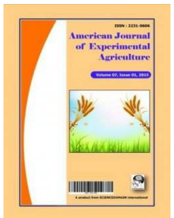

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Assessing Efficiency and Economics of Different Sources of Phosphorus in Alkaline Calcareous Soils for Wheat Production

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Authors' contributions

This work was carried out in collaboration between all authors. Author FB designed the study, performed the Plant analysis, statistical analysis, economic analysis and wrote the protocol and wrote the first draft of the manuscript. Authors IS and SE assisted in analyses and reviewed the experimental design and all drafts of the manuscript. Authors AN and SAA supervised the study in Laboratory and field. Author SS managed the literature searches. Author ZAA supervised the whole study. All authors read and approved the final manuscript.

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ABSTRACT

Phosphorus (P) is an essential nutrient needed for plant growth, root development and grain production. Application of humic acid (HA) is considered to improve the plant growth and enhances stress tolerance. The decrease in amount of arable land and hiking prices of chemical fertilizers are a huge challenge for farmers. The prices of phosphatic fertilizers, especially the diammonium phosphates (DAP) urge the need to explore the cheaper sources of P. Therefore a three year field study was conducted to compare the efficiency and economics of phosphoric acid (PA) with two other traditional sources of P viz. single super phosphate (SSP) and DAP for optimum wheat grain production. Six treatments applied were Viz. Control, recommended dose (RD) of P from SSP, RD of P from DAP, RD of P from phosphoric acid (PA), RD of P from SSP + HA, RD of P from DAP +

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HA. These P fertilizers were applied at the recommended rates for wheat (90 kg ha^{-1}) from SSP, DAP and PA. HA was also applied at the rate of 15 kg ha^{-1}. PA was applied at first irrigation of wheat crop. The experiment was conducted at Soil Chemistry Section, ISC&ES, Faisalabad, Pakistan, using RCBD with three repeats during (2011-14). Basic soil analysis showed that the field was free from salinity and sodicity hazards with low organic matter status while available P was in the range of low to marginal and extractable K was adequate. Maximum grain yield (4.98 t ha^{-1}) was obtained with the use of DAP fertilizer. The Cost Benefit Ratio (CBR) of DAP (3.0) proved it as most profitable P fertilizer with the maximum benefit return. Further the fertigation of PA did not proved better in terms of CBR while the application of HA with SSP and DAP significantly lowered the CBR.

Keywords: Phosphorus; economics; humic acid; alkaline; calcareous.

1. INTRODUCTION

Wheat is the most important cereal food grain in the world and a staple food of the subcontinent [1,2]. Among the cereals after rice wheat is next in area of production and yield [3]. Around the world, wheat is grown across a wide range of environments and it has the broadest adaptations of growth among all the cereal crops. It has good quantity of protein and gluten contents and contributes more calories and proteins to the world's human diet than any other cereals. Pakistan is one of the important wheat producing countries in the world. In Pakistan wheat contributes 10.1 percent to the value added in agriculture, 2.2 percent to GDP and cultivated in an area of 8693 thousand hectare during 2012-13 [4]. Fertilizer is the most important input which contributes significantly towards final grain yield of wheat and to exploit the inherited potential of a cultivar. Humic acid improves the physical, chemical and biological properties of the soil and influences plant growth [5]. It is reported that humic and fulvic acids enhance the root initiation and increase root growth, therefore, directly correlated with enhanced uptake of nutrients [6-8]. P is an essential nutrient for plant growth and development. Plants require adequate P from the very early stages of growth for optimum crop production [9]. It is generally agreed that higher P supply is a prerequisite for high yield potential of modern wheat cultivars [10]. P fertilizers are used worldwide to sustain and improve crop yields, which are required to meet the needs of both a growing world population and annual depletion of soil nutrients. Pakistani soils are alkaline and calcareous in nature. Therefore P availability to crops is very low. To maintain the P availability to crops, it is necessary to apply adequate quantities of phosphatic fertilizer into the soil [11].

