RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 55 Issue 1: 99-104 (February 2021)

Response of Wheat to Foliar and Soil P Fertilization on Grain Yield and Phosphorus use Efficiency in Southeastern Algeria

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10.18805/IJARe.A-576

ABSTRACT

Background: P deficiency is very common in alkaline - calcareous soil. Therefore, application of foliar-absorbed fertilizers may be an effective strategy to overcome the low bioavailability of phosphorus in soil, by improving phosphorus use efficiency and reduced nutrients loses.

Methods: A field experiment was carried out in 2006-07 growing season at El-Menia (southeastern Algeria) to evaluated the effect of two foliar P (agriphos and leader-start) and three soil P (TSP P 46, Fosfactyl NP 3:22 and NPKs 8:36:13,5+15) on yield and P use efficiency of durum wheat crop *Triticum durum* Desf. var. Carioca and on available P and total P in soil.

Result: Data showed that significant effect of soil P fertilizer on grain yield components (ears m^{-2}, grains ear^{-1} and the 1000 grains weight), grain P use efficiency and available P in soil. The best values were recorded by NPKs fertilizer, but no differences were observed for these parameters among foliar fertilizer sources.

Key words: Available P arid land, Durum wheat, Grain yield, P fertilization, P use efficiency.

INTRODUCTION

Phosphorus is one of the most widely occurring nutrients for development and growth of wheat. The problem for this element (P) is its bioavailability, which is essentially controlled by soil pH, slow diffusion and strong adsorption to soil particles (Goos and Johnson 2001, Pandey *et al.*, 2013).

Foliar P fertilization is recommended in dry environments, soils with the elevated P-fixing capacity and soils that are marginally deficient in an effort to avoid pathways that promote loss of soil P (Dhillon *et al.*, 2017). It may be an effective strategy to address the low bioavailability of phosphorus in soil and for the immediate improvement of nutritional stress (Goos and Johnson, 2000; Dixon, 2003; Maltais, 2006; Girma *et al.*, 2007). Several studies have shown that the use of foliar fertilization cannot be an alternative method to root fertilization, but rather complementary (Ling and Silberbush, 2002; Mengel, 2002; Toscano *et al.*, 2002; Pandey *et al.*, 2013).

The addition of fertilizer to the soil is the most common method for supplying minerals to plants. In this case, these elements are absorbed by the roots. However, higher plants can absorb leaf elements when taken at appropriate concentrations (Fageria *et al.*, 2009). So the root is not the only organ that is involved in the absorption of nutrients. The work of Barber (1995), Goos and Johnson (2001) and Pandey *et al.*(2013) showed that the bioavailability of phosphorus is mainly governed by the pH of the soil solution, its diffusion rate and its strong attachment to soil particles. Therefore, application of foliar-absorbed fertilizers may be an effective strategy to overcome the low bioavailability of phosphorus in soil and for the immediate improvement of nutritional deficit (Goos and Johnson, 2000, Girma *et al.*, 2007). But it can only partially cover insufficient uptake by the roots (Ling and Silberbush, 2002, Pandey *et al.*, 2013); it enhances fertilizer use efficiency and reduced nutrients loses (Qadri *et al.*, 2015).

The acquisition of inorganic nutrients by the roots is interdependent with the assimilation activities at the leaf level. When applied to the foliage, their penetration and uptake into the plant by the different pathways depends mainly on the ionic charge on the plant surface and molecular size (Pandey *et al.*, 2013) and requires a surface sufficient foliar for the foliar fertilizer to become effective (Ling and Silberbush, 2002).

Amanullah *et al.* (2016) reported that foliar fertilizers application is beneficial for improving growth, yield and yield components of field crops under moisture stress condition. The results obtained by Girma *et al.* (2007) indicated that foliar application improves corn grain and biomass (*Zea mays*) yields, as well as the efficiency of phosphorus utilization by minimizing the amount of phosphorus brought to the soil by fertilizers. According to Goos and Johnson (2001), early application of foliar phosphorus (4-5-leaf stage

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How to cite this article: Deraoui, N.B., Mekliche, L.H. and Mekliche, A. (2021). Response of Wheat to Foliar and Soil P Fertilization on Grain Yield and Phosphorus use Efficiency in Southeastern Algeria. Indian Journal of Agricultural Research. 55(1): 99-104. DOI: 10.18805/IJARe.A-576.

