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Research Article

Investigating Combination and Individual Impact of Phosphorus and Humic Acid on Yield of Wheat and Some Soil Properties

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Abstract

In order to evaluate the effect of different levels of Phosphorous (P) alone and in combination with Humic acid (HA) on the yield and P accumulation by wheat(*TriticumaestivumL*, CV Fakhr-e-Sarhad)., a field experiment was carried out at agriculture research station of Swabi, Pakistan during 2016-2017. A total of eight treatments replicated four times were arranged in Randomized Complete Block Design (RCBD) in the field. Two levels of HA including control (H0: control and H1: 500 g ha^{-1}) and four levels of P (P_2O_5) including control as Single Super Phosphate (SSP) (P0: control, P1: 60 kg ha^{-1}, P2: 90 kg ha^{-1}, and P3: 150 kg ha^{-1}) were utilized. ; Size of each plot was kept to 5x4 m. Addition of different levels of SSP alone and in combination with HA significantly ($P<0.05$) improved straw, grain and total wheat yield over control. HA in combination with 60 and 90 kg P_2O_5 ha^{-1} improved the grain yield by 22.4 and 6.5 % respectively as compared to the same amount of fertilizer applied alone. Total yield (Dry mass + Grains) of 20877 kg ha^{-1} was produced by the treatment P2H1 (90 kg P_2O_5 ha^{-1} + 500 g ha^{-1} HA) followed by the treatment P2H0, which were 78.69 and 75.03 % increases over the control. Significantly highest 1000- grain weight of 47.8 g was recorded in the treatment P2H1 while all other treatments showed non-significant increase in 1000- grain weight. Unlike soil pH values, improvement in the Soil Organic Matter content (SOM) was observed with the application of both HA and chemical fertilizers either applied alone or in combination. SSP applied either alone or in combination with HA increased significantly ($P<0.05$) the post-harvest soil P concentration as well as P accumulation by wheat plants over control. Results suggest that application 90 kg P_2O_5 ha^{-1} reinforced with HA (P2H1) may be considered as an optimum dosage for achieving optimum yield of wheat crop.

Key words: Humic acid, phosphorous, wheat, soil.

Introduction

Wheat (*TriticumaestivumL.*), belongs to family Poaceae and known as king of cereals. It is cultivated on a vast area about 8.1 million ha of Pakistan and used as a staple meal, contributes 83% of total cereal intake and used as a cheap nutritional diet provides 50% of the total calories and 60% of proteins consumed by total population of Pakistan. Although Pakistan is the 10th largest wheat producing country, produced an average yield of 2384 kg ha^{-1} of wheat yet its production is far below than its actual production potential of 6450 kg ha^{-1} , creates an enormous scope for increased output (MINFA, 2011).

Humic acid is a multifarious molecule of polymeric organic acid of aromatic structure replaced by carboxyl, phenolic, hydroxyl and alkyl groups associated together through ether linkage (Sutton and Sposito, 2005) and accumulates in environment as a result of decomposition of organic matter (Stott and Martin, 1990) and might be useful for crop growth by its chelating property and buffering pH(Julie and Bugbee, 2006). It is considered as one of the active constituents of organic fertilizers used as a cheap fertilizer to improve crop growth, yield , soil organic matter content as well as physical condition of the soil (Li et al., 2017; Karakurt et al., 2009).

Significance of HA in crop production have been consistently reported and it might be utalized as fertilizer in agriculture, in turn improve crop growth, nutrients uptake as well as soil moisture (Sharif et al., 2002; Cheryl et al., 2001). In alkaline calcareous soil the availability of nutrients is often low due to adsorption property and HA is used to convert these unavailable forms into chelating complex due to the existence of functional groups and increased nutrients uptake by crops (Chen et al., 2004) or by the presence of auxin or auxin-like compounds (Aguirre *et al*., 2009). HA has the ability of supplying N and P to the plants as it is the primary constituent of organic Carbon, Nitrogen and Phosphorous (Khattak and Muhammad, 2008,; Sharif *et al*., 2002). Published literature revealed that co-application of HA with either single nutrient or mixed with NPK fertilizers significantly increased the yield of crops (Selim*et al*., 2009). Ezzat*et al*., 2009 recorded 33 % increase in potato yield with K-humate application at 30 Mg ha^{-1}. Similarly in salt affected soil 2 kg ha^{-1}humic substances along with Cu and Zn improved wheat production(Manzoor*et al*., 2014).

