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Evaluation of Sorghum Response to Different Sources and Rates of Phosphorus Fertilizers

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POT EXPERIMENT was carried out to study the impact of different phosphatic fertilizers, sources and rates, on availability of N,P and K nutrients and some heavy metals in soil and their uptake by Sorghum plant.

-0Data revealed that phosphatic fertilizers positively affected the dry matter of sorghum plant grown on clay loam soil and the response was dependent on P-fertilizer sources and rates. The results indicate that the highest values for dry matter content were obtained when (DAP) was applied at either lower or higher rates of application. Meanwhile the lowest values of plant growth were found with (SSP) fertilizers and increase with plant age.

The analytical analysis of the soil samples after each cut show that, increasing rates of P-fertilization increase the availability of N P and K nutrients and Cd and Pb in the extraction solutions.

Data representing the uptake of N P K and Cd or Pb metals by sorghum as affected by different applications of sources and rates of P-fertilizers showed positive responses compared to control. Values being higher for Cd and Pb in the highest rate of (SSP) fertilizers compared to TSP and DAP fertilizers.

Keywards: Di-ammonium phosphate (DAP), Single super phosphate (SSP), Triple super phosphate (TSP), Heavy metals (Cd, Pb) , Sorghum.

Compared with other macronutrients, phosphorus is by far the least mobile and available to plant in most soil conditions especially in arid and semiarid regions. It is therefore, frequently a major or even the prime limiting factor for plant growth in such regions. It was estimate that 5.7 billions of hectares worldwide contain too little available phosphorus for sustaining optimal crop production. The poor mobility of soil inorganic phosphorus is due to the large reactivity of phosphate P-ions relative to numerous soil constituents such as clay, active calcium, calcium carbonate contents and to the consequent strong retention of most of soil phosphorus onto those. Therefore, only a marginal proportion of soil phosphorus is present as P-ions in the soil solution. Although P- ions can reach larger concentrations in highly fertilized soils, their concentration in the soil solution is in the micro molar range, ranging between 0.1 and 10 μM (Mengel & Kirkby, 1987; Raghothoma, 1999 and Frossard *et al.*, 2000).

Most Egyptian soils have very low levels of natural available phosphorus. Therefore, P-fertilizer applications are essential for the establishment and maintenance of most crops and horticultural plants. Gouda *et al.* (1990) stated that increasing P level up to 300 kg triple super phosphate per fadden in sandy soil causes a highly significant increase in groundnut pod yield and yield components.

Water soluble phosphate fertilizers such as Single super phosphate (SSP), with phosphorus content of 16% as phosphorus pentoxide (P_2O_5), Triple super phosphate with 48% P_2O_5 (TSP) and diammonium phosphate (DAP) with 48% P_2O_5 and 21% N, are produced by converting unavailable P in phosphate rocks PR (apetite rocks). The plant available P obtained by treating the PR with acids (sulfuric acid for SSP and phosphoric acid for TSP, moreover, when ammonia passed through phosphoric acid, ammonium phosphate fertilizers are produced (World Bank Group 1998). Single super phosphate has been the most widely used P fertilizer for agricultural purposes in Egypt. It contains around 15.5% P_2O_5, 11.9% sulfur and 20.4% calcium.

Increased Egyptian agricultural productivity, to meet the demands of the explosive population, was associated with excessive application of chemical fertilizers containing certain micronutrients and hazardous heavy metals. An accumulation of these heavy metals are likely to occur due to intensive application and repeated use of commercial fertilizers conforms a serious environmental problem which should be reflected on plant growth and crop quality (Kandil, 1997).

