an agreement with the findings of Tahoun *et al.*, (2004).

Table 3. Effect of added phosphatic fertilizer on the dry matter production by alfalfa in different soils.

Source of fertilizer	Level of fertilizer (Kg P fed^{-1})	Actual yield, g pot^{-1}			Relative yield (%) of maximum		
		1st cut	2nd cut	Total	1st %	2nd %	Total %
		El-Zani I (50 year-cultivated)					
SSP*	0	10.66	6.70	17.36	45.03	28.31	73.34
	45	11.59	8.13	19.72	48.96	34.35	83.31
	90	12.75	7.84	20.60	53.87	33.12	87.03
	135	13.32	9.31	22.63	56.28	39.33	95.61
	180	14.37	9.30	23.67	60.71	39.29	100.00
	450	14.49	7.70	22.19	61.22	32.53	93.75
	45	12.87	8.80	21.67	54.37	37.18	91.55
TSP	90	12.39	9.74	22.13	52.34	41.15	93.49
	135	12.91	8.13	21.04	54.54	34.35	88.89
	180	14.02	9.00	23.02	59.23	38.02	97.25
	450	14.85	8.14	22.99	62.74	34.39	97.13
RP	45	10.08	6.80	16.88	42.58	28.73	71.31
	90	9.95	7.92	17.87	42.04	33.46	75.50
	135	11.18	7.00	18.18	47.24	29.57	76.81
	180	11.62	6.91	18.53	49.09	29.19	78.28
	450	11.76	8.55	20.31	49.68	36.12	85.80
		El-Zani II (10 year-cultivated)					
SSP	0	6.8	5.13	11.93	28.73	21.67	50.40
	45	7.41	4.80	12.21	31.31	20.28	51.58
	90	8.05	5.10	13.15	34.00	21.55	55.56
	135	8.25	4.60	12.85	34.85	19.43	54.29
	180	7.85	4.70	12.55	33.16	19.86	53.02
	450	8.17	5.52	13.69	34.52	23.32	57.84
TSP	45	9.32	5.30	14.62	39.37	22.39	61.77
	90	9.22	6.00	15.22	38.95	25.35	64.30
	135	9.69	6.17	15.86	40.94	26.07	67.00
	180	9.29	7.01	16.30	39.25	29.62	68.86
	450	10.22	6.60	16.82	43.18	27.88	71.06
RP	45	10.44	6.09	16.53	44.11	25.73	69.84
	90	10.70	6.00	16.70	45.20	25.35	70.55
	135	9.82	6.30	16.12	41.49	26.62	68.10
	180	11.60	7.89	19.49	49.01	33.33	82.34
	450	11.52	8.00	19.52	48.67	33.80	82.47

Table 3. cont.

