Asian Journal of Crop Science, 2014
ISSN 1994-7879 / DOI: 10.3923/ajcs.2014.

Performance of Different Phosphorus Fertilizer Types on Wheat Grown in Calcareous Sandy Soil of El-Menia, Southern Algeria

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ABSTRACT

This study is part of a research program on the rational fertilization of durum wheat grown under a center-pivot irrigation system. A field experiment was conducted to determine the judicious use of phosphorus (P) at agricultural farm of Hadjadj Mahmoud in El-Menia during winter 2009 to find the performance of wheat yield under different fertilizer types and doses in calcareous light textured soil. Soil samples were collected before sowing of wheat crop and analyzed for physical and chemical properties of the soil. There were four treatments i.e., 30, 60, 90 and 120 kg P_2O_5 ha^{-1} with five replications. A basal dose of nitrogen as urea and ammonium nitrate (UAN 32%) at the rate of 158 kg ha^{-1}. The data of 1000-grain weight, grain and straw yield was recorded and grain and straw samples were collected and analyzed for P concentration and its uptake. The results showed that the wheat (*Triticum durum* L. cv. Carioca) responded positively at this phosphorus fertilization, maximum wheat yield of 7.4 t ha^{-1} was obtained by Fosfactyl fertilizer with 90 kg P_2O_5 ha^{-1} indicating importance of phosphorus at its highest dose in achieving maximum wheat productivity. The 1000-grain weight, grain and straw yields significantly increased with P levels. Phosphorus concentration in grain and straw and P uptake by wheat also significantly increased in all the treatments.

Key words: Wheat, wheat yield, P fertilizer, calcareous soils, southern Algeria

INTRODUCTION

Fertilizer is the most important input which contributes significantly towards final grain yield of wheat and to exploit the inherited potential of a cultivar (Kaleem *et al*., 2009). Phosphorus fertilizers can play a major role towards improving crop yields but a major constraint in achieving the proven crop potential is imbalance use of fertilizers, particularly low phosphorus use as compared to nitrogen (Mehdi *et al*., 2007).

Poor availability of nutrients rather than low nutrient content is one of the major factors for the widespread occurrence of plant nutrient deficiency in calcareous soils. The nutrient uptake of plant is governed by numerous soil factors. Among them, high soil pH and $CaCO_3$ contents are predominantly responsible for low availability of plant nutrients (Kaya *et al.*, 2009). Under unfavorable soil conditions with high pH and $CaCO_3$, only with application of N, P and K fertilizer can't resolve the nutrient deficiency.

In alkaline soils with high calcareous content, precipitation of insoluble Ca-P formation is considered to be the major factor for P unavailability (Bramley *et al.*, 1992). Application of phosphorus fertilizers in agricultural calcareous soils has introduced some problems mainly due to P fixation, low recovery and accumulation in soil. Information on the chemical forms of phosphorus is fundamental to understanding phosphorus dynamics and its interactions in calcareous soils that is necessary for management of P (Halajnia *et al.*, 2009). And low efficiency of P and the recovery ranges from 15-25% (Nisar, 1985). When super phosphate is applied to alkaline calcareous soils, about 49-59% and 14-19% is converted into insoluble calcium phosphate and aluminum phosphate, respectively while water soluble fractions ranges from 5-9% only (Ahmad *et al.*, 1992).

Wheat is the most important and widely cultivated crop of the entire world. It is principal food of human beings and Algeria is one of the important wheat importing countries in the world. Wheat yield responses to balance application of N:P. Appropriate and balanced fertilization on wheat not only causes yield enhancement but also has good impact on phosphorus uptake by these crop plants (Blaga *et al.*, 1989; Rehman *et al.*, 2006). To improve crop growth, farmers have used large amounts of P fertilizers over many decades. However, only a small fraction of the P applied with fertilizers is taken up by crops in the year of application and the effectiveness of any residual P fertilizer declines with time. This is a particular problem in highly P-sorbing soils such as calcareous soils. Calcareous soils are widespread throughout the world (Taalab *et al.*, 2008). At present, approximately 9 million hectares 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 having low nutrient content using of mineral fertilizers, including phosphate fertilizers became obligatory to obtain an acceptable agricultural production (Halilat, 2004).

