ORIGINAL ARTICLE

Effect of combined application of organic waste and inorganic fertilizer on growth, P-uptake and yield of wheat

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Abstract

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Due to continuous use of chemical fertilizers under intensive cultivation system, soils are being degraded physically as well as nutritionally. Integrated use of organic waste and chemical fertilizer is being emphasized for restoration of soil health and sustained crop productivity. A pot and a field experiment were conducted to study the effect of combined use of organic wastes and chemical fertilizer on wheat growth and yield. The results of both experiments showed that integrated use of organic industrial waste (Filter-cake, FC/Poultry waste, PW) and chemical fertilizers in 2:1 P ratio proved to be a better combination than integration of inorganic sources in the same ratio for increasing the P-fertilizer efficiency and enhancing grain yield of wheat. Combined application of PW and DCP (di-calcium phosphate) proved better than other combinations with relatively higher value: cost ratio as compared to DAP (di-ammonium phosphate) alone. Thus, substantial reduction in P fertilizer input may reduce the cost of production.

Key words : integrated use, inorganic fertilizer, organic waste, phosphorus, wheat

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Agriculture is the backbone of Pakistan's economy. It contributes 26% to the gross domestic product (GDP) and provides livelihood to more than 65% of the population. Large numbers of livestock also depend on agriculture and both of these serve as sources of raw materials to the agro-based industries. At present, there is no organized way of collecting the animal refuses, such as animal manure, blood or bones that can contribute considerable amounts of nutrients for crop growth if properly managed (Ahmad *et al*., 2000). It has been estimated that about 1.5 million tonnes of nutrients are available from the collected farmyard manure, which is only about 25% of the total quantity available. Latest estimates further show that about 290 million poultry could contribute about 100,000 tonnes of nitrogen, 58,000 tonnes of P_2O_5 and 26,000 tonnes of K_2O if their manure is properly collected (Ahmad, 2000). Similarly, the sugar industry is producing about 1.28 million tonnes of dry filter cake (FC) every year, which is a rich source of organic matter, macro- and micro-nutrients (Nasir and Qureshi, 1999). These organic wastes are not used for manuring the field by the farmers rather they are burned as fuel for baking bricks, which causes environmental pollution as well as a loss of considerable amounts of nutrients.

Results of some pot experiments indicate that FC, PW and DCP when applied alone, were as good a source of P as chemical fertilizer SSP (Single super phosphate) or DAP (Alam and Shah, 2002; Alam *et al*., 2003; Badr-uz-zaman *et al*., 1996). Similarly, in field trails FC when applied at higher rates alone or in addition to NPK produced equivalent yields of wheat, maize and sugarcane (Ibrahim *et al*., 1992; Nasir *et al*., 1994; Nasir and Qureshi, 1999). However, small farmers can afford to apply FC or PW only if the quantity required is reasonably small. The integrated use of these organic wastes with inorganic fertilizers has been shown to increase the efficiency of inorganic fertilizers (Alam *et al*., 2003; Alam *et al*., 2004).

Therefore, a pot experiment was conducted to test the effect of combined use of organic and inorganic fertilizers on wheat growth and yield. A field experiment was also conducted to confirm the effect of application of different combinations of fertilizers that produced good results in pot trials for their usefulness in practical crop production.

Materials and Methods

Pot study

Bulk soil sample (0-20 cm depth) collected from Nuclear Institute for Agriculture and Biology (NIAB) farm in Faisalabad was crushed, passed through a 2 mm sieve, mixed and a representative sample was analyzed for some physico-chemical properties (Table 1). Five kilograms of dry soil was put into individual plastic pots and phosphorus was applied at the rate of 100 mg P kg^{-1}, either as single super phosphate (SSP) alone, or in combination with the industrial by-products, i.e. filter cake (FC), poultry waste (PW) or di-calcium phosphate (DCP) applied in a P ratio of 2:1 (67 kg of P from organic waste and 33 kg of P from SSP) just before sowing. The treatments were replicated three times and the pots were arranged

Table 1. Some physico-chemical properties of soils.