Source of fertilizer	Level of fertilizer (Kg P fed^{-1})	Actual yield, g pot^{-1}			Relative yield (%) of maximum		
		1st cut	2nd cut	Total	1st %	2nd %	Total %
		El-Asfar I (50 year-cultivated)					
SSP	0	8.17	4.70	132.87	34.52	19.86	54.37
	45	9.28	5.11	14.40	39.21	21.59	60.84
	90	10.01	4.80	14.84	42.42	20.28	62.70
	135	8.68	5.03	13.71	36.67	21.25	57.92
	180	9.29	5.20	14.50	39.25	21.97	61.26
	450	8.84	6.00	14.84	37.35	25.35	62.70
TSP	45	6.31	5.40	11.71	26.66	22.81	49.47
	90	6.52	4.93	11.45	27.55	20.83	48.37
	135	6.92	4.94	11.86	29.24	20.87	50.11
	180	8.30	5.30	13.60	35.10	22.39	57.46
	450	7.50	5.16	12.66	31.69	21.80	53.49
RP	45	5.90	4.70	10.60	24.93	19.86	44.78
	90	5.41	4.91	10.32	22.86	20.74	43.60
	135	6.63	5.00	11.63	28.01	21.12	49.13
	180	6.31	5.30	11.61	26.66	22.39	49.05
	450	6.63	5.84	12.47	28.01	24.67	52.68
		El-Asfar II (10 year-cultivated)					
SSP	0	4.61	4.70	9.31	19.48	19.86	39.33
	45	5.60	5.10	10.70	23.66	21.55	45.20
	90	5.83	5.60	11.43	24.63	23.66	48.29
	135	6.32	4.71	11.03	26.70	19.90	46.60
	180	5.46	5.33	10.80	23.10	22.52	45.63
	450	5.32	5.32	10.64	22.48	22.48	44.95
TSP	45	5.73	5.30	11.03	24.21	22.39	46.60
	90	5.95	4.70	10.65	25.14	19.86	44.99
	135	6.35	5.52	11.87	26.83	23.32	50.15
	180	7.01	5.60	12.61	29.62	23.66	53.27
	450	8.39	5.71	14.10	35.45	24.12	59.57
RP	45	6.10	5.50	11.60	25.77	23.24	49.01
	90	6.10	5.40	11.50	25.77	22.81	48.58
	135	6.83	5.18	12.01	28.86	21.88	50.74
	180	5.95	5.23	11.18	25.13	22.10	47.23
	450	6.37	5.31	11.68	26.91	22.43	49.35

Table 3. cont.

Source of fertilizer	Level of fertilizer (Kg P fed^{-1})	Actual yield, g pot^{-1}			Relative yield (%) of maximum		
		1st cut	2nd cut	Total	1st %	2nd %	Total %
			El-Khattara (uncultivated)				
SSP	0	6.14	4.50	10.64	25.94	19.01	44.95
	45	6.22	4.66	10.88	26.28	19.69	45.97
	90	7.58	5.20	12.78	32.02	21.97	53.99
	135	8.00	4.76	12.76	33.80	20.11	53.91
	180	6.28	4.62	10.90	26.53	19.52	46.05
	450	6.87	5.00	11.87	29.02	21.12	50.15
TSP	45	8.40	5.11	13.51	35.49	21.59	57.10
	90	5.76	4.87	10.63	24.33	20.57	44.91
	135	7.32	5.00	12.32	30.93	21.12	52.05
	180	7.64	5.12	12.76	32.28	21.63	53.91
	450	8.21	4.77	12.98	34.69	20.15	54.84
	45	8.92	5.18	14.10	37.68	21.88	59.57
RP	90	7.88	5.17	13.05	33.29	21.84	55.13
	135	8.30	5.47	13.77	35.07	23.11	58.17
	180	8.52	5.10	13.62	35.99	21.55	57.54
	450	8.33	5.31	13.64	35.19	22.43	57.63
LSD 5%							
A) type of soil		0.30	0.21	0.38			
B) source of fertilizer		-	0.16	0.29			
C) P level		0.32	0.36	0.41			
A x B		0.51	0.23	0.65			
A x C		0.72	0.51	0.92			
B x C		0.56	-	0.72			
A x B x C		1.25	0.88	1.60			

* SSP = Single super phosphate TSP = Triple super phosphate

RP = Rock phosphate

Alfalfa metal uptake :

Figure 1 shows the amount of P uptake by alfalfa as a result of the different treatments. Plants grown on the sandy soil absorbed the lowest amount of P in the two cuttings, indicating the low potential fertility of the sandy soil. Moreover, with the exception of El-Zani II, addition of SSP or TSP, even at the lowest level of 45 kg fed^{-1} induced a consistent increase in P uptake.

The highest amount of P uptake by plant tissues were observed in TSP treatments, indicating that the P uptake by alfalfa was enhanced by the presence of TSP. Trends for cumulative P uptake by alfalfa were similar for all five soils. The addition of RP did not change P uptake significantly in most soils.

