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Effect of Incubation Period of Phosphorus Fertilizer on some Properties of Sandy Soil with Low Calcareous Content, Southern Algeria

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ABSTRACT

Fertilization practices can contribute to modify the properties of the soils, in particular salinity and the pH of soils. The main goal of this study is to demonstrate the impact of the physicochemical properties changes related to applied phosphorus fertilizers on phosphorus availability in light textured soils having low calcareous content. A short-term incubation experiment during 105 days was carried out in field conditions. Three different phosphorus fertilizers (monoammonium phosphate, fosfactyl and single super phosphate) were added in a sandy soil. The principal results indicated that the application of these fertilizers causes an enhancement in phosphorus availability in this soil. Through incubation period, the contribution of phosphorus showed a tendency to increase in the electrical conductivity value of the soil. The SSP fertilizer shows a highest degree of soil salinization with 7.57% compared to the control without phosphorus addition. On the other side the P fertilizers tested exert an acidifying effect, the addition of monoammonium phosphate causes a decrease in pH values of soil in the range of 6.71% compared to untreated samples. Therefore, the pH values of the control reflect the degree of acidification of phosphorus fertilizers used which constitutes an advantage in our Saharan climatic conditions. This study demonstrates that it is essential to choose appropriate fertilizers according to the components of the soils in order to have a suitably reasoned mineral fertilization and respectful of the physicochemical environment of soil and undergrounds waters properties.

Key words: Phosphorus availability, calcareous content, physicochemical properties, sandy soil, Sahara, Algeria

INTRODUCTION

Soil is an essential element of agriculture, its intrinsic component, obviously affects its agricultural value (Tischler, 1955; Kromp, 1999; Nietupski *et al.*, 2010; Gu *et al.*, 2011;

Santorufo *et al*., 2012; Keith *et al*., 2012). Among the most important factors influencing the properties of soil which determines soil properties are the type of soil management, soil tillage, cultivation and fertilization (Birkhofer *et al*., 2008; Sklodowski, 2009).

Agronomic technologies, such as fertilization practices, have a significant, although not always positive effect on soil properties. However, continued long term application of fertilizers can lead to P-accumulation in surface horizons greater than that required for optimum plant growth, thus increasing the potential for P loss to surface waters and eutrophication (Sui *et al*., 1999; McDowell *et al*., 2001). The application of mineral fertilizers in the soil has several effects on the properties of the soil, for example salinity values and soil pH. Judicious use of fertilizers has a number of beneficial effects on soil properties and the surrounding environment beyond the obvious enhanced food production. By improving growth there is more crop canopy and more root growth below the surface to protect the soil against the erosive action of wind and water.

At present, approximately 9 million ha of land area in Algeria is under agriculture, most of which are calcareous in nature and deficient in the required nutrients especially in P. In southern of Algeria, sandy soils often require fertilization with most essential nutrients, especially in irrigated agriculture. Using the mineral fertilizers in these light textured soils the phosphate fertilizers became necessary to obtain an acceptable agricultural production (Halilat, 2004). Nitrogen, P and K are the most essential plant nutrients with respect to increasing yield. Soil phosphorus (P) is often considered one of the most limiting nutrients for plant productivity. The importance of maintaining an adequate phosphorus (P) supply to crops in order to high-quality production has long been recognized and the routine application of P fertilizers to agricultural land have become an integral part of agriculture in developed countries (Withers *et al*., 2001).

Supervising the chemical environment of soils and their minerals content are of great practical interest in crop nutrition and in monitoring water quality near agricultural areas. The purpose of the present study has been to determine the influence of phosphorus fertilizers applied on the soil and their impacts on the selected physicochemical properties of soil, formed under the influence of short-term phosphorus fertilization.

MATERIALS AND METHODS

Study area: The experiment was conducted on an experimental farm of the University of Kasdi Merbah in Ouargla (southern Algeria) (31°57 N, 5°20 E, 133 m above sea level) from December 2010 to May 2011. This farm is located southwest of Ouargla, about 6 km from the city center. The regional climate is arid and characterized by warm dry summers, with maximum air temperature some times higher than 40°C and minimum relative air humidity often less than 20%. Therefore very low and erratic rainfall lower than 100 mm, almost exclusively concentrated in winter.