Soil property	Pot soil	Field soil
Soil series	Hafizabad	Lyallpur
Sub-group	Typic Calciargid	Typic Calciargid
Soil texture	Loam	Silt Loam
Soil pH (1:1)	7.51	7.87
EC (1:1) dS m^{-1}	0.51	0.81
Organic matter (%)	0.54	0.65
$CaCO_3$-equivalent (%)	1.65	3.4
Olsen -P (mg kg^{-1})	7.50	8.31

in completely randomized design in a net house. Basal nitrogen was equalized in all treatments at 135 mg kg^{-1} by adding required N as urea. Eight seeds of wheat (cv. Inqelab-91) were sown in each pot and only 5 seedlings per pot were maintained when they reached the 4-leaf stage. Additional nitrogen @ 50 and 65 mg kg^{-1} as urea solution was applied at late tillering and boot stage, respectively. Soil moisture was maintained at 75% of maximum water holding capacity throughout the growth period by the method of weighing. Two plants were harvested at late tillering stage while 3 plants were harvested at maturity. Grain was separated from straw and both were dried in an oven at 70ºC to record dry weight.

Field study

A field experiment was conducted at NIAB farm to confirm the results of the pot study with some selected treatments. As a standard chemical fertilizer, DAP was applied at the rate of 45 kg P ha^{-1} while the industrial waste was mixed with two chemical P sources, DAP or SSP in either a 2:1 or 1:1:1 P ratio (Table 3); these were incorporated into the soil at sowing. The experimental plots (7x3 m) were laid out in randomized complete block design with 4 replications. Seeds of wheat (cv. Inqelab-91) were sown with a single hand drill at the rate of 120 kg ha^{-1} in rows 30 cm apart. Urea was top-dressed at first irrigation, 4 weeks after sowing, to equalize the N rate at 100 kg ha^{-1} after adjusting the N added in the various organic and inorganic P sources. Additional N as urea @50 kg ha^{-1} was applied at second irrigation, 3 weeks later. Hoeing and weeding were done uniformly in all treatments. The third and fourth irrigations were both somewhat delayed due to closure of the irrigation canal. At maturity, data on plant height, number of tillers m^{-2} and thousand-grain weight (TGW) was collected. For the estimation of grain and straw yield, an effective area of 5x2 m was harvested in each plot.

Chemical analysis

Samples of dry matter, grain and straw from pot or field experiments were ground to 40 mesh powder in a Wiley mill and one gram portions of dry matter or grain and 2 gram portions of straw were digested in tri-acid mixture (Jackson, 1962). Phosphorus concentration was determined by measuring the intensity of molybdo-vanadate yellow color using a spectrophotometer. Phosphorus uptake was obtained by multiplying P concentration with yield. Phosphorus fertilizer

Table 2. Effect of integrated use of industrial waste and chemical fertilizer on dry matter yield, concentration and uptake of P by wheat at late tillering stage of growth.

Treatment[1]	Dry matter yield	P concentration	P-uptake
Source	(g pl.$^{-1}$)	(mg g^{-1})	(mg pl.$^{-1}$)
Control	0.29 c	1.84 d	0.48 d
SSP	2.60 a	4.29 b	11.14 ab
FC+SSP	2.91 a	3.00 c	8.69 b
PW+SSP	2.97 a	4.92 a	14.59 a
DCP+SSP	1.45 b	3.10 c	4.49 c
FC+PW+SSP	2.90 a	4.49 b	13.05 a

[1] **SSP = single super phosphate**
DCP = di-calcium phosphate
FC = filter cake
PW = poultry waste

Figures sharing common letters in a column do not differ significantly at P<0.05 as determined by DMR test.

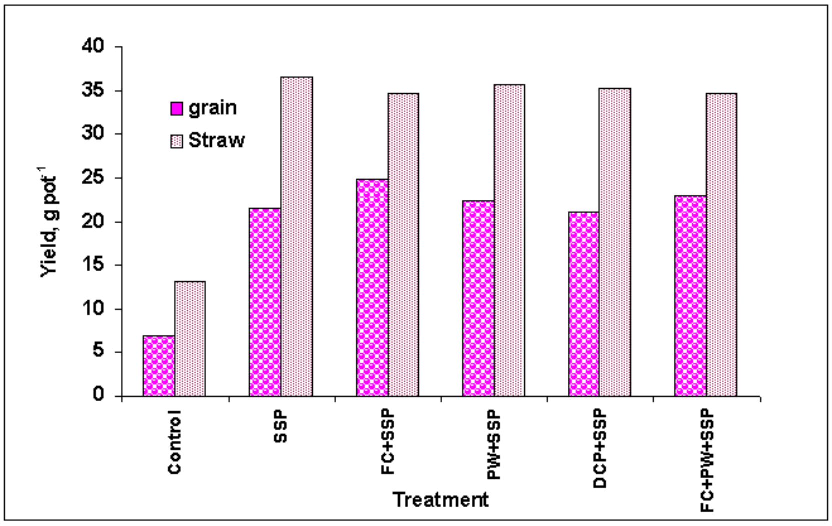

Figure 1. Effect of integrated use of fertilizer on the grain and straw yields of wheat grown in pots

efficiency (PFE) was calculated from the formula:

PFE = {P uptake (fertilized) - P uptake (control)}/ Amount of P applied

The data obtained were analyzed statistically using MSTAT-C software and the means were compared using the Duncan multiple range test.

Results and Discussion

Pot study

The effects of P application, through chemical source (SSP) alone or after integration with industrial waste, on the dry matter yield (DMY) and P-uptake by wheat at late tillering stage of growth are given in Table 2. It is evident that application of P from either source or combination increased the DMY of wheat over control. Integrated use of waste and chemical fertilizer produced DMY equivalent to that from SSP alone, except for DCP+SSP. However, the concentration and uptake of P by plants differed significantly due to sources of P application. Phosphorus concentration and uptake were highest for PW+SSP followed by FC+PW+SSP combination, but P-uptake from both combinations was statistically similar and higher than that of FC+SSP. Plants receiving P from the DCP+SSP combination showed significantly lower P-uptake than all other P treatments. This indicates that P availability to plants through integrated use of these two inorganic sources was low. The possible reason could be the low water solubility of DCP that could not meet the early high P demand and thereby resulted in low P-uptake by plants. In an incubation study, Akhtar and Alam, (2001) found that SSP was more readily available than DCP under an alkaline calcareous soil environment for the first three weeks; however, after four weeks, P availability from DCP improved and remained significantly higher than that of SSP up to 120 days of incubation. The increased P availability with time helped improve plant growth and increased straw and grain yield (Figure 1). Integrated use of organic/ inorganic waste and SSP in 2:1 P ratio produced grain and straw yields equivalent to that of chemical fertilizer alone. Similar results were obtained in an earlier study where DMY and P-uptake were found to be lower in the DCP compared to the SSP treatment at the early growth stage, but at maturity the two sources produced similar yields (Alam and Shah, 2002).

Table 3. Effect of integrated use of industrial waste and chemical fertilizer on concentration and uptake of P and P-fertilizer efficiency at maturity.

Treatment[1]	P concentration ($mg\ g^{-1}$)		P-uptake ($mg\ pot^{-1}$)		Total P- uptake ($mg\ pot^{-1}$)	PFE (%)
	Grain	Straw	Grain	Straw		
Control	2.12 d	0.16 d	14.95 b	2.05 e	17.0 d	-
SSP	3.96 a	0.27 b	85.63 a	9.90 b	95.5 ab	15.70 ab
FC+SSP	2.70 b	0.15 d	67.17 a	5.33 d	72.5 c	11.60 c
PW+SSP	3.86 a	0.44 a	85.73 a	15.87 a	101.6 a	16.92 a
DCP+SSP	3.40 b	0.19 c	71.54 a	6.88 c	78.4 bc	12.28 bc
FC+PW+SSP	3.06 c	0.19 c	69.95 a	6.54 cd	76.5 bc	11.90 bc

[1] See details given in table 2
Figures sharing common letters in a column do not differ significantly at $P<0.05$ as determined by DMR test.

Application of P from either source or their combination significantly increased the concentration of P in straw and in grain (Table 3). Integrated use of PW and SSP resulted in the highest, while the FC+SSP combination resulted in the lowest P concentration and P-uptake, both in straw and in grain. Other combinations of P sources resulted in P-uptake equivalent to chemical source (SSP) applied alone. The possible reason of higher yield and P-uptake with PW+SSP combination might be due to release of organic P as a result of acids produced during decomposition as well as the chelating effect of organic complexes with P (Trivedi *et al*., 1995). The variable P-uptake obtained due to application of various combinations of the fertilizers, affected the P-fertilizer efficiency (PFE); these ranged from 11.6 to 16.9%. The PW+SSP combination resulted in the highest PFE, which was not significantly different from SSP applied alone, while the FC+SSP combina-