Heavy metal uptake by alfalfa, as influenced by the different P fertilizer types and levels in the studied soils is presented in Table 4. There were significant differences in metal uptake by alfalfa between types of soil, type and dose of P fertilizer and their interaction (Table 4). There were differences in the metal uptake by alfalfa, but not in clear trends, between different P doses especially in El-Zani I, Al-Asfar II and El-Khattara.

Generally, the total amounts of Zn, Mn, Pb and Cd taken by alfalfa grown on the studied soils are closely related to the time of their cultivation. Zinc and Mn uptake could be descending arranged for the soils as follows: El-Zani I > El-Asfar I > El-Asfar II > El-Zani II> El-Khattara. However, Cd uptake could be arranged as follows : El-Asfar I > El-Asfar II > El-Zani I > El Zani II> El-Khattara.

The data indicate that all metals were taken up in small the quantities, except Cd in all soils and Pb in El-Khattara soil and with using a specific type of P fertilizer. The results of the present work are interpreted in terms of three possible reasons. First, when relatively soluble forms of P are added to soils some transformations are possible, including plant uptake, microbial immobilization, precipitation with metals (e.g., Ca, Cl, Mg, Al, Fe, Zn, Cd and Pb), and adsorption by inorganic and organic constituents. Laperche *et al.* (1997) conducted a bioassay experiment in a sand culture using sudax grass to evaluate the solubility of hydroxy pyromorphite (HP) with or without two apatite sources, synthetic hydroxapatite (HA) or natural rock phosphate (RP). They found