The present study aims to determine the influence of phosphorus fertilizers applied on the wheat yield and to recommend critical levels of P for wheat crops grown in light textured soils having a noticeable calcareous content in order to obtained maximum production and productivity.

MATERIALS AND METHODS

Study area and experimental design: The experiment was conducted on an agriculture farm in El-Menia (southern Algeria) (30°57 N, 2°78 E, 397 m above sea level). El-Menia is located almost in the center of Algeria (Fig. 1). El-Menia is characterized by an arid climate therefore very low and erratic rainfall. The experiment was set up in randomized block with two classification criteria (types of P fertilizers-P levels) was performed (Fig. 2), involving five blocks 1, 2, 3, 4 and 5 in which four treatments were designed and replicated.

Soil sampling and analyses: The bulk sample of soil used was collected after crop harvest (winter wheat) from the upper layer of an Arenosol (FAO, 2006), at depth of 0-30 cm sampled at five sampling points randomly selected along agricultural area in El-Golea (southern Algeria). Before analysis the collected samples were air dried, crushed, sieved through a 2 mm sieve and stored for chemical characteristics determination (Table 1). 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 (Yeomans and Bremner, 1998). Total nitrogen was determined by digestion with sulphuric acid and Kjeldahl distillation (Bremner, 1996). Phosphorus was determined colorimetrically in all extracts using Joret-Hébert method.

Field experiment: A field experiments was conducted in 2008-2009 harvesting seasons on wheat (*Triticum durum* L. cv. Carioca) to study the influence of phosphorus fertilization on wheat crop grown under a center-pivot irrigation system. In this study, three phosphorus mineral fertilizers were tested. Fosfactyl NP 3:22 and Single Super Phosphate (SSP) P 20.

After the seed bed preparation, all P and half of N were applied through broadcast followed by thorough mixing. The remaining N was applied with a center-pivot irrigation system. The plot size was 5×6 m and the experiments were laid out in Randomized Complete Block (RCB) design with five replications at both sites. Wheat variety "Carioca" with seed rate of 200 kg ha^{-1} was sown in lines 13 cm apart on 31th December 2009. All the management practices were carried out as and when required.

Following plant parameters were recorded during the course of study:

- **Number of grains per spike:** Ten spikes were selected randomly from each plot and grains per spike were counted were at the time of harvesting. The values were averaged to obtain the mean value
- **1000 grain weight (g):** A sample of 1000 seeds was taken randomly from the total seed lot of each plot and then weighed
- **Grain and straw yield (kg ha^{-1}):** The data of grain and straw yields was recorded by harvesting 1 m^2 per plot. Grains and straw were threshed and weighed manually and the obtained data was then converted to get the final yield in kg ha^{-1}
- **Phosphorus (P) concentration (%) in grain and straw:** At the harvesting stage total P in straw and grain was analyzed using the colorimetric ascorbic acid method
- **Phosphorus uptake by grain, straw and by wheat crop (kg ha^{-1}):** The P uptake by grain and straw and total uptake by wheat crop were calculated using the following equation:

$$\text{Total P uptake (kg ha}^{-1}\text{)} = \text{P conc. (\%) in plant part (dry matter)} \times \text{Yield (t ha}^{-1}\text{)} \times 10$$

Statistical analysis: All data in the study was recorded and classified using Microsoft Office Excel 2007. 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 6.0.

RESULTS AND DISCUSSION

Physicochemical properties of Soil: Basic parameters of selected physical and chemical properties of soil samples are given in Table 1. The soil was sandy in texture, alkaline, calcareous and low in EC. Very low in organic matter content, total nitrogen and phosphorus content (Table 1).

Characteristics of irrigation water: According to the classification diagram of irrigation water (Durand, 1983), the water used is located in the C2S1 class which has a good quality with low salinity risk even for sodicity (Table 2).

