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Residual effect of organic wastes and chemical fertilizers on wheat yield under wheat-maize cropping sequence

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Abstract

A field experiment was executed to study the residual effect of organic wastes on wheat (Triticum aestivum L.) yield applied to wheat – maize cropping system consecutively for two years either alone or in combinations with NPK mineral fertilizers. All organic wastes [municipal solid waste (MSW), crop residues (wheat/ maize), filter cake (industrial waste) and farm yard manure (FYM)] were applied at 3 t C ha^{-1}. Recommended NPK fertilizers were applied to wheat at120-90-60 and maize at 140-90-60 kg ha^{-1} during the experimental period. After two years, wheat cv. Bathoor was sown on same plots without any fertilizer application. Data depicted that all organic wastes exhibited considerable residual effect on yield of wheat. Among organic wastes, filter cake increased grain yield by 42% while MSW by 39% over control. Overall, MSW + full NPK and filter cake + full NPK treatments resulted in higher residual impact on wheat biomass, straw and grain yields under irrigated conditions. It is concluded that organic wastes, specifically filter cake and MSW can have long - term impact on crop productivity.

Keywords: *Wheat yield, organic wastes, mineral fertilizers, residual effect, integrated effect*

Introduction

Wheat (*Triticum aestivum* L.) is the major staple food crop of Pakistan grown on an area of 8.64 mha with an average grain yield of 2.71 t ha^{-1} (MINFAL, 2012). Maize (*Zea mays* L.) is another important cereal crop of Pakistan grown in rotation with wheat on 1.08 mha with an average grain yield of 4.0 t ha^{-1} (MINFAL, 2012). Both crops are highly nutrient exhaustive and their continuous cropping deplete the soil fertility. The prouctivity and fertility of soils are declining rapidly due to continuous intensive cereal based cropping system, imbalanced use of chemical fertilizers, their unavailability at proper time (Shah *et al.*, 2003) and intensive cultural practices (Mohammad *et al.*, 2008).

Ahmad and Rashid (2004) reported that about 90% cultivated soils of pakistan are deficient in nitrogen and phosphorus and 40% in potassium. Nitrogen (N) deficiency is one of the major yield limiting factors for crop productivity (Shah *et al.*, 2003) and hence N fertilizer application is an essential input for crop productivity (Ahmad, 1998; Idris and Mohammad, 2001). Moreover, the non-scientific fertilizer application practices adopted by farmers result in N and other essential nutrients losses (Iqbal *et al.*, 1995). The low utilization of N from chemical fertilizers due to undesirable soil and environmental conditions is considered as one of the major limitations for sustainable soil fertility, crop yields and improved environment (Mohammad *et al*., 2006).

Application of different organic wastes e.g. manures, plant residues and other waste materials is an effective management strategy to improve soil fertility, biological and chemical properties of soils, and phytoavailability of micronutrients (Goyal *et al.*, 1999; Rengel *et al*., 1999; Schulin *et al*., 2009). Moreover, they enhance nutrient use efficiency, increase ion exchange/water storage capacity and sustain high crop productivity (Khoshgoftarmanesh *et al*., 2010). In Pakistan, there is no proper organic wastes collection and disposal system, hence, wastes are polluting the environment. One option is that these wastes should be used as a source of nutrients on agricultural lands. Since organic materials slowly release the nutrients, the integrated use of organic wastes with chemical fertilizers is reported more beneficial (Alam *et al*., 2005). Long term use of organic and inorganic fertilizer is important for agricultural sustainability due to their residual effects on soil properties and crop productivity. Ramamurthy and Shivashankar (1996) reported that organic and inorganic fertilizers applied to preceding crops had a remarkable residual effect on yield and yield contributing components of succeeding crop. It was concluded that the residual effect of green manure may double the yield of subsequent cereal crop (Ghosh, 1980). In another study, residual effect was equivalent to 20% of NPK as chemical fertilizers on the yield of succeeding wheat and winter maize in rice-wheat and rice-maize cropping systems (Prasad, 1994).