On the other hand Phosphorus (P) is one of the essential macro nutrients needed by plants on regular basis and its significant role has long been recognized by several researchers (Ahmad *et al*., 2013; Naseer and Muhammad, 2014). Calcareous nature and high soil pH of Pakistani soil reduce the P availability due to sorption and fixation; P fixation can be decreased by interacting with humic substances and ultimately increased the P uptake of crop (Quan-Xian *et al*., 2008). Phosphorous fertilizer use efficiency by HA have also been reportedby (Delgado *et al*., 2002).

Keeping in mind the importance of Humic acid (HA) and Phosphorous (P), the present research aimed to study the impact of HA alone or in combination with P on wheat crop yield.

Material and Methods

Site characteristics

Experiment was conducted at Agricultural Research Station Swabi located at 34° 7' 48" N and 72° 28' 11" E of Khyber PakhtunKhwa, Pakistan, with average rain fall of 300 mm, during 2016-17.

Experimental design and treatments

Experiment was arranged in Randomized Complete Block Design (RCBD).There were total eight treatments, two levels of humic acid including control (H0: control and H1: 500 g ha^{-1}) and four levels of P as Single Super Phosphate (SSP) including control (P0: control, P1: 60 kg ha^{-1}, P2: 90 kg ha^{-1}, and P3: 150 kg ha^{-1}) replicated four times, which made a total of 32 plots, each of 5x4 m size. The row to row distance of wheat plants was 25 cm. Following treatments combination was utilized during the study.

Treatment 1	P0H0
Treatment 2	P0H1
Treatment 3	P1HO
Treatment 4	P1H1
Treatment 5	P2H0
Treatment 6	P2H1
Treatment 7	P3H0
Treatment 8	P3H1

Soil characteristics

Analysis of composite soil sample collected at 0-20cm depth before the experiment revealed that the soil was silty clay loam in texture, alkaline in reaction, calcareous in nature low in organic matter (OM) content (Table 1). The soil was also found poor in available phosphorous (P).

Table 1. Some soil physico-chemical properties (0-20 cm depth).

Property	Value
Clay (%)	24
Silt (%)	46.8
Sand (%)	27
Textural class	Silty Clay Loam (SCL)
pH (1:5; Soil:Water)	8.6
Organic matter (%)	0.69
Lime ($CaCO_3$) (%)	16.8
AB-DTPA P (mg kg^{-1})	5.72
AB-DTPA K (mg kg^{-1})	150

*AB-DTPA = Ammonium Bicarbonate Di-ethylene TriaminePenta Acetic Acid.

Post-harvest soil and plant analysis

Three central rows were harvested from each treatment plot at maturity stage and the yield parameters, grain yield, Total yield, Straw yield, and 1000-garin weight were recorded.

Data on the grain yield was recorded after threshing the bundles of wheat plants from each treatment and then converted into kg ha^{-1} .Thousand grain weight was recorded by counting 1000 grains selected randomly from each treatment and then weighed by electronic balance. Total yield and straw yield were recorded in each treatment after adequate dying and then converted into kg ha^{-1}. Soil samples collected from each treatment after crop harvest were analyzed for pH (Richards, 1954), Soil organic matter content (Nelson and Sommers, 1982), Phosphorous and Potassium (Soltanpour 1985). Plant samples selected from each treatment plot were analyzed for plant P and plant accumulations by wheat plants (Walsh and Beaton, 1973). Phosphorous Use Efficiency (PUE) is the percent recovery of the applied nutrient in the harvested portion of the crop and PUE were calculated as;

PUE=Pf-Pc /Px100

Pf and Pc are total Phosphorous uptake from fertilized and check (control) plots respectively and P is applied in kg ha^{-1} (Latif*et al*., 2003).

Statistical analysis

Statistical Analysis of the collected data were done by following the procedures given by Steel and Torrie (1980) using M Stat C package and least significant difference (LSD) test was used for any significant difference among the treatments.

