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EVALUATION OF UREA PHOSPHATE AS A PHOSPHORUS SOURCE FOR WHEAT CROP IN COMPARISON TO DAP IN CALCAREOUS SOIL

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ABSTRACT

The efficiency of acidic phosphate fertilizer is considered better as compared to basic phosphate fertilizers in calcareous soils. Urea phosphate (UP), an acidic fertilizer (pH, 2) having 17% N and 44% P_2O_5 was prepared and evaluated in greenhouse studies for its effect on wheat crop (variety Sehar) in comparison to di-ammonium phosphate (DAP), a basic fertilizer with pH~ 8. The soil used for the pot experiments was a sandy clay loam and calcareous in nature. Phosphorus treatments were applied at sowing time from either source @ 0, 20, 40, 45 60 and 80 mg P_2O_5 kg^{-1} soil. Urea was applied @ 120 mg N kg^{-1} soil in three splits to all the pots. Both the P fertilizer sources increased wheat grain yield over control (where no P was applied); which was higher in UP (42.98 – 48.44 g pot^{-1}) as compared to DAP (42.23 – 44.53 g pot^{-1}). Phosphorus uptake in grain was also higher with the application of UP (138 – 161 mg P_2O_5 pot^{-1}) as compared to DAP (134 – 145 mg P_2O_5 pot^{-1}).In all the treatments, nitrogen percentage in grains remained almost unchanged and it ranged from 1.93 – 1.94% and 1.87 – 1.91% for UP and DAP, respectively. The results suggested that UP was a better source of P for wheat in calcareous soil.

Keywords: Urea phosphate, Di-ammonium phosphate, wheat, grain yield, calcareous soil

INTRODUCTION

Phosphorus (P) is a major plant nutrient and its deficiency in soils is a widespread problem. Plants require adequate P-supply from the very early stages of growth (Grant *et al*., 2005) which is fulfilled by phosphate fertilizer application (Campbell *et al*., 1995). Hence, application of soluble forms of inorganic P is necessary for optimum crop production. The P use efficiency, following phosphate fertilizer application is low because of fixation and precipitation of P in soil due to formation of insoluble complexes (Vassilev and Vassileva, 2003). The phenomena of fixation and precipitation of P in soil is generally highly dependent on pH and type of soil. In acid soils, phosphorus is fixed by free oxides and hydroxides of aluminum and iron, while in alkaline soils it is fixed by calcium, causing low efficiency of P fertilizer. Baligar and Bennett, (1986) found that the efficiency of added P as top dressing was 10% in soil whereas the efficiency of none of the existing phosphate fertilizers applied through broadcast exceeded 20 per cent (Atif et al., 1993). Owing to the unavoidable chemical reactions in alkaline calcareous soil, a lion share (80 to 90%) of applied P is converted into complex forms unavailable to the plant. Therefore, management of crop P nutrition in alkaline and / or calcareous soils is a challenge and P fixation in these soils can be minimized by using appropriate P fertilizers (Bar-Yosef, 1999).

It has been reported that acidic P fertilizer when applied to alkaline calcareous soils reduced the soil pH (Al-Showk *et al*., 1987) and enhanced the availability of iron (Wallace, 1988). Raun *et al*, (1987) found that acidic fertilizers like SSP perform very efficiently in calcareous soils and DAP, being alkaline, performed worst in terms of yield of some crops. The work of Baker *et al*. (1975) and Papadopoulos (1992) indicated that phosphorus moved very little from the point of its application. While Mikkelsen and Jarrell, (1987) observed that the use of acidic phosphorus fertilizers under drip irrigation increased its movement. Rubeiz *et al*. (1991) studied the mobility and fixation of phosphorus from urea phosphate (UP) fertilizer. They found that P from UP stayed available for several weeks and moved considerably in a calcareous soil.