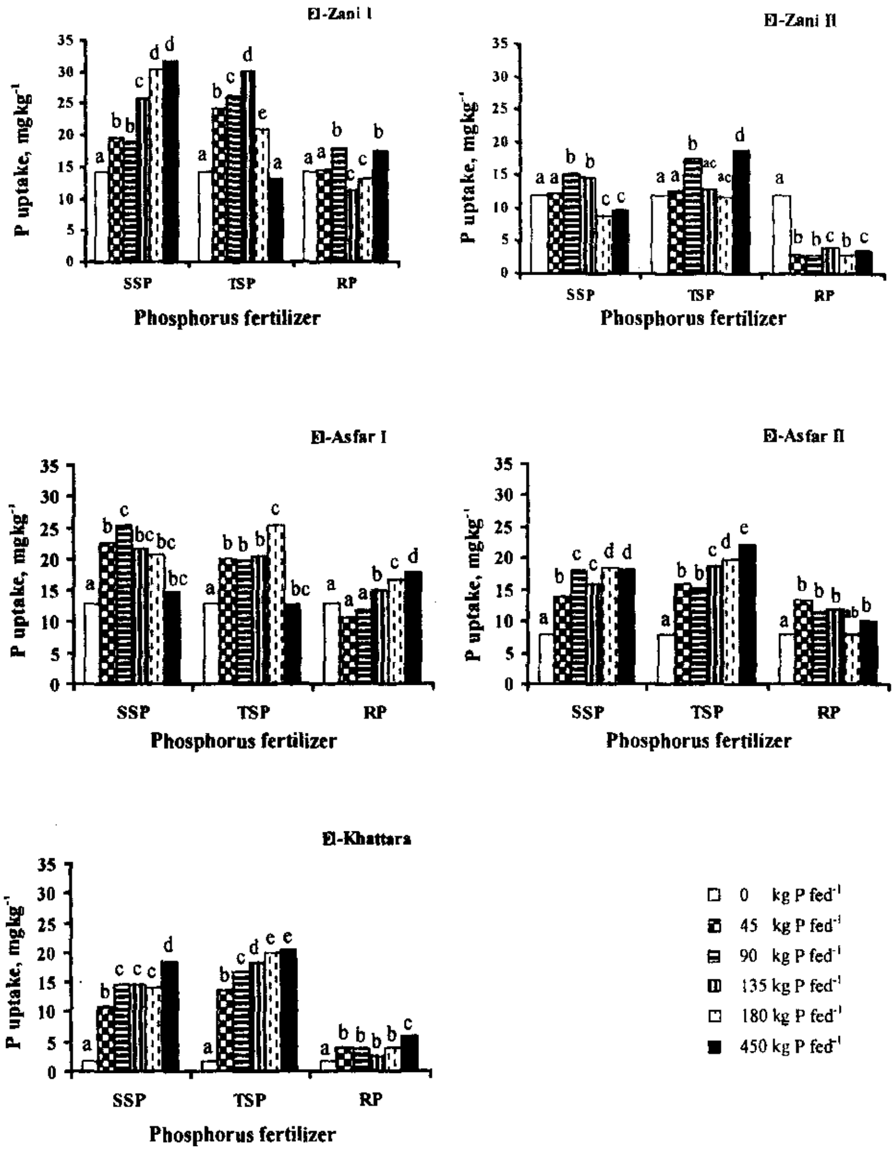

Fig. 1. Phosphorus uptake by alfalfa in different soils. Means with the same letter within a soil are not significantly different at $P<0.05$.

Table 4. Effect of added phosphatic fertilizer on the heavy metal uptake by alfalfa in different soils.

Source of fertilizer	Level of fertilizer (kg P fed^{-1})	Heavy metal uptake by alfalfa			
		Zn	Mn	Pb	Cd
		mgkg^{-1}		µgkg^{-1}	
		El- Zani I (50 year-cultivated)			
SSP*	0	1.17	0.37	7.80	0.40
	45	1.55	0.40	5.00	0.70
	90	1.02	0.34	3.00	0.71
	135	0.83	0.46	0.00	0.74
	180	0.51	0.45	0.00	0.78
	450	0.34	0.48	0.00	0.70
TSP	45	1.10	0.40	2.70	0.74
	90	0.78	0.45	0.00	0.51
	135	0.40	0.39	0.06	0.70
	180	0.32	0.46	0.00	0.79
	450	0.31	0.54	0.00	0.82
RP	45	0.96	0.26	33.00	0.36
	90	0.94	0.21	11.70	0.64
	135	0.95	0.22	12.00	0.57
	180	0.21	0.16	10.00	0.42
	450	0.24	0.20	12.60	0.61
		El-Zani II (10 year-cultivated)			
SSP	0	0.17	0.18	0.82	1.20
	45	0.16	0.14	0.00	0.33
	90	0.18	0.17	0.73	0.23
	135	0.18	0.17	0.39	0.44
	180	0.16	0.58	0.38	0.36
	450	0.21	0.28	0.06	0.12
TSP	45	0.69	0.21	0.15	0.06
	90	0.54	0.22	0.00	0.26
	135	0.46	0.18	0.00	0.37
	180	0.24	0.25	0.35	2.60
	450	0.23	0.38	0.00	0.60
RP	45	0.68	0.19	11.00	0.43
	90	1.13	0.19	11.00	0.52
	135	0.29	0.18	10.00	0.41
	180	0.34	0.19	13.00	0.33
	450	0.22	0.20	8.80	0.45

Table 4 cont.