Submitted: 01-06-2020 **Accepted:** 02-08-2020 **Online:** 29-09-2020

of wheat) increases phosphorus removal. Other studies by Mosali *et al.* (2006) and Al Harby *et al.* (2013) indicated that a two-node foliar phosphorus spray in winter wheat improves grain yield and phosphorus uptake; while at the heading stage, it provides a better efficiency of use of phosphorus (EUP).

Avila *et al.* (2012) found that there is no significant difference between the two sources of phosphite (KH_2PO_3) and phosphate (KH_2PO_4) foliar fertilizer. Foliar application significantly affected the leaf phosphorus concentration and not the grain yield of the crop compared to the control (Avila *et al.*, 2012; Ali *et al.*, 2014).

Several factors including plant management and environmental factors influence the benefit of foliar P applied (Al-Harby *et al.*, 2013), its effectiveness depends on the soil P fertility, soil moisture status, plant species, chemical form of fertilizer and prevailing climatic conditions (Noack *et al.*, 2010); leaf surface uptake and leaf area available for product interception (McBeath *et al.*, 2015). According to Hu *et al.* (2008), water stress reduced the absorption of K, Ca, Mg and P elements, which can be attributed to reduced transpiration of maize plants. Phosphorus deficiency can altered the surface structure and function of wheat leaves, whichbecame less permeable to foliar fertilizer (Fernández *et al.*, 2014). According to Ling and Silberbush (2002), the effectiveness of foliar fertilization appears to be limited by the retention capacity of the leaf surface, which has limited the penetration of solutes; the latter can be enhanced by using adjuvant (Noack *et al.*, 2010).

Improving nutrient use efficiency is being addressed through implementation of best management practices such as integrated nutrient management planning, improved irrigation scheduling, better application timing and placement and proper fertilizer material selection (Obreza and Sartain, 2010). In the present investigation the objective was to evaluate growth and phosphorus use efficiency by wheat plants fertilized with two foliar Pand three sources of soil pin calcareous-alkaline soil of arid land of Algeria.

MATERIALS AND METHODS

Field trial

The research was investigated in 2006-07 growing season at El-Menia located in Southeastern Algeria, 30°57 N, 2°78 E, latitude and longitude and 397 m above sea level. The region is characterized by an arid climate, therefore very low and erratic rainfall (<100 mm) and warm dry summers with maximum air temperature exceeding 40°C. The main soil characteristics are reported in Table 1.

The experiment was laid out in hierarchical two-factor model design, where, we studied the combined effect of two foliar fertilizers (Agriphos, Leader-start) and three soil P fertilizer (Triple Super Phosphate P 46, Fosfacty lNP 3:22 and NPKs 8:36:13,5+15) on winter wheat (*Triticum durum* Desf. Var. Carioca).

Crop husbandry

Irrigation

Crop was irrigated with center pivot system and receives an amount of 750 mm water during its growth cycle. Water is pumped from the continental interlayer at 250 m deep, and has a good quality with low salinity risk even for sodicity (Table 2).

Seeds and sowing

For each trait, plants were sown in 1800 m² plots (24×75 m). The seed rate was 200 kg ha^{-1}.

Fertilizer application

Soil P fertilizerswere applied at sowing timeat level 140 kg P_2O_5 ha^{-1} commonly used by farmers in the region; while P foliar fertilizers were applied at two stages of wheat, GS 13 and GS 23, according to Zadoks scaling system, 2.5 L ha^{-1} for each stage. The plots were fertilized with 212 kg N ha^{-1} as ammonium nitrate and urea (UAN 32), split into several provisions applied by fertigation.

Sampling and plant measurement

All measurements were carried out on five square meters for each treatment. The following yield parameters including the grain yield *viz*., ears number m^{-2}, grains number ear^{-1} and 1000-grain weight were recorded.

The aboveground biomass was determined at three wheat growth stages, second node detectable GS32,

Table 1: Physical and chemical properties of soil.

Parameters	Units	Values
Textural class		Sandy
Sand	g kg^{-1}	93.3
Silt+Clay	g kg^{-1}	7
Soil reaction (pH) (1:5 soil water extract)		7.8
EC (1:5 soil water extract)	dS m^{-1}	2,9
Lime content	%	5.93
Active lime	%	3.1
Organicmatter¶	%	0.06
Total nitrogen†	%	0.054
Available P ‡	mg kg^{-1}	6.52
Total P	mg kg^{-1}	18.06

¶ Walkley-Black method.
† Kjeldahl method.
‡ Olsen method.