The major source of P fertilizers, rock phosphate, is a non-renewable source that has no known substitutes in agriculture. About 80 per cent of the currently mined phosphate rock is used to manufacture P fertilizers (Heffer *et al*., 2006). How long existing phosphorus reserves will last is difficult to forecast. Some estimates vary between 50 to 100 years (Cordell, 2010) and others estimate it around 350 years, based on current production capacity and excluding increased demand for phosphorus (IFDC, 2010; USGS, 2011). Hence, more rock phosphate will be required in future to meet the food demand for rapidly growing global population which is expected to reach 9.1 billion by 2050 (United Nations, 2009)., The emphasis is, therefore, needed to be focused on the efficient use of P fertilizers. Keeping in view the nature of Pakistani soils (calcareous and alkaline), the present study was conducted to evaluate the efficacy of urea phosphate (an acidic fertilizer) in comparison to di-ammonium phosphate (a basic fertilizer) in wheat crop.

MATERIALS AND METHODS

Bulk surface soil (0-15 cm) sample was collected from NIAB experimental farm area and analyzed for physio-chemical characteristics like particle size, pHs, ECe, SAR, organic matter, calcium carbonate, extractable K, Olsen P following the standard procedures as described by US Salinity Lab. Staff (1954), inorganic N (Akhtar et al., 2011) and total N (Bremner and Mulvaney, 1982). The collected soil was air dried and ground to pass through a 2mm sieve. Ten kg of prepared soil was filled in plastic pots and phosphorus was applied @ 20, 40, 60, and 80 mg P_2O_5 kg^{-1} soil either as diammonium phosphate (DAP) or urea phosphate (UP) at sowing time, whereas no P was applied to control pots. Each treatment was replicated five times and the pots were arranged in completely randomized design. The soil in all the pots was maintained at field capacity and seven seeds of wheat (variety Sehar) were sown. After their germination, three uniform plants per pot were allowed to grow. Urea was applied to all the pots @ 120 mg N kg^{-1} soil in three splits at sowing, tillering and anthesis. The other cultural practices were followed uniformly throughout the growing season. The data regarding plant height and number of tillers per pot were recorded at maturity and post harvest data including 1000 grain weight, straw and grain yields were recorded. Straw and grain samples were digested in H_2O_2 and H_2SO_4. Total N in digests was determined by Kjeldahl method and total P was determined colorimetrically by yellow colour method. Phosphorus and nitrogen uptakes in grain and straw were determined by multiplying their contents with yields. All the relevant data were statistically analyzed using MSTAT-C (Russel and Eisensmith, 1983).

RESULTS AND DISCUSSION

The physico-chemical properties of soil used for experiment are given in table-1. The soil was sandy clay loam in texture having 56.0 % sand, 26.0 % silt and 18.0 % clay, alkaline in reaction and calcareous in nature (pH, 7.6 and $CaCO_3$, 7.2 %), non saline (ECe, 3.3 dSm^{-1}; SAR, 4.04), low in total N (0.06 %) and organic matter (0.87 %) and medium in available P (13.2 mg kg^{-1}). The extractable K and available N were 185 and 27.9 mg kg^{-1}, respectively.

The results described that grain, straw and total biomass (straw + grain) yields, number of tillers pot^{-1} and thousand grain weight of wheat were significantly ($p < 0.05$) increased by P application from either source compared with control treatment (Table 2). The increase in yield by P application has been reported by Khan *et al*. (2007) in wheat and rice, and Mujeeb *et al*. (2010) in maize. Generally UP produced more straw, grain and biomass than DAP. Highest grain yield (48.44 g pot^{-1}) was obtained with UP @ 80 mg P_2O_5 kg^{-1}soil (T9) which was statistically at par with UP @ 60 mg P_2O_5 kg^{-1}soil (T8). Both the higher rates of UP (60 and 80 mg P_2O_5 kg^{-1}soil) produced significantly higher grain yield in comparison to the same rates of DAP. At lower P fertilization rates (20 and 40 mg P_2O_5 kg^{-1}soil), UP produced higher grain pot^{-1}than DAP but statistically the differences were non significant ($p < 0.05$). Almost similar trend was observed for straw yield which improved with increasing P application rates of both the fertilizers except for DAP @ 80 mg P_2O_5 kg^{-1}soil. UP treatments produced more straw than their respective DAP treatments but statistically the differences were not significant ($p < 0.05$). Total biomass yield also improved with the P fertilization and was maximum (117.41 g pot^{-1}) with UP @ 80 mg P_2O_5 kg^{-1}soil. At lowest P rate (20 mg P_2O_5 kg^{-1}soil) UP and DAP produced statistically similar biomass but at higher rates (60 and 80 mg P_2O_5 kg^{-1}soil) UP gave significantly higher biomass than their respective DAP treatments. Tillers pot^{-1} and 1000 grain weight improved significantly ($p < 0.05$) by the application of P fertilizers than control; however the variations were non significant ($p < 0.05$) among the applied P treatments. A non significant ($p < 0.05$) trend was observed in case of harvest index and plant height. Increase in yield and yield parameters by UP compared to DAP might be due to its highly acidic nature (pH, 2). Studies in Egypt have shown that acid based fertilizers such as UP has increased agronomic effectiveness of N and P (Saleh and Aboushal, 1998). More acidic fertilizers extend the time of availability of phosphate ions for wheat (Gracia, *et al*., 1997; Ristimaki, 1999). The superiority of UP over the other P sources has also been reported by Mamdouh *et al*., (2010) for the same crop. UP increases the Mn and Zn availability in calcareous soil (Ryan *et al*., 1986) which might have resulted in the increase in yield.