Increased environmental concern is frequently express nowadays about the concentration of heavy metals especially Cd and Pb in soils and their possible effect on human beings after entering into the food chain through the food crops raised in such heavy metal contaminated soils (Palaniappan *et al.*, 2002). Cadmium is a biologically non-essential element, which is a most dangerous environmental pollutant because of its diverse toxic effects. When it enters into the food chain of higher animals, it is stored in the liver and kidney and causes bone deformities and kidney damage in human beings. Lead is another heavy metal that also finds its way to the soil through phosphatic fertilizers in addition to the major pollution sources like petroleum emission from motor vehicles (FAO, 1984). El-Dewiny (2001) added that amounts of Cd in phosphatic fertilizers are dependent on the source of rock phosphate and the concentration of Cd in phosphate fertilizers, values being generally variable from 10 to 91 ppm. On the other hand, lead content of phosphate fertilizers was about 7 to 225 ppm (Senesi & Polemio, 1981).

The main objectives of this research work is to investigate the impact of different sources and rates of phosphatic fertilizers on available nutrients in soil , the plant growth, nutrients and some heavy metal uptake by sorghum plants.

Material and Methods

The study was performed at greenhouse in the National Research Centre, Cairo Egypt. Soil sample was collected from the surface layer of the Experimental Station at South El–Tahreir province.

Ten kilograms of air-dried soil were packed in plastic pots with a height 35 cm and diameter 30 cm. The Physical and chemical characteristics of the soil were determined as described by Black *et al.* (1982) and the values are illustrated in Table 1.

TABLE 1 . Some physical and chemical properties of the studied soil.

Soil characteristics	Data
Particle size distribution %	
Sand	41
Silt	30
Clay	29
Texture	Clay loam
pH (1:2.5) in suspension	7.87
EC (1:5) ds m^{-1}	0.95
$CaCO_3$ %	4.24
O.M %	0.52
Soluble cations and anions (meq $100g^{-1}$soil)	
$CO_3^{=}$	--
HCO_3^{-}	1.5
Cl^{-}	4.5
$SO_4^{=}$	3.4
Ca^{++}	1.5
Mg^{++}	2.8
K^{+}	1.3
Na^{+}	3.8
Available macro-nutrients %	
N	0. 017
P	0.0005
K	0.072
Soluble heavy metals (ppm)	
Cd	0.12
Pb	0.54

Three different sources of phosphatic fertilizers such as Single super phosphate (SSP), Triple super phosphate (TSP) and Di-ammonium phosphate (DAP) at three rates namely 150, 200 and 300 mg P_2O_5 kg^{-1} soil were used. Nitrogen and potassium fertilizers were applied at normal rates, *i.e.*, 120 kg N and 50 kg K_2O per fadden in the forms of urea and potassium sulfate fertilizers respectively. Iron, Mn, Zn and Cu were applied at the rate of 5, 5, 5 and 2.5 mg kg^{-1} soil in the forms of Fe-EDDHA and sulfate compounds respectively. Treatments were arranged in a randomized complete block design with three replications. Control treatment received no P fertilizer while N and K_2O were applied with the previous same rates as mentioned above.

Twenty of Sorghum *(Sorghum sudanese* L.*)* seeds were sown in each pot and after 3 weeks the seedlings were thinned to 15 seedlings per pot. After that, two cuts (each fifteen days) of randomized 5 plants per pot were cut 1 cm above the soil surface and the fresh and the dry weight of these 5 plants were recorded. The result of the fresh and dry weight of each cut was statistically analysed using the GLM repeated measures procedure according to Norusis (1994).

After each cut soil samples were collected to measure the extractable N PK and Cd or Pb by ammonium bicarbonate-EDTPA extraction method. The wet ashing methods were employed for digesting plant materials using a mixture of concentrated sulfuric acid and H_2O_2 solutions (Soltanpour, 1985). The obtained digests were then used for determination of the selected heavy metals Cd and Pb using the atomic absorption spectrophotometer (Perken Elmer, 2380).