Source of fertilizer	Level of fertilizer (kg P fed^{-1})	Heavy metal uptake by alfalfa			
		Zn	Mn	Pb	Cd
		$mgkg^{-1}$		μgkg^{-1}	
		El-Asfar I (50 year-cultivated)			
SSP	0	0.70	0.21	1.40	1.10
	45	1.20	0.23	1.60	2.50
	90	0.93	0.31	0.80	4.90
	135	0.58	0.28	0.00	4.30
	180	0.41	0.28	0.00	2.90
	450	0.33	0.56	0.00	3.40
TSP	45	1.05	0.25	2.50	4.70
	90	0.91	0.28	1.40	1.50
	135	0.57	0.29	1.40	2.00
	180	0.46	0.41	0.45	3.50
	450	0.42	0.47	0.40	1.10
RP	45	0.51	0.10	7.70	1.70
	90	0.46	0.90	7.00	2.70
	135	0.52	0.11	7.90	3.20
	180	0.49	0.10	7.60	3.30
	450	0.29	0.80	8.40	5.20
		El Asfar II (10 year-cultivated)			
SSP	0	0.25	0.18	0.00	1.90
	45	0.31	0.34	0.00	0.76
	90	0.33	0.28	0.49	3.80
	135	0.32	0.30	0.00	3.60
	180	0.26	0.23	0.00	4.30
	450	0.26	0.57	0.46	3.60
TSP	45	0.26	0.25	2.00	2.70
	90	0.31	0.26	0.00	1.40
	135	0.33	0.31	0.00	1.90
	180	0.33	0.32	0.00	2.20
	450	0.30	0.58	0.00	7.30
RP	45	0.30	0.12	7.40	2.70
	90	0.41	0.12	7.00	2.60
	135	0.43	0.13	7.30	3.40
	180	0.30	0.09	6.10	3.40
	450	0.30	0.12	5.90	3.30

Table 4 cont.

Source of fertilizer	Level of fertilizer (kg P fed^{-1})	Heavy metal uptake by alfalfa			
		Zn	Mn	Pb	Cd
		mgkg^{-1}		µgkg^{-1}	
		El –Khattara (uncultivated)			
SSP	0	0.13	0.10	4.00	0.15
	45	0.14	0.12	5.90	0.22
	90	0.15	0.23	7.10	0.33
	135	0.15	0.22	7.10	0.36
	180	0.12	0.26	4.00	0.34
	450	0.17	0.35	6.30	0.36
TSP	45	0.13	0.18	8.60	0.27
	90	0.14	0.18	6.80	0.23
	135	0.17	0.20	7.90	0.32
	180	0.15	0.27	7.90	0.33
	450	0.15	0.33	6.60	0.13
RP	45	0.18	0.11	9.80	0.36
	90	0.20	0.11	7.80	0.48
	135	0.21	0.11	8.30	0.39
	180	0.16	0.12	7.00	0.27
	450	0.15	0.11	7.40	0.35
LSD 5%					
A) type of soil		0.07	0.02	0.83	0.26
B) source of fertilizer		0.50	0.02	0.64	0.20
C) P level		0.07	0.02	0.91	0.28
A x B		0.11	0.04	1.44	0.45
A x C		0.16	0.05	2.03	0.64
B x C		0.12	0.04	1.57	0.49
A x B x C		0.28	0.09	3.52	1.10

* SSP = Single super phosphate   TSP = Triple super phosphate

RP = Rock phosphate

that in the absence of either apatite source, the Pb concentration in the shoots increased by an average of 10 to 100 times, depending on the amount of HP used, compared with the corresponding treatments with HA or RP plus HP. Second, there were no significant relationships between plant metal concentrations and the DTPA-extractable metal fractions. Third, many metals of environmental concern (e.g., Cd, and Pb) are taken up in very small amounts by plants, Moreover, most of the Pb and Cd taken up by plants often is retained in the roots. Additionally, because plants take up Pb from the soil solution, the low solubility of soil Pb (e.g. < 4 mg Pb L^{-1} of soil solution for soil containing 2500 mg $Pbkg^{-1}$, Huang *et al.*, 1997).

In general, trends for Cd uptake by alfalfa from the three soils were similar. Cadmium uptake ranged from 0.12 to 7.30 μgkg^{-1}, while that of El-Asfar soils ranged from 1.1 to 7.3 μgkg^{-1}. The trends for Pb uptake by alfalfa on the four soils were similar. Pb uptake ranged from 0 to 33.0 μgkg^{-1}, while that of El-Khattara ranged from 4.0 to 9.8 μgkg^{-1}. The low content of heavy metal uptake from El-Kattarra soil is probably due to low quantities of colloids (clay and organic matter) in that soil. However, appreciable amount of Pb taken up by plants grown in this soil (sandy soil).