Results and Discussion

Post-harvest soil pH and organic matter

The analysis of data on soil pH revealed that lowest soil pH (8.12) was recorded in the treatment P3H1 followed by P2H1 (Table 2). The decrease in soil pH with HA application was also reported by Mahmoud and Hafez, (2010) stated that during mineralization process of organic and inorganic fertilizers the H^+ ions released resulted decrease in soil pH, while in another study Ali and Mindari (2016) recorded lower soil pH with addition of 400 ml HA to5kg soil. Soil organic matter (SOM) content significantly increased over control ($P< 0.05$) with the addition of P alone as well as in combination with HA (Table 2). Maximum SOM content of 1.3 % was recorded in the treatment P3H1 followed by 1.23 % at treatment P2H1, however non-significant differences were observed between treatments P0H1 and P1H1 (Table 2).

In the present study SOM content was improved by 21- 45% with the addition of HA alone and in combination with P fertilizer as compared with control (Fig 1). Increases of 11 and 13 % were recorded in SOM, when 60 and 90 kg ha^{-1} P was applied along with HA as compared to the same rate of P fertilizer applied alone. The increase in SOM content with addition of organic fertilizers was also reported by Khaled and Fawy (2011) concluded that HA increased the organic matter content of the soil and promote the chelation of many elements and increased the chances of availability to plants. Organic materials increased the O.M content of soil up to 1.17-2.85 kg ha^{-1} and reduced the oxidation stability of SOM (Wang *et al*., 2015 and Li *et al*., 2017).

Table 2. Effect of different levels of Phosphorous alone as well as in combination with humic acid on post-harvest soil pH and OM.

Treatments	pH (1:5; Soil: Water)	Organic Matter (%)
*P_0H_0	8.4	0.86 d**
P_0H_1	8.24	1.04 c
P_1H_0	8.21	1.03 c
P_1H_1	8.24	1.13 bc
P_2H_0	8.20	1.12 bc
P_2H_1	8.15	1.23 ab
P_3H_0	8.20	1.18 ab
P_3H_1	8.12	1.30 a

*P (P0, P1, P2 and P3): P2O5 levels (control, 60, 90 and 150 kg ha^{-1}) and HA (H0 and H1): Humic acid levels (control and 500 g ha^{-1}).

**Means with different letter (s) in columns are significantly different at $p<0.05$.

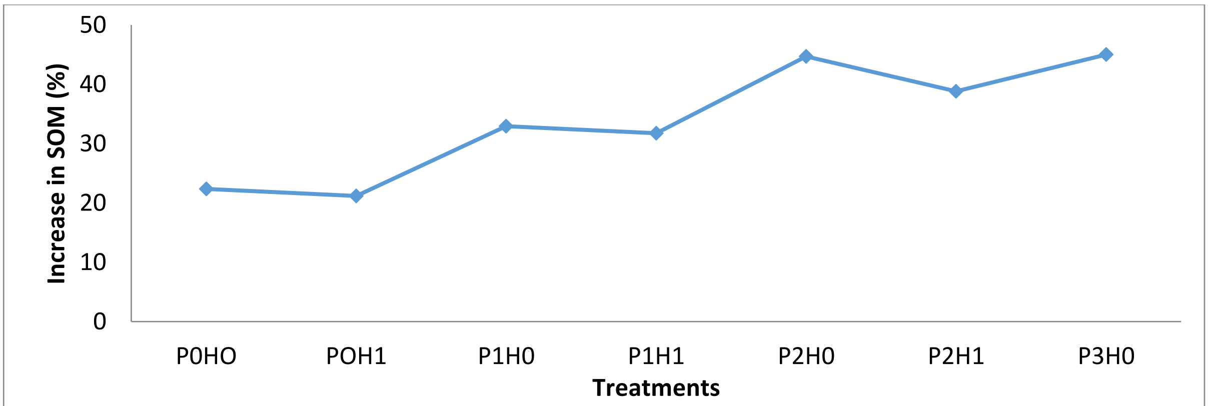

Figure 1. % increase in post-harvest SOM as effected by P alone and in combination with HA.

Grain yield

Wheat grain yield significantly increased (P<0.05) over control with addition of P and HA. The maximum grain yield of 5112 kg ha^{-1} was recorded in the treatment P2H1. Further increase beyond this level has no effect on yield (Table 3). However non-significant differences were found among treatments P2H0, P2H1, P3H0 and P3H1. Percent increases over control were in the order P2H1>P3H1>P3H0>P2H0>P1H1>P1H0>P0H1 (74.13, 67.41, 65.43, 63.49, 60.00, 30.75, and 27.11 %), respectively.