Table 2: Chemical composition of irrigation water and electrical conductivity.

Parameters	Values
pH	7.80
EC (dS m^{-1})	0.38
Ca^{2+} (mmol L^{-1})	0.77
Mg^{2+} (mmol L^{-1})	10.5
K^+ (mmol L^{-1})	0.34
Na^+ (mmol L^{-1})	1.5
Cl^- (mmol L^{-1})	2.5
SO_4^{2-} (mmol L^{-1})	25.6
HCO_3^- (mmol L^{-1})	15.30

flowering GS61 to GS69 and maturity GS91. Samples were analyzed for total P, using colorimetric ascorbic acid method. Phosphorus use efficiency (PUE) was determined at maturity for grain wheat and calculated according to Moll *et al*. (1982). Who defined PUE as grain weight (GW) per unit of P available in soil (P soil):

$$PUE = \frac{GW\ (Kg/\ ha)}{Psoil\ (Kg/\ ha)}$$

Statistical analysis

Experimental data were recorded and classified using Microsoft Office Excel 2010. The significance between the means was determined using analysis of variance (ANOVA) at the level P ≤0.05 with the software package Statistica 8.0.

RESULTS AND DISCUSSION

Yield components, Grain yield and aboveground biomass yield

Data shows a significant effects of soil P fertilizer on number of ears m^{-2} (p <0.05), the number of grains ear^{-1} (p <0.01) and the 1000-grains weight (p <0.001), where, the best values were recorded by NPKs and TSP for ears m^{-2}, NPKs for number of grains ear^{-1} and Fosfactyl for the 1000-grains weight; while, the effect on grain yield was not significant (Table 3).

Aboveground biomass yield also showed positive and significant response to P fertilizers soil applied in the three wheat stages, two nodes (p <0.01), flowering (p <0.05) and maturity (p <0.05). NPKs fertilizer promoted greater dry matter accumulation at three wheat stages (Table 4). While, foliar phosphorus application had non-significant effects in all studied traits.

The number of ears m^{-2}, the number of grains ear^{-1} and the 1000 grain weight are the main components of wheat grain yield. These traits are genetically controlled and are highly influenced by environmental factors, primarily nutrients available in the soil (Kousar *et al.*, 2015). Grain yield was positively linked to grains number ear^{-1} (r = 0.25*) and biomass yield at maturity.

Application of soil P with supplement foliar P resulted in a better grain yield in most instances where significant was observed (Al Harby *et al.*, 2013). In previous study (Boukhalfa-Deraoui*et al.*, 2011), application of 180 kg P_2O_5 ha^{-1} as TSP fertilizer to soil without foliar P supplement recorded 46 q ha^{-1} of grain yield, however, in the present study, and for the same fertilizer (TSP) applied at 140 kg P_2O_5 ha^{-1} with P foliar application, recorded an average grain yield of 50.02 q ha^{-1}, either a difference of 8 per cent (Table 3).

Application of foliar P in early growth stage can increase the number of fertile tillers and crop growth (Grant *et al.*, 2001). Al Harby *et al.* (2013) reported a significant increase in wheat grain yield was observed with P foliar application at two nodes detectable when compared with flowering stage P application. This response to foliar application will be more in P deficient condition. Similar type of results reported by Rafiullah *et al.*, 2017.

The comparison between the two type offoliar fertilizers *viz*., Leader-start and Agriphos revealed no significant effect on the improvement of grain yield, biomass and phosphorus uptake by wheat crop. Comparable results are obtained by Ling and Silberbush (2002), which illustrate non-significant differences between the different forms of mineral and organic foliar fertilizer on a maize crop. Corroborating Ling and Silberbush (2002) and the study by Avila *et al.* (2012) reported that regardless of the foliar fertilizer sources phosphite (KH_2PO_3) or phosphate (KH_2PO_4), common bean growth is not affected.

Rafiullah *et al.* (2017) in their hydroponic study concluded that P applied as foliar spray up to 144 Mm KH_2PO_4 could be an effective way to enhance the plant growth in P deficient condition and without any detrimental effect on wheat crop. On the other hand, Kaya *et al.* (2001) found that KH_2PO_4 spraying enhances the negative effects of salt stress on strawberry fruit growth and yield.