The amount of Pb taken by alfalfa from each soil tended to decrease with increasing the P level of each fertilizer type (Table 4). As a result of P (hydroxyaptite) addition to soil, Pb concentration in shoot tissue of sudax was reduced from 170 to 3 $mgkg^{-1}$ (Laperche *et al.*, 1997). It is also clear that the soil amended with RP resulted in highest amounts of Pb taken up by alfalfa. This could conclude the RP may contain appreciable amounts of available Pb for plants.

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تقييم تأثير أنواع ومستويات مختلفة من الأسمدة الفوسفاتية على محتوى البرسيم الحجازى من العناصر الثقيلة والفوسفور

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يهدف هذا البحث إلى تقييم تأثير أنواع ومستويات مختلفة من الأسمدة الفوسفاتية على نمو ومحتوى كل من الفوسفور، الزنك، المنجنيز، الرصاص والكادميوم فى البرسيم الحجازى، ولهذا الغرض تم اختيار ثلاثة مناطق، المنطقة الأولى تمثل الأراضى الطينية المنزرعة لمدة ١٠، ٥٠ عاما وتروى بمياه النيل أخذت من الزينى – مركز الحسينية – محافظة الشرقية، والمنطقة الثانية تمثل الأراضى الطميية المنزرعة لمدة ١٠، ٥٠ عاما وتروى بمياه الصرف الصحى من منطقة الجبل الأصفر بمحافظة القليوبية ، المنطقة الثالثة تمثل الأراضى الرملية البكر من مزرعة كلية الزراعة – الخطارة – محافظة الشرقية.

وتم تصميم التجربة من ١٨ معاملة، تتكون من ثلاثة أنواع من الأسمدة الفوسفاتية هى السوبر فوسفات الأحادى والسوبر فوسفات الثلاثى وصخر الفوسفات. مع ٦ مستويات متزايدة هى صفر، ٤٥، ٩٠، ١٣٥، ١٨٠ ، ٤٥٠ كجم P للفدان. تم زراعة البرسيم الحجازى فى تجربة أصص كدليل نباتى لامتصاص كل من الفوسفور، الزنك، المنجنيز، الرصاص والكادميوم وقد اوضحت النتائج ما يلى:

- ارتفاع محتوى السوبر فوسفات الثلاثى من الزنك بالمقارنة بالسوبر فوسفات الأحادى أو صخر الفوسفات بينما محتوى صخر الفوسفات من المنجنيز أعلى بالمقارنة بالمصدرين الآخرين.
- انخفاض محتوى الرصاص والكادميوم فى الأسمدة الفوسفاتية المستخدمة فكان ١٣,٦ ± ٢,٥ ملليجرام / كجم للرصاص ، ٣,٤ ± ٠,٧ ملليجرام / كجم للكادميوم.
- زيادة محصول المادة الجافة مع زيادة معدلات الفوسفور المضافة.
- كمية كل من الزنك ، المنجنيز ، الرصاص والكادميوم الممتص بواسطة البرسيم الحجازى مرتبطة معنويا بسنوات الزراعة. وتدخل كل الكميات الممتصة ضمن المدى العادى لنمو وتطور البرسيم الحجازى. وعلى وجه العموم تركيز الزنك ، المنجنيز ، الرصاص والكادميوم فى البرسيم الحجازى ينخفض معنويا مع التسميد الفوسفاتى.
- تأثير التسميد الفوسفاتى على محتوى البرسيم الحجازى من الرصاص والكادميوم عند تساوى كمية الفوسفور المضافة كان أعلى ما يمكن مع إضافة صخر الفوسفات ثم السوبرفوسفات الأحادى ثم السوبرفوسفات الثلاثى.

وبالتالى يمكن استنتاج أهمية الحاجة إلى دراسة أخرى للتنبؤ بمدى صلاحية الرصاص والكادميوم فى الأراضى على المدى الطويل ومن المهم المتابعة المستمرة لمعدلات الإضافة السنوية لهذه العناصر.