Despite of being grown on larger area, average yield at farmers' fields is still far below than the potential [12]. Although with favorable climatic conditions and irrigation water availability, wheat suffers from under production in terms of yield per hectare in Pakistan [13]. The reason for this low yield is less use of chemical fertilizers especially P. The consistently increasing prices of P fertilizers especially DAP and their less availability in market at the right time of application mostly accounts for low fertilizer usage [14]. [15] also reported that elevated P fertilizer prices and their scarcity at the right time of application to crop mostly accounts for low fertilizer usage. In Pakistan small land holding farmers are unable to purchase these very expensive chemical fertilizers. Besides this the high priced phosphatic fertilizers, especially the DAP compel the researchers to explore the cheaper sources of P. PA was considered a cheaper source of P as compared to DAP. So keeping in view the important role of this key element in wheat growth and grain yield a three year field study was conducted with the objective to compare the P use efficiency and economics of different P fertilizers (SSP, DAP and PA) and organic fertilizer (HA) in alkaline calcareous soils for wheat cropping.

2. MATERIALS AND METHODS

The experiment was conducted at research area of soil chemistry section, ISC&ES, Faisalabad, Pakistan, during the Rabi seasons of three years (2011-14). The experiment was laid out in RCBD, having a plot sized 7.5 m x 5 m with three repeats. Wheat cultivar AARI 10, was sown using seed rate 100 kg ha^{-1}. The experiment comprised of T_1 = Control, T_2 = RD of P from SSP, T_3=RD of P from DAP, T_4=RD of P from PA, T_5=RD of P from SSP + HA @ 15 kg ha^{-1}, T_6 = RD of P from DAP + HA @ 15 kg ha^{-1}. All the treatments were applied before sowing of wheat except PA which was applied at first irrigation of crop through mixing in irrigation water. HA was also used along with SSP and DAP fertilizer. Nitrogen and potash were applied as Urea and

Table 1. Physico-chemical properties of soil before the start of experiment

Soil depth (cm)	pHs	Ece (dS m^{-1})	Av. P (ppm)	Av. K (ppm)	O.M (%)	Texture
0-15	7.95	2.85	7.98	160	0.69	Sandy clay loam
15-30	7.99	2.13	4.00	150	0.63	

potashium sulphate (SOP) @ 120-50 kg ha^{-1} respectively. Whole P and K were applied at the time of sowing while half Nitrogen was applied at the time of sowing and remaining half at the time of first irrigation. During experiment 100 cm ha^{-1} water was applied in 4 irrigations. Electrical conductivity of soil extract of pre sowing composite soil samples was measured by method of [16], with a conductivity meter (model: Corning Conductivity meter 220) and the pH of soil samples were measured with the glass electrode pH meter method in a soil saturated paste (ORION Research 611). Organic matter contents of soil samples were estimated following the method of [17]. Potassium in the extract was analyzed by flame photometry method [18]. Available P was determined by the Olsen P method [18]. Textural class was determined with particle size distribution hydrometer method [19]. Plants from 1 m^2 were selected at random for recording plant height (cm), spike length, grains $spike^{-1}$ and 1000 grain weight at harvest. An area of 9 m^2 was selected at random from each plot to collect plant biomass from which grain and straw yield was calculated in t ha^{-1}.

2.1 Chemical Analysis of Plant Samples

After maturity, the harvested wheat grain and straw samples were used to analyze P. Plant samples were dried in an oven at 70℃ to obtain constant weight. Oven dried samples were ground in a Wiley Micro Mill, passed through 40 mesh screens, mixed well and stored in plastic bags. Grain and straw samples were analyzed to determine the amount of P contents. Plant samples were wet digested with tri acid mixture of HNO_3- H_2SO_4-$HClO_4$. P was measured by metavanadate yellow colour method [20] with Spectrophotometer IRMECO model U-2020. Then from the standard curve, P contents (%) in grain and straw were calculated. P uptake and PUE in wheat straw and grains was calculated according to formulae given by [21] and [22].