Results and Discussion

Plant growth

The application of different sources and rates of phosphorus fertilizers on the fresh and dry weight of sorghum plants are presented in Table 2. It was observed that addition of di-ammonium phosphate (DAP) had significant increase on the fresh and dry weight of sorghum plants at different stages of growth as compared to control. However, the addition of single super phosphate (SSP) gave the lowest effect on fresh and dry weight of sorghum plants than triple super phosphate (TSP) or (DAP). Result also showed that the fresh and dry weight of sorghum plants increased significantly with increasing rates of phosphorus with respect to all phosphorus fertilizer sources. The lowest fresh and dry weight at different stages of plant growth were recorded for the control and the highest for DAP applied at 300 mg P_2O_5 kg^{-1} soil. Irrespective to P rates, the data also showed that the addition of DAP had the highest pronounced effect on sorghum plant growth at different stages when compared with TSP or SSP. For example, the average percent of increase in the fresh weight of sorghum at first cut as compared with control treatment were about 92, 74 and 57 for DAP, TSP and SSP respectively.

Data also showed that application of different sources and rates of phosphorus fertilizers gradually increased sorghum plant growth with increasing plant age. The average increases of plant dry weight were 5.59 and 9.00 g pot^{-1} for the first and second cut respectively.

Soil

The values in Table 3 indicated that the available N P K or extractable Cd and Pb was depended on the studied factors including the source and rate of applied phosphatic fertilizers. After the first cut, the mean values of available N, P and K nutrients for the three studied rates were found to be 176, 7.71 and 136 for (SSP) and 190, 7.78 and 129 for (TSP) and 219, 8.5 and 155 for (DAP) respectively. For the investigated heavy metals Cd and Pb, the mean values were 1.4, 17.9 for (SSP), 1.06, 15.5 for (TSP), 0.80, and 15.2 for (DAP) respectively. Indicated results reflect the high amounts of imputers in SSP when compared with ether DAP or TSP fertilizers. Similar results were observed by Mullins *et al.* (1990); El-Kassas (1996); Garica *et al.* (1996) and El-Dewiny (2001) who concluded that water insoluble P- compounds in commercial triple super phosphate (TSP) fertilizers are less available than the P- in di-ammonium phosphate (DAP). On the other hand, di-ammonium phosphate has an acid effect upon the soil similar to anhydrous ammonia.

TABLE 2. Fresh or dry weight (g pot^{-1}) of Sorghum cuts (5 seedlings per cut) as affected by different sources and rates of phosphatic fertilizers.

P-Fertilizer		First cut				Second cut			
Sources*	mgP_2O_5 kg^{-1}soil	Fresh weight	Increase %	Dry weight	Increase %	Fresh weight	Increase %	Dry weight	Increase %
Control		13.5	-	2.13	-	27.9	-	5.74	-
SSP	150	19.2	42	3.84	80	50.3	80	6.93	21
	200	20.2	50	4.01	88	56.7	103	7.53	31
	300	24.2	79	4.69	120	60.4	117	8.93	56
	Mean	21.2	57	4.18	96	55.8	100	7.80	36
TSP	150	20.4	51	5.20	144	55.8	100	7.06	23
	200	24.3	80	5.68	167	62.3	123	9.15	59
	300	25.8	91	6.71	215	69.9	151	10.4	82
	Mean	23.5	74	5.86	175	62.7	125	8.88	55
DAP	150	24.3	80	5.44	155	56.4	102	8.24	44
	200	25.1	86	6.74	216	68.4	145	10.5	82
	300	28.5	111	8.01	276	75.6	171	12.0	114
	Mean	26.0	92	6.73	216	66.8	140	10.3	80
L.S.D 5%		1.32	-	0.25	-	3.01	-	0.56	-

*SSP = Signal super phosphate.
TSP = Triple super phosphate .
DAP = Di ammonium phosphate.

TABLE 3. Status of elements (ppm) in the soil samples after each cut.