For long term sustainability of soil fertility and environment, it seems a better option to use organic wastes

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alone or in combination with mineral fertilizers to get maximum benefits from its residual effect on crop productivity. The present study was therefore undertaken to assess the residual effect of organic wastes and mineral fertilizers on wheat yield applied to wheat-maize cropping system for two consecutive years.

Materials and Methods

Background of the study

The experimental site is situated at Research Farm of the Nuclear Institute for Food and Agriculture (NIFA), Tarnab located at $34^0$01'N and $71^0$50' E with an altitude of 400 m above sea level in the Peshawar valley of Khyber Pakhtunkhawa, Pakistan. The area has a semi-arid climate with cool winter and warm to hot summer. The mean maximum temperature in summer surpasses 40 °C (104 °F) while minimum is around 25 °C (77 °F). The mean minimum temperature during winter is 4 °C (39 °F) and maximum 18.35 °C (65.03 °F). Soil of the experimental site (Table 1) was clay loam (Order: *Inceptisols*, Sub order: *Ustepts*, Soil great group: *Haplustepts*, Soil Sub group: *Udic Haplustepts*, Family: *Fine, mixed, hyperthermic, Udic Haplustepts, Taru* Soil Series (US Soil Taxonomy)), alkaline in reaction (pH, 7.8) and non saline (EC_e, 0.36 dSm^{-1}).

Table 1: Physicochemical properties of experimental soil (0-15 cm) before application of treatments

Property	Value
Sand	21%
Silt	43%
Clay	36%
Textural Class	Clay Loam
pH (1:2.5)	7.8
Bulk density	1.24 g cm^{-3}
EC_e (1:2.5)	0.36 dS m^{-1}
Total organic carbon	0.88%
Organic Matter	1.2%
Total Nitrogen	0.08%
Total mineral N	42 µg g^{-1} soil
Available Phosphorus (P_2O_5)	11 µg g^{-1} soil
Available Potassium (K_2O)	80 µg g^{-1} soil
Available Zn	1.06 µg g^{-1} soil
AB-DTPA Extractable Fe	7.72 µg g^{-1} soil
Lime	19%

Four organic solid wastes were applied to crops under wheat-maize cropping system during 2010-12. Farm yard manure (well rotten, from cattle source) was collected from the local farmers. The wheat and maize crops residues were collected after each harvest of the same crop. Municipal solid waste (MSW) was collected from dumping ground at Ring Road, Peshawar and after drying, was sorted into decomposable and non-decomposable material. The unwanted particles like plastic, glass and stone were removed as non-decomposable material from collected MSW and well decomposed MSW was used in the study. Filter cake was collected from Khazana Sugar Mill, Peshawar, Pakistan. All organic wastes, after collection, were spread on plastic sheet under shade for drying. After air drying, a representative sample was taken and transferred to the laboratory for further processing. After drying in oven at 70 ^oC for 24 hours, all waste samples were ground to powder in a Wiley Mill and analyzed for N (Bremner and Mulvaney, 1982) and P (Page *et al*., 1982). Total C was determined by dichromate digestion method in a microwave oven (Azam and Sajjad, 2005) and the data are presented in Table 2. Organic waste materials were applied at 3 t C ha^{-1} (Muhammad *et al.*, 2011) to designated treatment plots during the both seasons. Crop residues were chopped into small pieces (6- 8 mm) before they were applied to soil. The waste materials were well mixed and inverted in to soil before sowing. The treatments applied to preceding crops are given in Table 3.

The soil analyses after 2 years long experiment and before sowing of test (wheat) crop are presented in Table 4, 5 and 6. The maximum TOC contents (9.5 t ha^{-1}) were retained by MSW + full NPK treatment followed by 8.4 t ha^{-1} by filter cake + full NPK treatment (Table 5). However, the highest total mineral N contents were recorded by filter cake + full NPK followed by filter cake + half NPK and MSW + full NPK treatments (Table 6).

Experimental details of residual study

Wheat (cv. Bathoor) was sown in November 2012 without any further fertilizer application on same plots where organic amendments were applied to wheat and maize crops for two consecutive years (2010-12). The objective of the study was to find out the residual effect of all treatments on wheat yield under irrigated conditions. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The treatment plot size was kept 3×5 m^2. Recommended row to row distance (30 cm) was maintained. Canal water was used for irrigation and applied as and when needed. Weeds were controlled manually. The crop was harvested at physiological maturity and yield data (total dry matter yield, straw yield and grain yield) were recorded.