P uptake kg ha^{-1} = P contents (%) in plant part (dry matter) × Yield (kg ha^{-1})/100

PUE (%) = {[Total P uptake (kg ha^{-1}) in fertilized plot]-[Total P uptake (kg ha^{-1}) in control plot]/P dose applied (kg ha^{-1})}/100

2.2 Data Analyses

Statistical analysis of data in this experiment was performed using Analysis of Variance (ANOVA) using the computerized system Statistix® for Windows version 8.1 (Analytical Software ©). Difference among the treatment means were compared using least significant difference at 5% probability level [23].

2.3 Economic Analysis

A cost benefit analysis was conducted to estimate the economic feasibility of different P sources and along with HA application to increase net economic returns of wheat production as described by [24].

Basic soil analysis showed that the field was free from salinity and sodicity hazards. The organic matter status was very low while available P was in the range of low to marginal and extractable K was adequate (Table 1 above).

3. RESULTS AND DISCUSSION

3.1 Effect of P Sources on Growth Parameters

Three years pooled results showed that wheat growth parameters (Plant height, spike length, grains $spike^{-1}$, 1000 grain weight) were significantly affected by P sources and the highest results were obtained with the application of DAP (Table 2). Similar trend was found by [25]. Application of P fertilizer significantly increased the growth parameters over the control. [26] has shown that the application of P fertilizer (SSP) to wheat crop has significantly increased the plant height, number of tillers $plant^{-1}$ over control. The differences among different P sources were statistically insignificant but maximum growth was observed where DAP fertilizer was applied followed by SSP. This is also reported by [27] that use of DAP resulted in more plant growth than other P sources. The results revealed that PA did not significantly improved the growth and yield of wheat rather DAP significantly improved the plant height, spike length, number of grains $spike^{-1}$, 1000 grain weight and grain yield of wheat as compared to control. These results are in line with the findings of [28-30]. They reported that the increase in biological yield is due to the use of chemical fertilizers as compared to PA.

3.2 Effect of P Sources on Grain Yield

Year wise three year pooled grain yield data is presented in Fig 1. The pooled results showed that similar trend was observed in all the three years and all the P sources had a significant effect on grain yield over the control. [26] also reported the increase in wheat grain yield due to application of P fertilizers. Data revealed that highest (40% more as compared to control) grain yield (4.98 t ha^{-1}) was recorded where DAP was applied as P source followed by SSP (4.56 t ha^{-1}) and PA (4.25 t ha^{-1}). The increase in yield with DAP fertilizer is in line with findings of [27,30]. DAP and SSP increased grain yield up to 17 and 7 percent more as compared to PA respectively. Decline in yield was observed when DAP and SSP were applied along with HA. The reason for this decrease in yield is unknown but it may be due to complex formed between HA and P which made P less available to crop [31]. The P fixed in HA complex becomes unavailable to the recent crop as compared to SSP and DAP treatments which lowered the yield of wheat grain. This decrease in yield may also be due to more vegetative growth due to HA addition.

Three years averaged pooled data showed that with the use of fertilizers there was an increases in PUE and P uptake in wheat grain [26]. Data revealed that highest PUE and P uptake were obtained (22%, 22 kg ha^{-1}) where DAP was applied as P source over the other treatments (Fig. 2). [27] also reported the increase in PUE with the use of DAP fertilizer. The reason behind is that DAP fertilizer is the best P source in alkaline calcareous soils. This is also reported by [32] that application of DAP resulted in highest concentration of P in grain which leads to more P uptake. There is lesser P fixation due to acidic localized reaction of DAP and more availability to plant, lesser chances of P fixation and Precipitation [33]. In contrast where SSP and PA were applied, PUE and P uptake were recorded comparatively lower than DAP but higher than no fertilizer and SSP + HA and DAP + HA. The results showed that percent increase in P uptake and PUE with the use of DAP as compared to PA fertilizer is 16 and 56 respectively in wheat grain.