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

Parameters	Values
Mechanical properties	
Textural class	Sandy
Sand (g kg^{-1})	93.300
Silt+clay (g kg^{-1})	6.700
Physico-chemical properties	
Soil reaction (pH) (1:5 soil water extract)	8.400
Lime content (%)	8.930
Active lime (%)	6.880
EC (dS m^{-1}) (1:5 soil water extract)	0.170
Organic matter (%)	0.106
Total nitrogen (%)	0.080
Avalable P (mg kg^{-1} soil)	2.400

Table 2: Chemical composition of irrigation water and electrical conductivity

Parameteres	Values
pH	7.80
EC (dS m^{-1})	0.38
Ca^{+2} (mmol L^{-1})	0.77
Mg^{+2} (mmol L^{-1})	10.50
K^{+} (mmol L^{-1})	0.34
Na^{+} (mmol L^{-1})	1.50
Cl^{-} (mmol L^{-1})	2.50
SO_4^{-2} (mmol L^{-1})	25.60
HCO_3^{-} (mmol L^{-1})	15.30

Table 3: Effect of different rates of phosphorus application on 1000 grain weight (g) and grain and straw yield (t ha^{-1}) of wheat

		Grain yield	Straw yield
Treatments P_2O_5 (kg ha^{-1})	1000 grains weight (g)	---------------------------(t ha^{-1})-----------------------------	
Fosfactyl			
30	57.83	7.17	4.57
60	59.54	6.86	4.38
90	59.17	6.82	5.07
120	61.96	7.49	5.24
SSP			
30	59.96	4.95	3.50
60	57.73	7.41	4.84
90	55.48	7.10	5.01
120	60.62	6.87	4.76

Influence of P fertilization on 1000 grains weight, grain and straw yield: Table 3 indicated that the values of the three parameters studied showed a fluctuation with increasing rates of P application. But in most cases the rate of 120 kg P_2O_5 ha^{-1} which showed the highest values. The maximum 1000 grains weight was recorded by Fosfactyl at the rate 120 kg P_2O_5 ha^{-1} (T4). The results showed that maximum wheat yield of 7.49 t ha^{-1} were obtained in the treatments T4 with Fosfactyl fertilizer indicating importance of phosphorus at its highest dose in achieving maximum wheat productivity. Figure 1 indicated that increasing levels of P can contribute to ameliorate obtained grain yield of wheat, grain yield showed a polynomial relationship to phosphorus uptake, a positive correlation was obtained (R = 0.257).

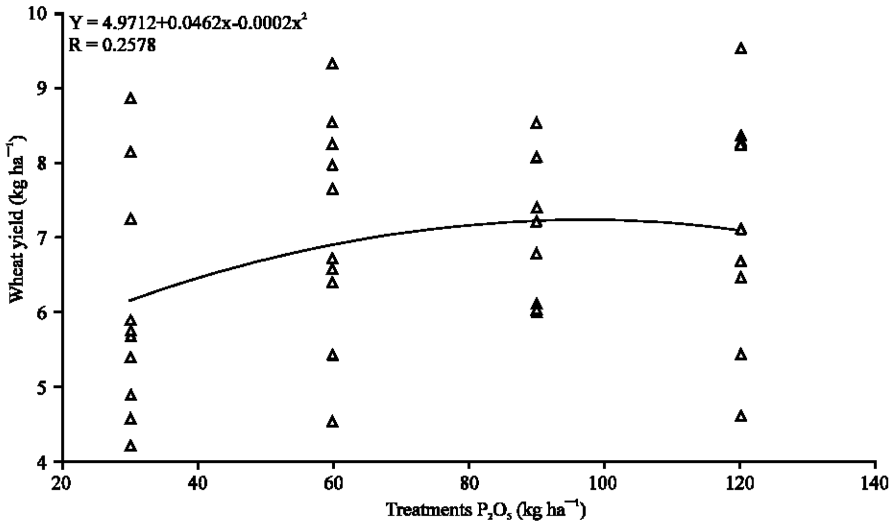

Fig. 1: Evolution of wheat yield according to the various phosphorus rates

Table 4: Effect of different rates of phosphorus application on P concentration (%) in grain and straw of wheat

	Concentration (%)	
Treatments P_2O_5 (kg ha^{-1})	Grain	Straw
Fosfactyl		
30	0.72	0.11
60	0.70	0.12
90	0.78	0.13
120	0.73	0.11
SSP		
30	0.75	0.08
60	0.78	0.11
90	0.71	0.14
120	0.72	0.11

The optimum levels of P for maximum yield depend upon the type of soil and specie of crop. The availability of P could be closely associated with the content of lime present in the soils (Delgado *et al.*, 2002). Wheat responded significantly up to 80 kg P_2O_5 ha^{-1} (Azad *et al.*, 1993).