Experimental design and sampling management: The experiment was set up in randomized block with two classification criteria (types of P fertilizers-incubation period) was performed, involving four blocks 1, 2, 3 and 4 in which four treatments were designed and replicated according to the number of incubation periods (07 times), giving a total of 28 samples per block. The treatments were as follows: Untreated samples (control), samples with monoammonium phosphate, fosfactyl and single super phosphate. All treatments are subjected to daily rotation in order to homogenize the effects of environmental factors.

Soil sampling and analyses: The bulk sample of soil used was collected after crop harvest (winter wheat) from the upper layer of an Arenosol at depth of 0-30 cm sampled at five sampling points randomly selected along agricultural area in El-Golea (southern Algeria). The collected samples were air dried, crushed, sieved through a 2 mm sieve and stored for chemical characteristics determination. Routine analysis of the tested soil was determined according to the standard methods published by Richards (1954) and Jackson (1958). Soil pH and electrical conductivity were measured in deionized water (1:5 soil to solution ratio). The total $CaCO_3$ by the gasometric method by using the calcimeter of Bernard. The total soil organic carbon was quantified by the Walkley-Black method modified (Yeomans and Bremner, 1998) and total nitrogen was determined by digestion with sulphuric acid and Kjeldahl distillation (Bremner, 1996). Phosphorus was determined colorimetrically in all extracts using the ammonium molybdate-ascorbic (Olsen *et al*., 1954; Bowman and Cole, 1978) and exchangeable potassium analyzed by the ARNOLD method (Arnold and Close, 1961). Cation Exchange Capacity (CEC) was measured with ammonium acetate (1 mol L^{-1}, pH 8.7) leaching method (Metson, 1961).

Incubation experiment: In this study three phosphorus minerals fertilizers were tested: Monoammonium Phosphate (MAP) NP 12:52, fosfactyl NP 3:22 and super phosphate (SSP) P 20. All P fertilizers were ground in powder form in order to increase their effectiveness and thoroughly mixed with soil samples at one rate i.e., 250 mg kg^{-1} and a control (no P). Under field conditions 1 kg of each treatment transferred to plastic cylinders with 6 and 25 cm in diameter and height, respectively. The experiment started in 1/30/2011 and the treatments were incubated for 15, 30, 45, 60, 75, 90 and 105 days. The appropriate amount of distilled water was added to bring the soil to the estimated field capacity. The samples were kept moist at field capacity by adding distilled water as needed. After the specified time, sub-samples were taken and air dried before analysis. After each incubation period sub-samples were analyzed for Olsen's bicarbonates extractable P, soil pH and electrical conductivity (1:5 soil to solution ratio).

Statistical analysis: All data in the study were recorded and classified using Microsoft Office Excel 2010. The significance of differences between the means was determined using analysis of variance (ANOVA) at the level of significance $p<0.05$ with the software package Statistica 8.0.

RESULTS AND DISCUSSION

The data regarding physico-chemical properties of soil presented in Table 1 reveals that the soil was sandy in texture, alkaline, non saline, very low in organic matter content and moderately rich in available phosphorus evaluated by the Olsen method.

Evolution of available phosphorus levels in the soil: The knowledge of the dynamics of an element is essential for the diagnosis of soil fertility and estimation of corrective measures (Bosc, 1976). The change in the composition of the soil solution by adding fertilizer to the soil; this can affect the dynamics of phosphorus (Delgado *et al*., 2002).

Characterization of available phosphorus is still necessary to establish a late diagnosis or judgment on the behavior of culture about this element, so it can develop a prognosis on phosphate soil fertility and advocate recommendations for fertilization.