Results revealed that HA applied alone (500g ha^{-1}) significantly increased the yield from 2936 kg ha^{-1} to 3732 kg ha^{-1} which was 27 % as compared with control (Fig.2). 60 and 90 kg P_2O_5 ha^{-1} along with 500 g ha^{-1} HA increased the grain yield up to 22.4 % and 6.5 % respectively as compared with the same amount of P applied alone. Our results were in lined with Sharif *et al.*, (2002) who studied 25-69% increases in grain yield over control with HA application. Increased in the grain yield and straw yield of wheat by 26% and 23.8 % with HA application was also reported (Brunetti*et al*., 2007). The highest yield 1314 kg ha^{-1} of rain fed wheat was achieved with the application of HA and inorganic fertilizers (Khan *et al*., 2010).

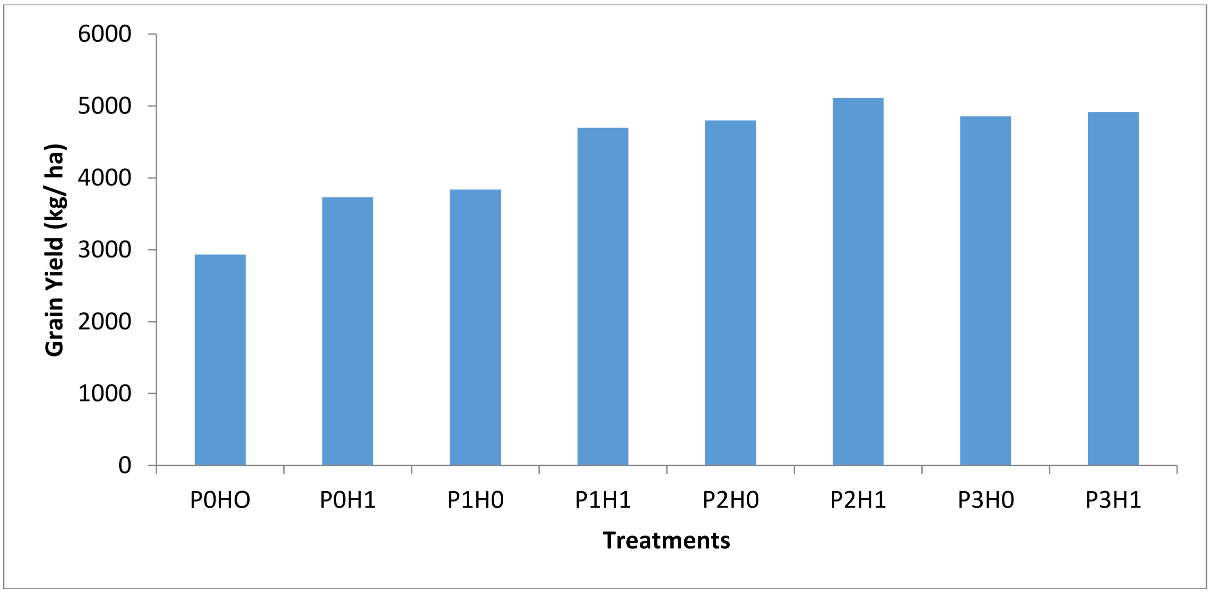

Figure 2. Effect of different treatments on the grain yield of wheat.

Total yield (Dry mass + Grains)

The increasing trend of total yield with P and HA was almost similar to that of grain yield (Table 3). All the treatments in different combinations increased the total yield of wheat significantly (P< 0.05) over control. Maximum total yield of 20877 kg ha^{-1} was obtained from the treatment P2H1 followed by 20449 kg ha^{-1} by treatment P2H0 which were 78.69 and 75.03 % increases over control (Figure 3.). Publish literature reveled HA alone produced significantly (*P*<0.05) maximum grain yield of wheat (2999.9 kg ha^{-1}) and increased the yield by 24% over the control(Khan *et al*., 2010), while Delgado *et al*., (2002) reported that foliar applied humic acid along with split soil N significantly improved the grain yield as well as grain protein.