At different location in a soil low in available P and suggested that in order to obtain the maximum yield, application of 69 kg P_2O_5 ha^{-1} must be achieved. A significant increase in biomass yield can be obtained in wheat crop with the application of P at 75-100 kg ha^{-1} (Khalid, 1995; Hussain *et al.*, 2004). Similarly, the critical ranges for wheat from 15-69 kg P_2O_5 ha^{-1} (Tandon, 1992). The rate of 90 kg P_2O_5 ha^{-1} can be considered as optimum level for wheat crop (Rahmatullah *et al.*, 1994; Tisdale *et al.*, 1997).

Phosphorus concentration in grain and straw of wheat: Table 4 shows that the fertilizers tested revealed no significant effect on P concentration in grain and straw of wheat with increasing rates of P application and maximum P concentration in grain and straw of wheat was noted at the rates of 90 and 60 kg P_2O_5 ha^{-1} of Fosfactyl and SSP, respectively.

As wheat has extensive root system which absorbed P from soil in which P in solution is available, resultantly more P concentration in grain and straw of wheat was observed with the increasing rates of P application. The reason might be that when P is applied to soil, its more concentration is available for plant absorption and with passage of time it undergoes to chemical reaction and due to its adsorption on different sites its availability becomes slow. These results are in line with Qaisar *et al*. (2005).

Phosphorus uptake by grain, straw and by wheat: Table 5 indicates that P uptake in grain and straw of wheat and total uptake by wheat crop were significantly increased with increasing rates of P application and generally in most of cases maximum P uptake values was noted where P was applied at the rate of 90 kg P_2O_5 ha^{-1}, an uptake of 63, 69 and 61 kg ha^{-1} was obtained by Fosfactyl and SSP, respectively (Fig. 3). Grain yield showed a linear relationship to phosphorus uptake, a strong positive correlation was obtained ($R = 0.866$, $p<0.01$) (Fig. 2). Also a high relationship between P uptake by wheat and P applied ($R = 0.590$) (Fig. 4).

Table 5: Effect of different rates of phosphorus application on P uptake by grain, straw and total P uptake by wheat (kg ha^{-1})

Treatments P_2O_5 (kg ha^{-1})	P uptake by grain	P uptake by straw	Total P uptake by wheat (grain+Straw)
Fosfactyl			
30	51.74	4.73	56.46
60	48.15	5.14	53.28
90	57.48	6.15	63.63
120	55.08	5.49	60.57
SSP			
30	35.35	3.20	38.55
60	55.12	3.66	58.78
90	55.39	5.61	61.00
120	49.13	6.72	55.86