Table 1: Basic parameters of selected physical and chemical properties of pre-incubation soil

Parameters	Value
Mechanical properties	
Textural class	Sandy
Sand (g kg^{-1})	93.3
Silt (g kg^{-1})	4.4
Clay (g kg^{-1})	2.3
Physico-chemical properties	
Soil reaction (pH) (1:5 soil water extract)	8.6
Lime content (%)	1.84
EC (dS m^{-1}) (1:5 soil water extract)	0.11
Organic matter (%)	0.6
Total nitrogen (%)	0.01
Olsen P (mg kg^{-1} soil)	45.66
Exchangeable potassium (mg kg^{-1} soil)	63
Cation exchange capacity	4.2

Table 2: Evolution of available phosphorus levels in the soil during incubation period

	Incubation period (days)										
Treatments	15	30	45	60	75	90	105	Average value	C.V (%)	Source of variability	p<F
Control	28.30	69.17	81.61	43.47	41.79	41.69	38.37	49.20	19.8		
MAP	145.50	115.90	113.10	66.87	66.06	64.41	58.08	89.98		Incubation period	***
Fosfactyl	105.90	83.31	80.00	79.90	71.36	66.86	30.62	73.99		Fertilizer	***
SSP	117.60	109.10	108.90	85.99	80.00	76.50	68.79	92.41		T*fertilizer	***
Average value	99.34	94.36	95.36	77.58	72.46	69.25	52.49	76.40			

SSP: Single super phosphate, MAP: Mono-ammonium phosphate. ***Significant $p<0.001$

Indeed, the evolution of available phosphorus in the soil is still affected by a number of parameters, namely: pH, organic matter, limestone, soluble salts etc. All these parameters come into play in the soil phosphorus status. The mean values obtained from the assay of available phosphorus (Olsen) of all treatments are shown in Table 2.

The phosphorus fertilizers applied revealed a very highly significant effect on the evolution of available phosphorus levels in the soil (CV = 19.8%). Comparing averages over different fertilizers identified three homogeneous groups a, b and c overlap.

The results prove to be significant compared to the prefectures of interpretation usually employed (Couvreur, 1981). Studied the treatment proved rich in soluble. Phosphorus availability rate of phosphorus supplied to the soil is high in sandy soils and low in clay soil (Olsen *et al.*, 1954).

The results also indicated that adding P fertilizers caused the enrichment of soil available phosphorus. The main results showed that the values of fertilized samples is higher compared to the control with an increase of the order of 87.83, 82.88 and 50.38%, respectively for treatments with single super phosphate, MAP and fosfactyl. During incubation and the fifteenth day until the end, all treatments showed a decrease over time in the amounts of available phosphorus (Table 2). In general, the mean values decreased from 99.34-52.49 mg kg^{-1} for a rate of reduction is about 50%.

The decrease in the amounts of P can be generated by a P fixation by soil. The amounts of P retained can be increased when the contact time between the soil and the phosphorus supplied increases (Akinremi and Cho, 1991). Akhtar and Alam (2001) in their study showed that increasing the time of incubation, P availability in soil decreased for both organic and inorganic P sources. The amount of P decreased in incubated soil, between one and six weeks (Al-Rohily *et al.*, 2013).

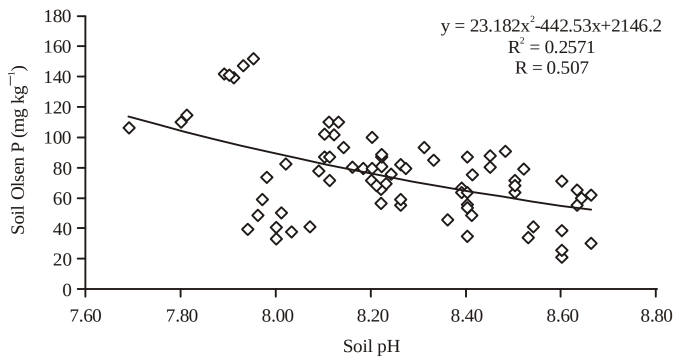

Fig. 1: Relationship between available Olsen-P and soil pH values

This phenomenon starts at the beginning with a fast rhythm and continuous in all treatments to evolve more slowly with a slower rhythm and becomes almost steady during the time especially for MAP and control after 60 days. The results are in agreement with findings of Kaloi *et al.* (2011) and Nafiu (2009), who reported that kinetics of P release from soils, can be described as an initial rapid rate followed by slower rate.