Application of Phosphorus fertilizers had a significant effect on PUE and P uptake in wheat straw. It was observed that P uptake was low (5 kg ha^{-1}) in control where no fertilizer was applied as compared to treatments where fertilizers applied. Highest P uptake and PUE (16 kg ha^{-1}, 29%) were recorded where DAP was applied as compared to SSP (11 kg ha^{-1}, 16%) and PA (28 kg ha^{-1}, 24%). These results are also in line with [27]. [34] reported that highest P recovery can be achieved with proper P fertilizer application. In alkaline calcareous soils DAP is the best P fertilizer with highest PUE. The wheat straw accumulated less P than wheat grain and decrease in P uptake and PUE was also recorded in wheat straw. This decrease may be attributed to fixation of soil P to unavailable form in later stages of growth resultantly low P use efficiency [35].

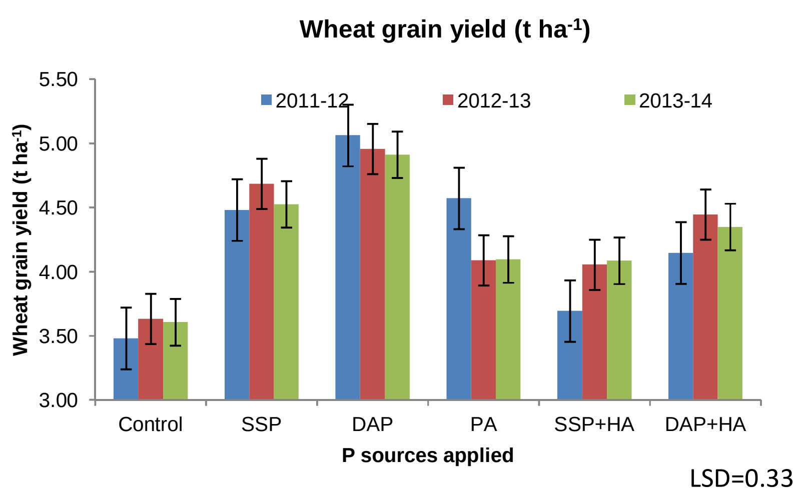

Fig. 1. Grain yield of wheat crop (t ha^{-1})

Table 2. Yield contributing parameters

Treatments	Plant height (cm)	Spike length (cm)	Grains spike^{-1}	1000 grain wt (g)
Control	85.3b	14.0b	42.3b	31.0c
RD of P from SSP	98.3a	15.6ab	47.7ab	33.3ab
RD of P from DAP	103.0a	16.4a	51.3a	35.0a
RD of P from Phosphoric Acid	98.7a	14.0b	46.3ab	31.7bc
RD of P from SSP + Humic Acid	101.0a	15.7ab	48.0ab	32.3bc
RD of P from DAP + Humic Acid	98.3a	15.7ab	48.7a	32.7bc
LSD	6.04	2.02	5.89	1.93

Means for each parameter sharing similar letters do not differ significantly at P = 0.05