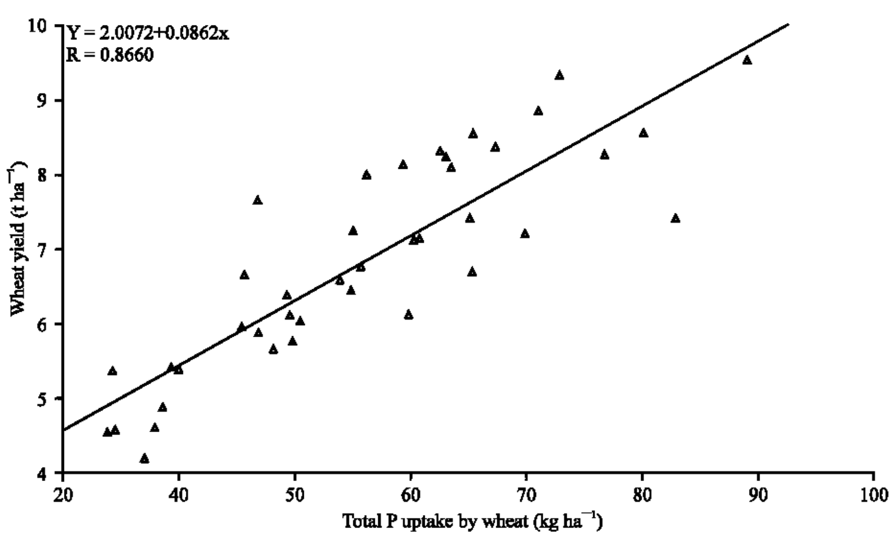

Fig. 2: Relationship between total phosphorus (P) uptake and grain yield

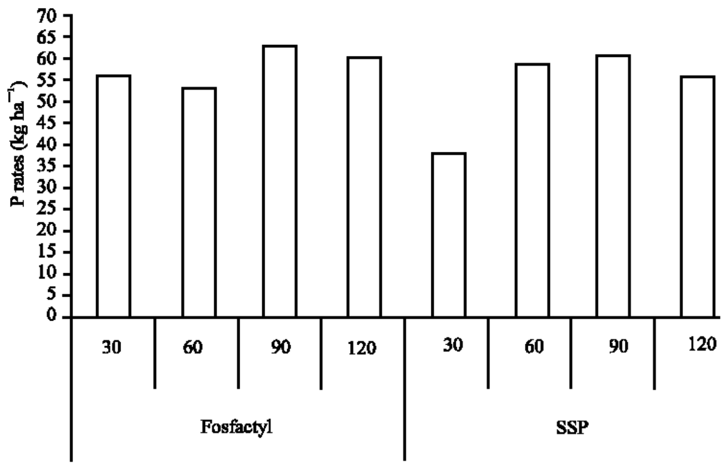

Fig. 3: Evolution of total P uptake according to the various phosphorus rates

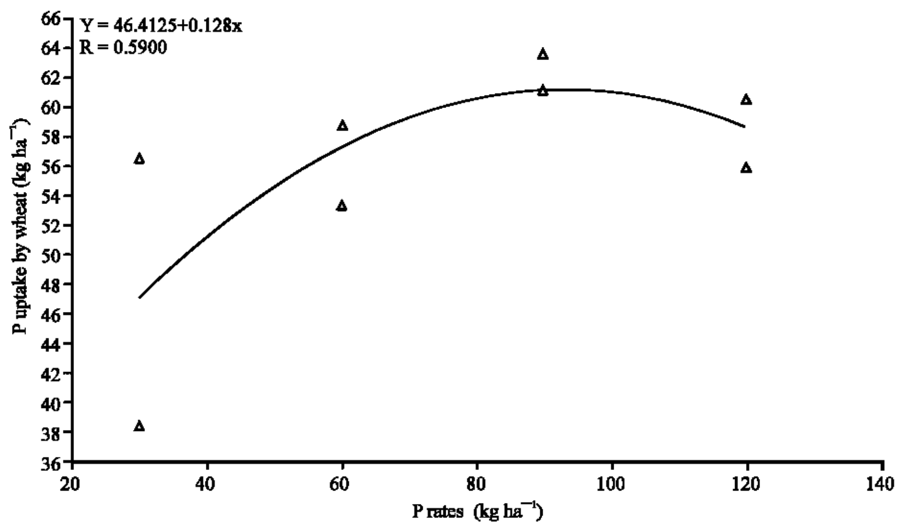

Fig. 4: Relationship between total P uptake by wheat and P rates

CONCLUSION

In Algerian Saharan conditions, sandy soils are very poor in nutrients, organic matter and available phosphorus content, using mineral fertilizers in these conditions, became the most important solution for obtaining good yields. Application of phosphorus fertilizers in these calcareous soils has introduced some beneficial effects on wheat crop grown under center-pivot irrigation system. Maximum and economic wheat yield can be obtained by applying phosphorus at the rate of 90 kg P_2O_5 ha^{-1}.

ACKNOWLEDGMENT

I wish to thank the farmer Hadjadj Mahmoud and all the engineers of this agricultural farm for their contribution and helps during the field experiment period.

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