The amounts of P available from SSP remained significantly higher than that of MAP, fosfactyl and control for the last six weeks period studied (Table 2). This indicated that SSP under an alkaline soil conditions maintained P availability in soil for a longer period of time.

Phosphorus reacts first with Ca^{2+} of the adsorption complex then with the free Ca^{2+} in the soil solution and finally the phosphorus reacts with Ca^{2+} present on the surface of calcite (Akinremi and Cho, 1991). Naseri *et al.* (2010), indicating that phosphorus deficiency is widespread in calcareous soils and it is the main factor limiting yields of annual crops in acid and alkaline soils (Fageria, 2001).

The study on the behavior of P in various soil samples, characterized by different degrees of calcium concentrations, shows that the maximum of P is determined by the soil which has the maximum free $CaCO_3$ (Aslam *et al.*, 2000).

Influence of P fertilizers on the soil pH: The dissolution of mineral fertilizers in the soil has several effects on soil properties, including pH and soil salinity are most apparent. The pH values during incubation are consigned in Table 3. The fertilizers tested revealed a very highly significant effect on the evolution of pH in the soil (Table 3). Compared to the control treatment, the contribution of phosphorus fertilizers caused a decrease of the pH values in all the treatments.

The lowest values recorded in the case of MAP treatment are the result of the nature of the fertilizer, during 105 days of incubation; the fertilizer tested caused a slight acidification of the soil around 7.15, 4.25 and 3.74% compared to the control treatment, respectively for MAP, SSP and fosfactyl. The MAP is an acidifying product (pH = 4.5) this acidification can be explained by the generation of acid ions H^+ and NH^{4+}. Similar results showed that long-term (Moughli, 2000) or short-term (Goh *et al.*, 2013) MAP fertilizers use has a strongly acidic effect on soil. The fosfactyl after its dissolution induces an enrichment of the soil solution by sulphate ions SO_{4^-}; they can react eventually with H^+ cations forming acids which will acidify soil. This acidification cans contribute in improving the bioavailability of phosphorus to the crop particularly in the case of soils with an alkaline pH as our case. A negative correlation was obtained between available Olsen-P and pH values of soil (Fig. 1).

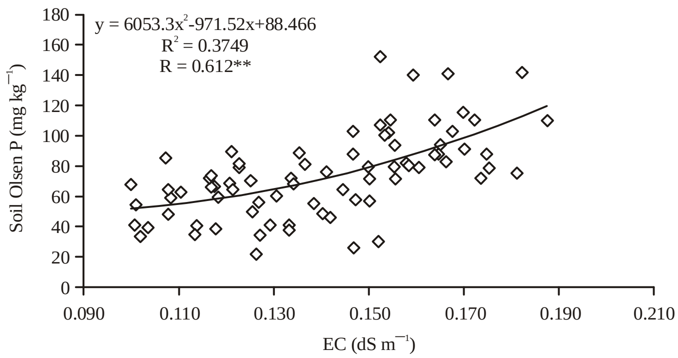

Fig. 2: Relationship between available Olsen-P and soil electrical conductivity values

Table 3: Evolution of pH of the various treatments during incubation period

	Incubation period (days)										
Treatments	15	30	45	60	75	90	105	Average value	C.V (%)	Source of variability	p< F
Control	8.60	8.55	8.43	8.44	8.51	8.45	8.520	8.480	1.44		
MAP	7.84	7.91	7.81	8.01	8.00	7.92	7.910	7.914		Incubation period	n.s
Fosfactyl	8.11	8.18	8.16	8.24	8.26	8.15	8.120	8.174		Fertilizer	***
SSP	8.12	8.14	8.13	8.22	8.22	8.07	8.040	8.134		T*fertilizer	n.s
Average value	8.17	8.20	8.13	8.13	8.22	8.24	8.147	8.180			

SSP: Single super phosphate, MAP: Mono-ammonium phosphate. ***Significant at p<0.001, ns: Non-significant