P-Fertilizer		First cut					Second cut				
Sources	mgP_2O_5 kg^{-1} soil	N	P	K	Cd	Pb	N	P	K	Cd	Pb
Control		155	6.70	121	0.66	12.2	111	3.76	86	0.16	10.1
SSP	150	164	6.83	120	1.04	15.4	100	4.95	94	0.41	11.8
	200	169	7.75	122	1.49	18.9	104	5.44	110	1.19	12.6
	300	195	8.56	165	1.67	19.5	132	7.22	115	1.34	13.4
TSP	150	172	6.84	125	0.87	13.4	119	1.02	96	0.28	11.5
	200	185	7.84	126	0.97	16.3	121	1.34	101	0.62	12.0
	300	213	8.67	136	1.35	16.9	123	1.53	125	0.73	12.8
DAP	150	194	7.76	128	0.73	13.4	151	1.13	99	0.13	11.1
	200	205	8.05	144	0.80	15.6	157	1.53	114	0.38	11.9
	300	258	9.69	194	0.86	16.6	193	1.94	125	0.46	12.2

* SSP = signal super phosphate .
TSP = Triple super phosphate .
DAP = Di ammonium phosphate .

Plant composition

With regard to the P- fertilizer sources and rates, data illustrated in Fig. 1 showed that single super phosphate addition gave the lowest value of N, P and K uptake at different plant stages compared with other treatments. It was noticed that the addition of triple super phosphate enhanced the utilized of N, P and K uptake through improving the nutrient supply. Whereas, the application of di-ammonium phosphate at high dose was more pronounced effect on the N, P and K uptake at different stages of plant growth. This result may be due to the effectiveness of DAP for supplying the plant with two especial nutrients i.e. N and P or may be due to that di-ammonium phosphate has an acid effect upon the soil similar to anhydrous ammonia. Hedley *et al.* (1994) stated that such result could be explained by the beneficial effect of the DAP and TSP used and increases the solubility of DAP and TSP by the action of acid generated through nitrification of the ammonium ions. Results also revealed that the addition of DAP and / or TSP increase the N, P and K uptake at different stages of plant growth.

Concerning the levels of phosphorus, it was noticed that increasing levels of super phosphate SSP stimulate the N, P and K uptake by plant. Whereas, the addition of TSP at high dose had a more remarkable effect on N , P and K uptake by plant at different stages as compared with SSP. Data also showed that increasing levels of DAP had more pronounced effect on N, P and K uptake as compared to other treatments. This result can be explained by the interaction between ammonia and phosphoric acid, which enhances the dissolution of phosphorus in the soil. In general, a clear increase in the concentration of N, P and K in the plant growth stages was observed as a result of phosphatic fertilizers application in the order: DAP>TSP>SSP.