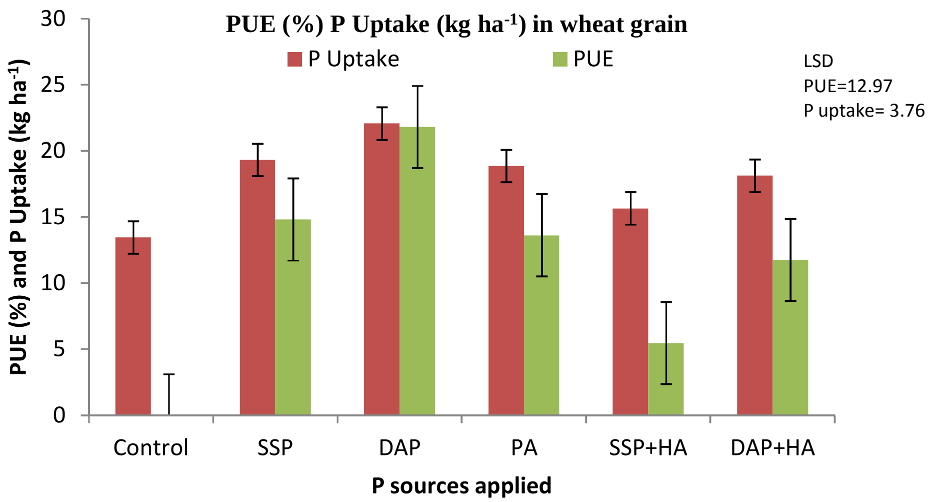

Fig. 2. P concentration and PUE (%) and P uptake (kg ha^{-1}) in grain

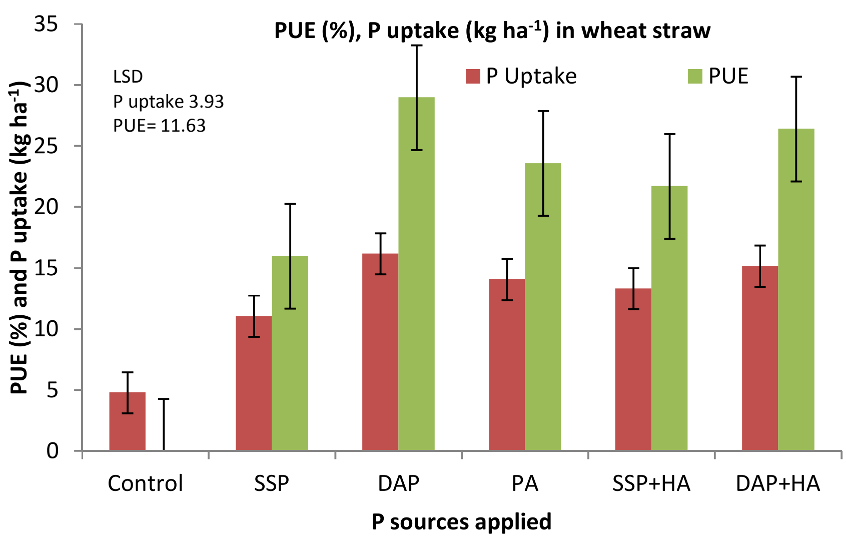

Fig. 3. P concentration and PUE (%) and P uptake (kg ha^{-1}) in straw

Table 3. Cost benefit ratio of different sources of P for wheat crop (2011-14)

Treatment55 \\s	Grain t ha^{-1}	Cost (USD) ha^{-1}	Wheat price (USD)	Net profit (USD)	CBR
Control	3.57	0	1096.06	------	-----
RD of P from SSP	4.56	117.9	1400.01	303.95	2.6
RD of P from DAP	4.98	146.15	1528.96	432.90	3.0
RD of P from Phosphoric Acid	4.25	326.57	1304.83	208.77	0.6
RD of P from SSP+Humic Acid	3.95	134.48	1212.73	116.67	0.9
RD of P from DAP+Humic Acid	4.31	162.73	1323.25	227.19	1.4

Cost benefit ratio on three year average yield was calculated (Table 3). Wheat price of the final year was used to calculate the price of wheat grain. Similarly cost was calculated by using the final year price of fertilizers. It was recorded that DAP was most economical and profitable fertilizer among three P fertilizers (DAP, SSP, PA) and their use along with HA, similar results were reported by [27]. Use of HA not only increased the cost of production but also not an efficient fertilizer to increase the grain yield. With the use of DAP, on expending one rupee farmer can earn 3 rupees followed by 2.6 rupees from SSP. DAP saved 5 times more input cost followed by SSP (4 times) as compared to PA.

4. CONCLUSION

It was concluded from this study that DAP is the best and most profitable source of P fertilizers and use of DAP and SSP along with HA will earn no more benefit than alone, rather it will increase cost of production. Use of DAP fertilizer saves 400% input cost followed by SSP (333%) as compared to PA. Therefore use of PA is uneconomical as compared to SSP and DAP fertilizers and also to their combined use with HA.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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