Table 4. Effect of integrated use of industrial waste and chemical fertilizer on some yield components, wheat yield, total P-uptake and P-fertilizer efficiency

Treatment[1]	Yield components			Yield		Total P-uptake ($kg\ ha^{-1}$)	PFE[2] (%)
	Plant height (cm)	Tillers ($no.m^{-2}$)	TGW[3] (g)	Grain ($t\ ha^{-1}$)	Straw ($t\ ha^{-1}$)		
Control	101 a	248 d	36.5 a	4.2 b	9.8 c	14.40 c	-
DAP	106 a	353 b	37.9 a	5.7 a	12.2 a	23.21 a	19.58 a
FC+SSP	107 a	304 c	39.3 a	5.2 a	11.0 abc	19.65 b	11.67 a
PW+DCP	105 a	401 a	38.1 a	5.3 a	11.2 abc	20.03 ab	12.52 a
DCP+DAP	106 a	337 c	39.2 a	5.4 a	10.5 bc	20.42 ab	13.38 a
FC+PW+SSP	104 a	317 c	38.0 a	5.3 a	11.6 ab	21.53 ab	15.84 a

[1] DAP = di-ammonium phosphate
SSP = single super phosphate
DCP = di-calcium phosphate
FC = filter cake
PW = poultry waste
[2] PFE = P-fertilizer efficiency
[3] TGW = thousand grain weight
Figures sharing common letter in a column do not differ significantly at $P<0.05$ as determined by DMR test.

Table 5. Economics of integrated use of industrial waste and chemical fertilizers

Treatment[1]	Cost of P fertilizer	Value of wheat (Rs.ha^{-1})[2]			Increase in gross income Total	Value: cost ratio (Rs.ha^{-1})
		(Rs.ha^{-1})	Grain	Straw		
Control	-	31,470	7,408	38,878	-	-
DAP	3,156	42,802	9,189	51,991	13,113	4.15
FC+SSP	1,371	39,390	8,283	47,673	8,795	6.41
PW+DCP	1,102	39,802	8,439	48,241	9,363	8.49
DCP+DAP	2,914	40,552	7,885	48,437	9,559	3.28
FC+PW+SSP	1,264	39,607	8,725	48,332	9,454	7.52

[1] **DAP = di-ammonium phosphate @ Rs.14.10 kg^{-1}**
SSP = single super phosphate @ Rs. 5.00 kg^{-1}
DCP = di-calcium phosphate @ Rs. 11.50 kg^{-1}
FC = filter cake @ Rs.125.00 t^{-1}
PW = poultry waste @ Rs. 90.00 t^{-1}
[2] **Straw @ Rs. 0.75 kg^{-1}, Grain @ Rs. 7.50 kg^{-1}, 1 US$ = 58 Rs.**

tion resulted in a significantly lower P-fertilizer efficiency.

Field study

Under field conditions, the efficiency of the use of various combinations of industrial wastes and chemical fertilizer were compared with DAP, which is the dominant P source used in Pakistan (Ahmad, 2000). The data in Table 4 indicate that different combinations of organic and inorganic fertilizers resulted in grain yields that were equivalent to that obtained with standard fertilizer DAP. However, application of DAP alone resulted in a significantly higher straw yield compared to the DCP+DAP combination. The yield components studied did not differ except that the DCP+DAP combination produced the highest number of tillers m^{-2} but this did not increase the yield over DAP alone. Phosphorus application from any P source or combination significantly increased total P-uptake as compared to the control. Again, the FC+SSP combination resulted in the lowest P-uptake among all P treatments. Application of DAP alone resulted in the highest total P-uptake, but this was not statistically different from most other P sources. Due to the relatively low variation in P-uptake, the PFE varied only from 11.7 to 19.6% and this was not significantly different among P sources.

In order to determine the profitability of using different combinations of organic and chemical fertilizer, their cost of production and the value cost ratio (VCR) were calculated (Table 5). It was observed that the PW+DCP combination resulted in the highest VCR of 8.49, followed by the FC+PW+SSP and the FC+SSP combinations, while the lowest value was recorded by the DCP+DAP combination which was lower than the DAP alone. Thus, the organic waste FC or PW could be integrated with an inorganic source of P such as SSP or DAP in order to reduce the cost of P fertilizer and increase net income.

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