P concentration, P uptake and P use efficiency

Data on P concentration, P uptake and P use efficiency is furnished in Table 5. The data revealed that P concentration

Table 3: Mean grain yield and yield components under foliar P and soil P applied.

Variables	Ears m^{-2}	Grains ear^{-1}	1000 GW (g)	Grain yield (q ha^{-1})
Soil P fertilizers				
Fosfactyl	309.3^{b}	34.55^{b}	50.95^{a}	52.09
TSP	343.0^{a}	35.23^{ab}	48.43^{b}	50.02
NPKs	363.5^{a}	37.13^{a}	49.01^{b}	58.13
	*	**	***	ns
LSD (5%)	31.05	2.09	1.39	-
Foliar fertilizers				
Agriphos	336.6	35.52	49.54	51.50
Leader-start	340.5	35.75	49.38	55.31
	ns	ns	ns	ns
General means	338.6	35.63	49.46	53.41
CV %	20.80	13.31	6.36	25.91

*,**,*** Significant at P ≤0.05, P ≤0.01 and P ≤0.001, respectively, ns: Not significant, different superscript letters in a column shows significant difference.

Table 4: Mean Biomass yield (q ha^{-1}) of wheat at different stages under foliar P and soil P applied.

Wheat stages	Twonodes	Anthesis	Maturity
Soil P fertilizers			
Fosfactyl	19.42[b]	103.01[b]	108.6[b]
TSP	23.28[a]	109.9[a]	98.8[b]
NPKs	23.79[a]	105.9[ab]	118.9[a]
	**	*	*
LSD (5%)	2.267	6.858	10.93
Foliar fertilizers			
Agriphos	22.86	107.9	106.7
Leader-start	21.46	104.4	110.9
	ns	ns	ns
General means	22.16	106.2	108.8
CV %	23.09	14.57	22.67

*,**,*** Significant at P ≤0.05, P ≤0.01 and P ≤0.001, respectively, ns: Not significant, different superscript letters in a column shows significant difference.

and P uptake of shoots are highly affected by soil P fertilizers (p <0.001), at the two wheat stages *viz*., two nodes and flowering, where NPKs fertilizer gave the best values.

For the two wheat stages, successively, positive relationships were observed between shoots P content and earsm^{-2} (r = 0.283*, r = 0.285*) on the one hand and on the other hand with grains numberear^{-1}(r = 0.411***, r = 0.413***). P uptake was significantly correlated to grains number ear m^{-2} (r = 0.389***) at flowering stage, and P use efficiency (PUE) was closely related to grain yield (r = 0.389***).

Foliar P application enhanced availability of nutrients to crop for obtaining higher yield (Arif *et al.*, 2006). The results obtained by Avila *et al.* (2012) and Ali *et al.* (2014)pointed out that the application of foliar fertilizer significantly affected leaf phosphorus concentration and not the grain yield of the crop compared to the control. Ali *et al.* (2014) showed an 11.6 per cent increase in grain phosphorus concentration relative to the control. According to Dixon (2003), foliar P can increases fertilizer use efficiency. Indeed, Helmy (2013) concluded that spraying

Table 5: Mean wheat P concentration (%DM), P uptake and PUE of wheat grainsunder foliar P and soil P applied.

Variables	[P]S1	[P]S2	EXP P S1	EXP P S2	PUE
Soil P fertilizers					
Fosfactyl	0.391[c]	0.345[c]	7.46[c]	36.55[c]	64.27
TSP	0.563[b]	0.485[b]	13.0[b]	51.16[b]	63.49
NPKs	0.833[a]	0.743[a]	19.4[a]	79.65[a]	73.47
	***	***	***	***	ns
LSD (5%)	0.031	0.032	2.10	7.157	-
Foliar fertilizers					
Agriphos	0.592	0.511	13.62	57.92	64.47
Leader start	0.598	0,537	12.96	53.66	69.68
	ns	ns	ns	ns	ns
General means	0.595	0.524	13.29	55.79	67.08
CV%	8.99	10.79	27.45	22.24	35.00

S1: two nodes stage, S2: anthesis stage, S3: maturity stage.*,**,*** Significant at P ≤0.05, P ≤0.01 and P ≤0.001, respectively, ns: Not significant, different superscript letters in a column shows significant difference.

Table 6: Mean available P and total P under foliar and soil P applied.