Table 4: Evolution of total salinity of the various treatments during incubation period

	Incubation period (days)										
Treatments	15	30	45	60	75	90	105	Average value	C.V (%)	Source of variability	p< F
Control	0.144	0.150	0.147	0.145	0.108	0.121	0.125	0.134	8.29		
MAP	0.144	0.150	0.147	0.145	0.108	0.121	0.125	0.134		Incubation period	***
Fosfactyl	0.164	0.167	0.188	0.129	0.102	0.108	0.110	0.138		Fertilizer	n.s
SSP	0.172	0.161	0.164	0.156	0.117	0.117	0.121	0.144		T*Fertilizer	n.s
Average value	0.168	0.147	0.155	0.147	0.123	0.136	0.139	0.145			

SSP: Single super phosphate, MAP: Mono-ammonium phosphate. ***Significant at p<0.001, ns: Non-significant

Effect of P fertilizers application on electrical conductivity: The total soil salinity, represented by electrical conductivity, defined the total amount of soluble salts and it depends on the content and nature of soluble salts in the soil. The results obtained during incubation of various treatments are listed in Table 4.

Compared to the initial value of soil salinity (0.114 dS m^{-1}), the addition of fertilizers contributed in increasing values of the electrical conductivity of the soil thus enriching the soil solution by soluble salts. A slight salinization of the soil was observed around 6.94 and 2.89% compared to the control treatment, respectively for SSP and fosfactyl. This phenomenon can be explained by the specific characteristics of the fertilizer on salinity represented by its partial salt index. This index corresponds to a salinity generated by the addition of 1 kg of nutrient as fertilizer (Moughli, 2000). There are probably other factors involved in this salinization with the release of exchangeable bases by the adsorbent complex to the soil solution essentially relating to the most hydrated cations Na^+ and K^+. Hartsock *et al*. (2000) and Yegul *et al*. (2011) found that soil electrical conductivity was positively related to soil Ca^{2+} and Mg^{2+} and soil moisture content. Strong correlations were founded between EC and Cl^-, HCO^{3-}, SO_4^{2-}, K^+ and Na^+ (Yegul *et al*., 2011).

Concerning the evolution of soil salinity, the results show a decrease in all treatments over time (Table 4). Figure 2 shows a significant relationship between soil EC and Olsen P (r = 0.612). The elevation values of the electrical conductivity at the end of incubation could be attributed to a greater dissolution of the soluble salts in the soil due to the progressive increase of air temperature (summer conditions). Soil EC is affected by cropping, irrigation and land use, application of fertilizer, manure and compost. Irrigating in amounts too low to leach salts, or with water high in salts, allows salts to accumulate in the root zone, increasing EC.

CONCLUSION

In light textured soil low in organic matter and lime contents, the incubation of three phosphate fertilizers showed significant effects on the evolution of the studied parameters. The results shown and discussed in this study provide the following conclusions.

The assessment of the effectiveness of different phosphate fertilizers tested in soil enrichment for available phosphorus was carried out through periodic soil analysis; it shows that the P fertilizer caused an increase in amounts of soil P. The increase over control (without fertilizer) rates are approximately 87, 82 and 50%, respectively for the single super phosphate, monoammonium phosphate and fosfactyl treatments. Whatever treatment there's a progressive decrease in the amount of available phosphorus. This decrease is probably due to the immobilization of phosphorus reacts with Ca^{2+}, especially in the case of a non-migrant irrigation resulting in the transfer of phosphorus in not available forms.

During 105 days a slight increase in the electrical conductivity values was observed, on the other side a very significant decrease in the acidity, the fertilizers applied caused an acidification of soil in all treatments. This slight acidification can thereby significantly increasing and may constitute an advantage in our alkaline calcareous soils. So, the application of mineral fertilizers in the soil has several effects on soil properties, the most often salinity and soil pH. It is in that context that the current research is directed towards the proper reasoning of mineral fertilizers by the materialization of an optimal dose of fertilizer that promotes a great economic profitability of agricultural crops but also a better preservation of the chemical environment of soil.

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