Straw yield

Wheat straw yield significantly increased over control with application of both P and HA either alone or in combination. However no significant difference was observed between P fertilizers applied alone or in combinations with HA. The significantly maximum straw yield of 15906 kg ha^{-1} was obtained from the treatment P2H1 (Table 3 and Figure. 4). However no significant difference was found between treatments P2H0 and P2H1. Our results were in lined with the findings of (Anwar and Yousaf, 2000) found that wheat under rainfed condition could be increased significantly by the application of both organic and inorganic fertilizers. While in another study it was revealed that effects of HA and P application was more effective on growth and growth parameter than each separate effect, the highest total dry matter of peeper plant (69 mg kg^{-1}) was obtained with P application and 1500 mg HA kg^{-1} application (Çimrin*et al*. 2010).

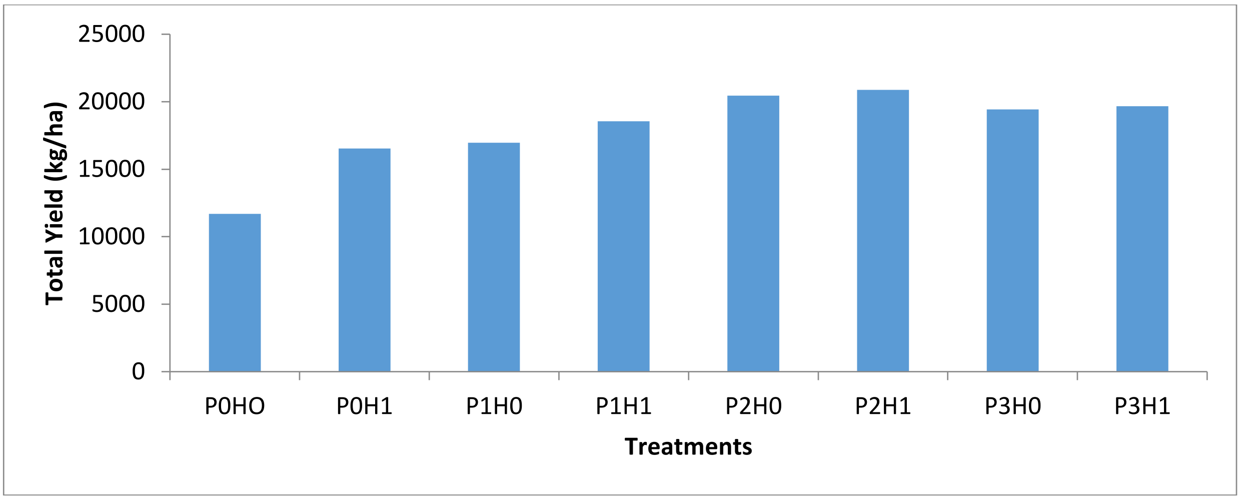

Figure 3. Effect of different treatments on total yield (Dry Mass +Grain) of wheat.