Phosphorous concentration and uptake in straw and grain increased significantly ($p < 0.05$) by P application through either source (Table 3). An upward trend in P content of straw and grain was found with gradual increase in P fertilization from both the sources. Phosphorous content in straw ranged from 929 to 969 mg kg^{-1} and 929 to 981 mg kg^{-1} with DAP and UP, respectively. While in grain ranged from 3170 to 3302 mg kg^{-1} with DAP and 3216 to 3328 mg kg^{-1} with UP treatments. A similar trend was observed in P taken up by straw and grain as well as total P uptake (Table 3). Generally UP performed better than DAP for P uptake. UP @ of 60 and 80 mg P_2O_5 kg^{-1}soil accumulated significantly ($p < 0.05$) more P in grain compared to the same rates of DAP and total P uptake was also significantly ($p < 0.05$) higher in UP treatments than DAP except the lowest one (20 mg P_2O_5 kg^{-1}soil). In column studies using calcareous soil, Ibrahim *et al.*, (1992) reported that P from UP moved considerably (20 cm below and below and above the point of application) and remained available for several weeks. In our study, wheat plants fed with UP fertilizer have taken up more P and have higher P concentration compared to DAP fed ones. These results substantiate with the findings of Mamdouh *et al*., (2010).

Table 1. Some physico-chemical properties of the experimental soil.

Physical properties	
Particle size distribution	
Sand (%)	56.0
Silt (%)	26.0
Clay (%)	18.0
Texture	Sandy clay loam
Chemical properties	
pHs	7.6
ECe (dSm^{-1})	3.3
SAR	4.04
CaCO3 (%)	7.2
Organic matter (%)	0.87
Extractable-K (mg kg^{-1})	185
Olsen-P (mg kg^{-1})	13.2
Total-N (%)	0.06
Inorganic-N (NH_4 + NO_3) (mg kg^{-1})	27.9

Table 2. Effect of various levels of P from DAP and UP on plant height, tillers per plant, grain weight, straw and grain biomass, and harvest index.

Treatments/ source	P_2O_5 (mg. kg^{-1} soil)	Plant Height (cm)	Tillers. Pot^{-1}	1000 Grain weight (g)	Yield (g pot^{-1})			Harvest index (%)
					Total Biomass	Straw	Grain	
T1 (control)	0	89.8	13.4 b	41.6 b	73.59 f	41.76 e	31.83 d	43.3
T2 (DAP)	20	92.1	19.4 a	46.5 a	99.34 e	57.11 d	42.23 c	42.5
T3 (DAP)	40	92.7	20.6 a	47.9 a	102.61 de	59.99 cd	42.62 bc	41.6
T4 (DAP)	60	93.5	20.4 a	49.9 a	112.28 b	67.75 ab	44.53 bc	39.7
T5 (DAP)	80	95.0	19.6 a	48.9 a	107.22 cd	64.40 abc	42.82 bc	40.0
T6 (UP)	20	92.5	20.0 a	48.3 a	102.21 e	59.23 cd	42.98 bc	42.1
T7 (UP)	40	92.6	20.6 a	49.4 a	108.10 bc	63.33 bc	44.78 b	41.5
T8 (UP)	60	95.8	21.6 a	49.3 a	117.27 a	68.87 a	48.40 a	41.3
T9 (UP)	80	95.3	20.2 a	49.8 a	117.41 a	68.96 a	48.44 a	41.3
LSD 0.05		ns	1.645	3.036	4.497	4.952	2.214	ns