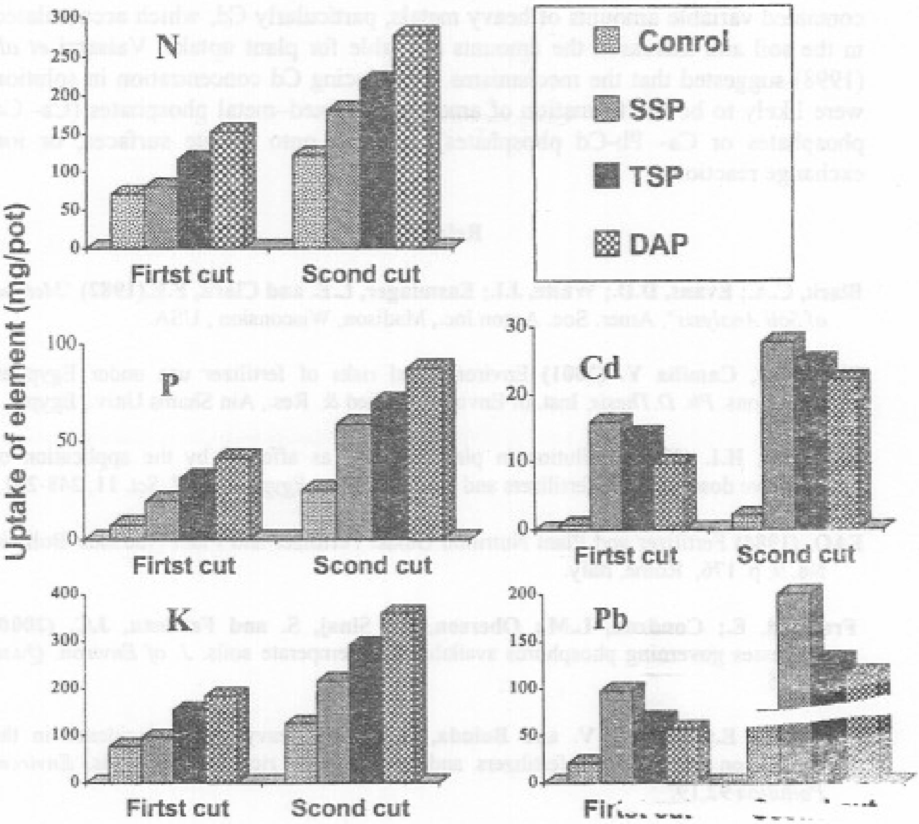

Fig.1. Effect of P- fertilizers sources and rates (mean values) on uptake of N P K nutrients and Cd & Pb heavy metals by sorghum plants at different plant growth.

Because of the potentially adverse effects of Cd or Pb human health, the data in the same Fig. 1 showed that positive responses compared to control, values being higher for Cd or Pb uptake but lower for Contents. Application of SSP gives the higher values compared to TSP and DAP. Similar results were reported by (Schroeder & Balassa, 1963).

Mortvedt & Giordano (1977) reported that greater Cd uptake by maize from commercial DAP fertilizers which contained from 100- to 260 mg Cd kg $^{-1}$ P than from reagent grade DAP (5 mg Cd kg $^{-1}$ P). They added that plant uptake of Cr, Ni and Pb was quite variable and was not directly related to their concentration in

P fertilizers. Pezzarossa *et al.* (1990) who reported that the SSP added to the soil contained variable amounts of heavy metals, particularly Cd, which accumulated in the soil and increased the amounts available for plant uptake. Valsami *et al.* (1998) suggested that the mechanisms for reducing Cd concentration in solution were likely to be the formation of amorphous mixed–metal phosphates (Ca- Cd phosphates or Ca- Pb-Cd phosphates), sorption onto apatite surfaces, or ion exchange reactions.

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تقيم استجابة نباتات السورجم للمصادر والمعدلات المختلفة للأسمدة الفوسفاتية

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أجريت تجربة أصص بصوبة المركز القومي للبحوث لدراسة تأثير إضافة مصادرو معدلات مختلفة من الأسمدة الفوسفاتية على تيسر وامتصاص بعض العناصر الضرورية الكبرى مثل NPK وأيضا بعض العناصر الثقيلة مثل الكادميوم والرصاص ٠ فقد تمت إضافة سماد السوبر فوسفات العاديSSP، ثلاثى سوبر فوسفات TSP و ثنائي امونيوم فوسفات DAP بمعدلات ١٥٠ ، ٢٠٠، ٣٠٠ ملليجرام فو٢ أ٥ لكل كجم تربة. بعد ذلك تمت زراعة بذور السورجم وتم اخذ عينات تربة ونبات على فترتين (كل ١٥ يوم) لإجراء تحليل لعينات التربة والنبات وأوضحت النتائج ما يلي:

• أدى زيادة معدل السماد الفوسفاتي المضاف للأرض الى زيادة معنوية لنمو النبات معبرا عنه بالوزن الطازج او الجاف وقد ظهرت هذة الزيادة واضحة في كلا الحشتين لكل من مصادر الأسمدة تحت الدراسة مقارنة بمعاملة الكنترول.

• إضافة الأسمدة الفوسفاتية بمصادرها ومعدلاتها تحت الدراسة أدى الى زيادة تيسير و امتصاص بعض العناصر الغذائية مثل N P K وأيضا بعض العناصر الثقيلة مثل الكادميوم و الرصاص، وان أكثر الأسمدة ضررا من حيث إمداد التربة ومن ثم النبات بهذه الملوثات هو السوبر فوسفات العادى يليه التربل سوبر فوسفات ثم أخيرا ثنائي امونيوم فوسفات.