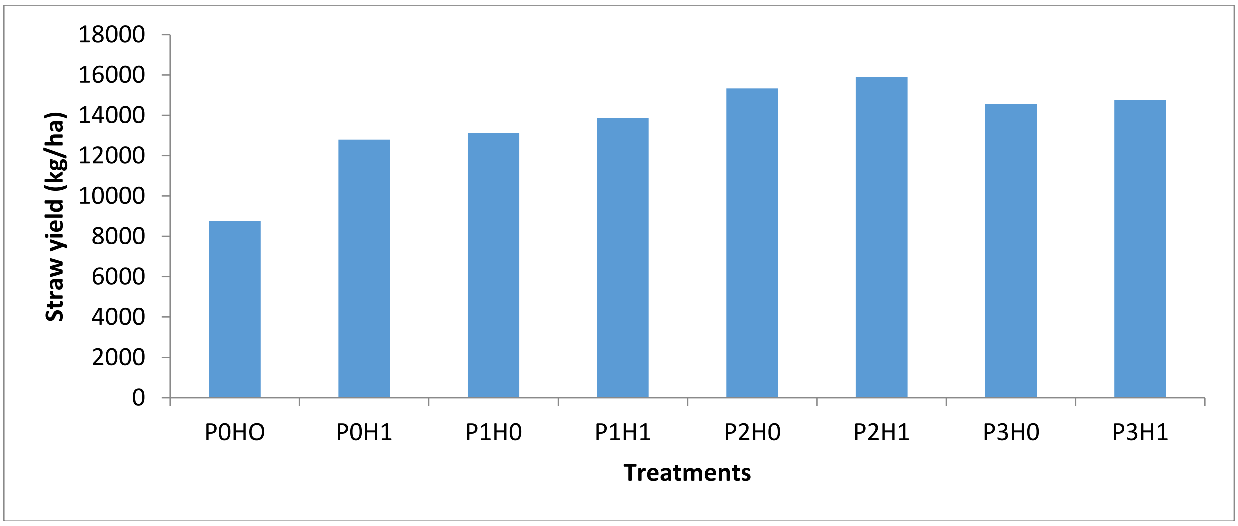

Figure 4. Effect of different treatments on Straw yield of wheat.

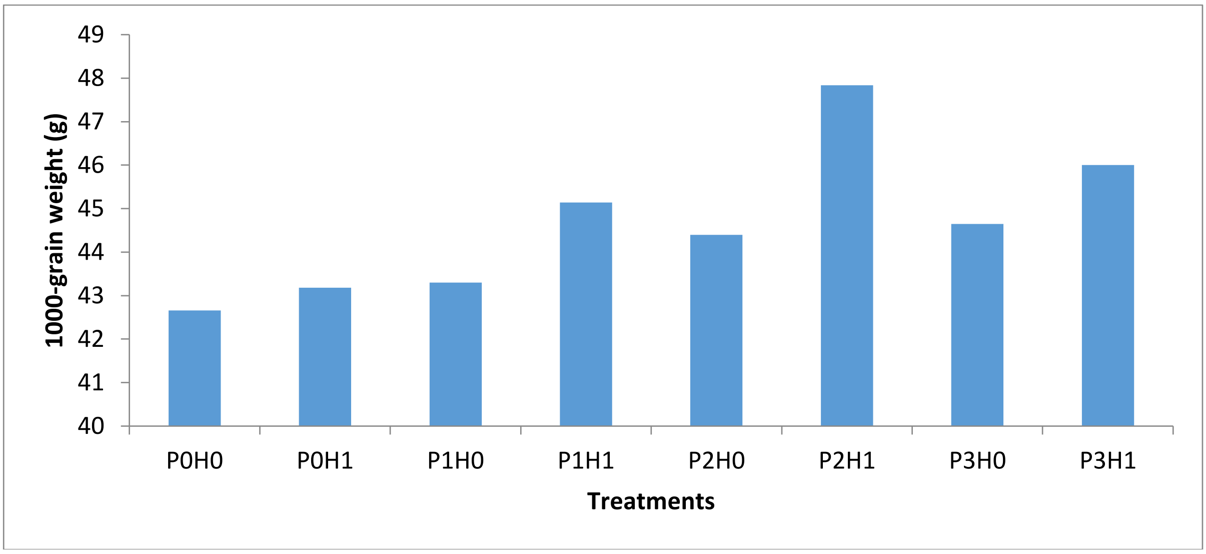

Figure 5. Effect of different treatments on 1000-grain weight (g) of wheat.

1000 grain weight

Data analysis regarding 1000- grain weight revealed that HA along with 90 kg ha^{-1} P2O5 (P2H1) significantly increased 1000- grain weight over control (Figure 5). The highest 1000- grain weight of 47.84 g was recorded in treatment P2H1 (Table3). Furthermore all the levels of P either alone or in combination with HA increased 1000- grain weight but not significantly (Table 3). Published literature also confirmed increased in 1000- grain weight of wheat with HA application, Inamullah and Ali (2014) obtained maximum thousand grain weight (44.72 g) with 2 kg HA ha^{-1}, while in another study Ulukan (2008) found maximum 1000- grain weight (38.08 g) of wheat with 2 kg HA ha^{-1}.

Table 3. Effect of different levels of phosphorous alone as well as in combination with humic acid on grain yield, total dry matter, Straw yield and 1000- grain weight of wheat.