Means followed by same letter (s) within the column do not differ significantly at $p<0.05$; ns = non significant

Unlike phosphorous, nitrogen content in straw and grain varied non-significantly ($p < 0.05$) among the treatments. But N uptake in grain and straw was significantly ($p < 0.05$) affected by P application by either source (Table 4). The lowest N uptake in straw (120 mg pot^{-1}) and grain (597 mg pot^{-1}) was observed for control and enhanced significantly ($p < 0.05$) for the subsequent treatments. The highest N uptake in straw (201 mg pot^{-1}) was determined for UP @ 40 mg P_2O_5 kg^{-1}soil (T7) whereas in grain (938 mg pot^{-1}) it was obtained by UP @ 60 mg P_2O_5 kg^{-1} soil (T8). Total N uptake and N taken up by grain were significantly ($p < 0.05$) higher in UP compared to the respective rates of DAP except lowest one (20 mg P_2O_5 kg^{-1}soil) for grain. UP dropped the soil pH from 7.3 to 6.3 at the placement point which lasted for three weeks (Ibrahim et al., 1992) and reduced the ammoniacal losses of

N as compared to urea in calcareous soil (Stumpe *et al*., 1984) which might be one of the reasons for higher uptake of N in UP treated plants.

Table 3. Effect of various levels of P from DAP and UP on P concentration and uptake by wheat straw and grains.

Treatments/ source	P_2O_5 (mg. kg^{-1} soil)	P concentration (mg. kg^{-1})		P uptake (mg. pot^{-1})		
		Straw	Grain	Straw	Grain	Total
T1 (control)	0	804 e	2764 e	33.6 f	87.9 d	121.5 e
T2 (DAP)	20	929 d	3170 d	53.0 e	133.9 c	186.9 d
T3 (DAP)	40	950 c	3247 bc	57.0 de	138.4 bc	195.4 c
T4 (DAP)	60	956 bc	3264 abc	64.8 abc	145.4 b	210.1 b
T5 (DAP)	80	969 ab	3302 ab	62.4 bc	141.4 bc	203.8 b
T6 (UP)	20	929 d	3216 cd	55.0 e	138.2 bc	193.2 cd
T7 (UP)	40	955 bc	3246 bc	60.5 cd	145.3 b	205.8 b
T8 (UP)	60	967 abc	3276 abc	66.6 ab	158.6 a	225.2 a
T9 (UP)	80	981 a	3328 a	67.6 a	161.2 a	228.8 a
LSD 0.05		16.42	67.65	4.697	7.748	6.933

Means followed by same letter(s) within the column do not differ significantly at $p<0.05$

Table 4. Effect of various levels of P from DAP and UP on N concentration and uptake by wheat straw and grains.

Treatments/ source	P_2O_5 (mg. kg^{-1} soil)	N concentration (%)		N uptake (mg. pot^{-1})		
		Straw	Grain	Straw	Grain	Total
T1 (control)	0	0.286	1.876	120 d	597 d	716 f
T2 (DAP)	20	0.282	1.866	161 c	788 c	949 e
T3 (DAP)	40	0.283	1.908	170 bc	813 c	983 de
T4 (DAP)	60	0.291	1.862	197 a	829 bc	1027 cd
T5 (DAP)	80	0.282	1.888	181 abc	808 c	990 de
T6 (UP)	20	0.301	1.930	178 abc	830 bc	1008 d
T7 (UP)	40	0.318	1.942	201 a	870 b	1071 bc
T8 (UP)	60	0.284	1.936	196 a	938 a	1134 a
T9 (UP)	80	0.275	1.924	190 ab	932 a	1121 ab
LSD 0.05		ns	ns	22.83	50.81	52.11

Means followed by same letter(s) within the column do not differ significantly at $p<0.05$; ns = non significant.

Conclusion

Urea phosphate is an innovative phosphate source of acidic nature. It is a unique product with additional agronomic advantages like increased efficiency of nutrient uptake. It performed better than DAP in terms of yield and quality of the produce. It could be the best choice as a P source for alkaline calcareous soils of Pakistan.

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