Variables	APS1	APS2	APS3	TPS1	TPS2	TPS3
Soil P fertilizers						
Fosfactyl	14.23[b]	14.11[b]	13.99[b]	36.85[c]	36.50[c]	36.71[c]
TSP	15.83[a]	16.21[a]	16.10[a]	43.31[b]	43.60[b]	44.23[b]
NPKs	13.43[b]	13.19[b]	13.62[b]	48.80[a]	50.14[a]	48.81[a]
	***	***	***	***	***	***
LSD (5%)	1.054	1.12	1.007	3.64	3.809	3.367
Foliar fertilizers						
Agriphos	14.34	14,45	14.30	42.98	43.00	43.19
Leader start	14.65	14,56	14.84	42.99	43.82	43.30
	ns	ns	ns	ns	ns	ns
General means	14.50	14,51	14.57	42.99	43.41	43.25
CV%	12.6	13,4	11.9	14.7	15.2	13.5

AP: available phosphorus, TP: total phosphorus, S1: second node detectable stage, S2: flowering stage, S3: maturity stage.*,**,*** Significant at P ≤0.05, P ≤0.01 and P ≤0.001, respectively, ns: Not significant, different superscript letters in a column shows significant difference.

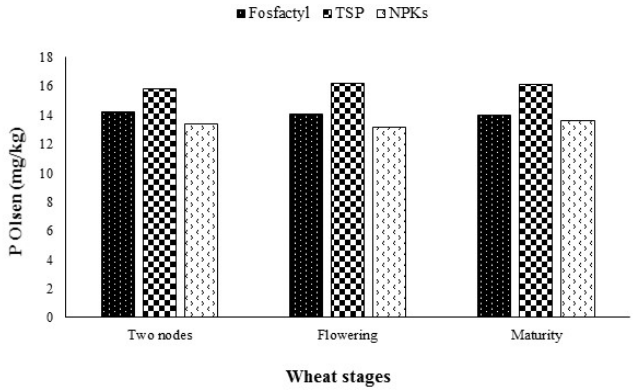


Fig 1: Evolution of available phosphorus in soil during wheat growth.

citrin (Fe, Mn and Zn) on common wheat significantly improves phosphorus and nitrogen uptake by grain, resulting in a high PUE compared to unsprayed treatment. Qadri *et al.* (2015) indicated that foliar application of urea reduces nitrogen losses and increases plant nitrogen use efficiency. Kolota and Osinska (1999) found that foliar application of fertilizer increased marketable yield of field vegetables significantly.

Available phosphorus and total phosphorus in soil

Referring to the results of Table 6, available and total P in soil at different stages (two nodes, flowering and maturity) are significantly ($p < 0.001$) affected by soil P fertilizers. No differences were observed for these parameters among foliar fertilizer sources. The highest contents of available P are obtained by TSP fertilizer (Fig 1) and those of total phosphorus are made by NPKs fertilizer at the three growing stages. On the other hand, the lowest values are obtained by the Fosfactyl fertilizer regardless of the stage of sampling. NPKs fertilizer improved in better wheat growth, favoring not only the best grain yield andbiomass yield, but also nutrient efficiency.

Available P was negatively correlated to total phosphorus at second node detectable (r= -0.323**), flowering (r= -0.355**) and maturity (r= -0.28*) of wheat. The negative relationship between total phosphorus and available phosphorus could be explained in part by the transfer of phosphorus to non-assimilable forms when the contact time between fertilizer and soil particles increases (Fardeau, 1993, Gao and Grant, 2012).

Phosphorus use efficiency was closely linked to available phosphorus at three wheat stages respectively, r = -0.366**, r = -0.399*** and r= -0.35**.Indeed, total phosphorus in soil influenced significantly P content at second node detectable (r = 0.52***) and flowering (r = 0.542***).

The proper fertilizer material selection allows a better efficiency of fertilizer use and result in better growth and yield. In the present study, NPKs fertilizer gave the best results due to its acidifying property.

CONCLUSION

The soils of arid Algerian regions, among them the soil of experimental site are characterized by high content of limestone with an alkaline pH, therefore, the use of foliar-absorbed phosphate fertilizer appears a best management practice and must be integrated into the technical itinerary of cereal crops to improve nutrient uptake through root and decrease the amounts of soil phosphorus fertilizer applied in southeastern Algeria.

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