Treatments	Grain yield (kg ha^{-1})	TDM (kg ha^{-1})	Straw yield (kg ha^{-1})	1000-grain weight (g)
P_0H_0	2936 c*	11683 d*	8748 d*	42.66 b*
P_0H_1	3732 b	16534 c	12802 c	43.18 b
P_1H_0	3839 b	16969 bc	13130 bc	43.30 b
P_1H_1	4697 a	18556 abc	13859 abc	45.14 ab
P_2H_0	4800 a	20449 a	15336 ab	44.40 ab
P_2H_1	5112 a	20877 a	15906 a	47.84 a
P_3H_0	4857 a	19427 abc	14570 abc	44.65 ab
P_3H_1	4915 a	19659 ab	14749 abc	46.00 ab

*Means with different letter (s) in columns are significantly different at p<0.05.

Post harvest soil phosphorous concentrations and plant accumulation

Application of different levels of P and HA either applied alone or in combination significantly (P<0.05) increased soil P concentration over control (Table 6).However non significant difference was found between P applied alone or reinforced with HA. Maximum post harvest soil P concentration of 9.00 mg kg^{-1} was found in the treatment P3HO (Table 6, Fig.6). Both HA (P0H1) and P fertilizer (P1H0) applied alone showed non significant difference from each other. Similarly the treatments P1H1, P2HO, P3H0, P2H1, and P3HI were significantly (P<0.05) different from control but showed non significant difference from each other. HA addition to the soil generally reduce P fixation and increase the recovery of P (Delgado *et al*., 2002;Satisha and Deverajan, 2005; Sharif *et al*., 2002).

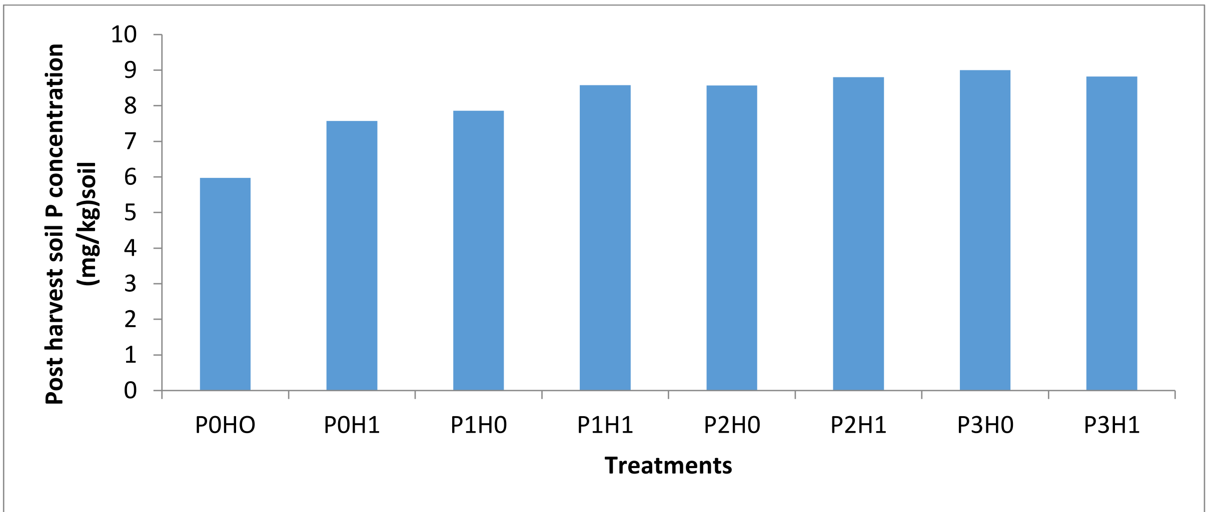

Figure 6. Effect of different treatments on post-harvest soil P concentration.

On the other hand P accumulation by wheat plants significantly (P<0.05) increased over control by application of both P and HA either applied alone or in combination (Table 6 and Fig.7). Maximum P accumulation of 18.53 kg ha^{-1} was recorded in the treatment P3HO; however the treatment P3HI showed a decline in P accumulation as compared to P3HO. HA had a significant effect on P concentration as well as an important factor in nutrients uptake (Canellas *et al*., 2002; Mahmoud and Hafez, 2010).

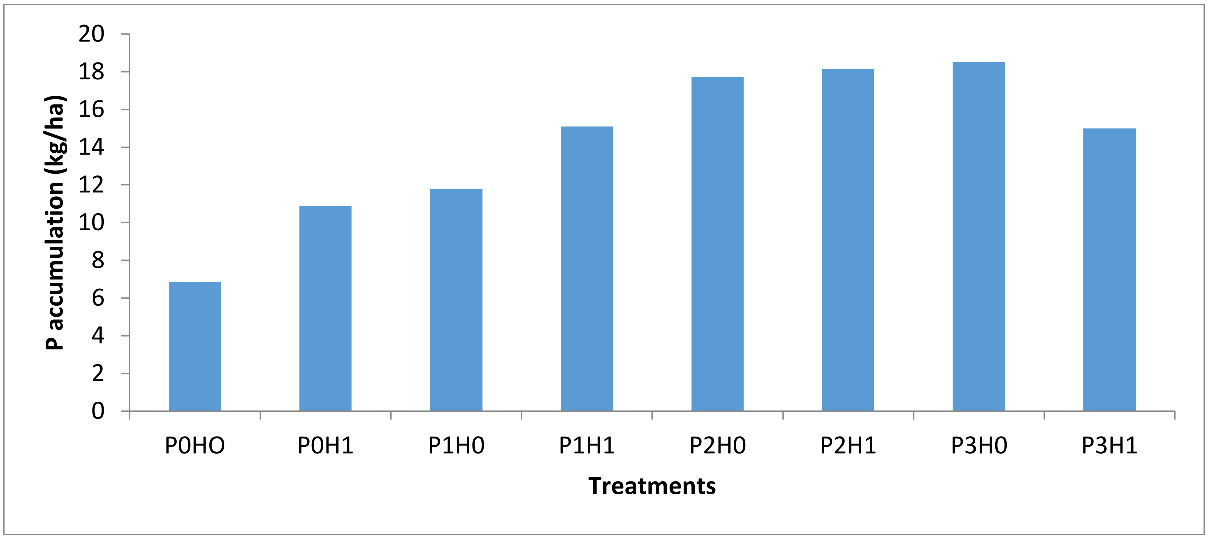

Figure 7. Effect of different treatments on P accumulation by wheat plants.

Table 6. Effect of different levels of P alone and in combination with HA on post harvest soil P concentration and its accumulation by wheat plants.

Treatments	Available P concentration in soil (mg kg^{-1})	Total P accumulated by wheat plants (kg ha^{-1})
P_0H_0	5.97 c*	6.85 e*
P_0H_1	7.57 b	10.88 d
P_1H_0	7.86 b	11.79 d
P_1H_1	8.58 a	15.09 c
P_2H_0	8.57 a	17.72 ab
P_2H_1	8.80 a	18.13 bc
P_3H_0	9.00 a	18.53 a
P_3H_1	8.82 a	15.00 c

*Means with different letter(s) in columns are significantly different at p<0.05.

Phosphorous use efficiency

Phosphorous Use Efficiency (PUE) is the percent recovery of the applied nutrient in the harvested portion of crop. Maximum P use efficiency was obtained with minimum fertilizer level reinforced with HA (P1H1), while minimum PUE was observed in the treatment P3H1 supplied with highest fertilizer P level of 150 kg ha^{-1} reinforced with HA (Table 7). Many investigators including (Sharif *et al*., 2002, Cimrin*et al*., 2010) concluded that crops utilize 5-35 % of the applied P and the rest is retained in the soil.

Table 7. Effect of different levels of P alone and in combination with HA on P use effeciency.

Treatments	P uptake (kg ha^{-1})	P use efficiency (%)	Yield increase (%)
P_0H_0	6.85 e*	____________	____________
P_0H_1	10.88 d	____________	27.1
P_1H_0	11.79 d	9.88	30.7
P_1H_1	15.09 c	16.48	60.0
P_2H_0	11.72 ab	10.87	69.3
P_2H_1	18.13 bc	11.28	74.1
P_3H_0	18.53 a	7.79	65.4
P_3H_1	15.00 c	5.43	67.4

Conclusions

It was concluded from the results that the effect of HA on wheat yield is more pronounced at low level of SSP as compared to higher levels. Moreover 90 kg ha^{-1} P along with 500 g HA was more effective in making the soil environment conducive for soil P and for plant nutrients availibility. Organic matter status of soil could be built gradually by the use of small quantity of humic acid, combined application of chemical and organic fertilizers is inevitable and the use of humic acid alone can not substitute chemical fertilizers completely in case of wheat crop. Further investigations are strongly suggested to study the effect of different levels of P alone as well as in combination with HA on various crops.

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