The data were statistically analyzed by using analysis of variance (ANOVA) technique. In case of significant differences, Least Significance Difference (LSD) test was applied at the probability level of $p \leq 0.05$. (Steel and Torrie, 1984).

Table 2: Chemical analysis of organic wastes used in the study

Organic Waste	Total C	Total N	C:N	P_2O_5	K_2O
	%			%	
Maize Residues	46	0.78	59.0	0.1	1.50
Wheat Residues	50	0.50	100	0.1	2.0
FarmYard Manure	11	0.50	22	0.37	1.20
Municipal Solid waste	7	0.72	9.7	0.25	1.25
Filter Cake	26	3.40	7.6	1.12	1.30

Table 3: Treatments for wheat – maize cropping sequence

Treatment		Wheat	Maize
T_1	Control	✓	✓
T_2	PK only (Recommended dose)	(90:60) kg ha^{-1}	(90:60) kg ha^{-1}
T_3	Farm Yard Manure (F.Y.M)	✓	✓
T_4	Crop Residues	Maize residues	Wheat residues
T_5	Municipal Solid Waste (MSW)	✓	✓
T_6	Filter cake (Industrial waste)	✓	✓
T_7	NPK (recommended dose)	✓	✓
T_8	F.Y.M (3 t C ha^{-1}) + ½ NPK *	✓	✓
T_9	Crop residues (3 t C ha^{-1}) + ½ NPK	Maize residues + ½ NPK	Wheat residues +½ NPK
T_{10}	MSW (3 t C ha^{-1}) + ½ NPK	✓	✓
T_{11}	Filter cake (3 t C ha^{-1}) + ½ NPK	✓	✓
T_{12}	F.Y.M (3 t C ha^{-1}) + full NPK **	✓	✓
T_{13}	Crop residues (3 t C ha^{-1}) + full NPK	Maize residues + full NPK	Wheat residues + full NPK
T_{14}	MSW (3 t C ha^{-1}) + full NPK	✓	✓
T_{15}	Filter cake (3 t C ha^{-1}) + full NPK	✓	✓

Where 1/2 NPK* = half of recommended dose, Full NPK** = Recommended dose

Results and Discussion

Dry matter yield of wheat (DM)

The influence of residual effect of organic solid wastes and NPK mineral fertilizers on DM yield of wheat was statistically significant ($p \leq 0.05$) among treatments (Table 7). Greater dry matter yield of wheat was obtained where full dose of NPK was applied along with filter cake or MSW to preceding crops.

The comparison of residual impact within organic wastes revealed that filter cake produced 35% more yield over control followed by MSW and FYM. However, crop residues alone had dry matter yield statistically equal to that received from FYM alone treatment. Budher *et al.* (1991) reported that higher rice yields were obtained with organic manures indicating residual effect of manures on crop yield in rice- wheat rotation.

Residual effect of organic wastes integrated with NPK fertilizers improved the wheat dry matter yield. Filter cake and MSW along with full dose of NPK, enhanced the dry matter yield by 39% over NPK alone treatment, whereas crop residues with full NPK increased the yield by 25% and FYM by 18% along with NPK.

Planned mean contrast analyses (Table 8) revealed that all the treatments had highly significant residual impact on wheat dry matter yield as compared to control. All organic wastes along with NPK (half and full) combinations produced highly significantly ($p \leq 0.01$) yield than organic wastes sole treatments. The data further showed that organic fertilizers along with half NPK produced yield (13633 kg ha^{-1}) almost equal to NPK mineral fertilizer treatment (13350 kg ha^{-1}). However, organic wastes with full NPK dose produced dry matter yield highly significant to NPK sole treatment.

Table 4: Total organic carbon (TOC) at 0-15 cm depth as influenced by organic and inorganic sources after two years of application

Treatment	TOC (t ha^{-1}) †
Farm Yard Manure	4.13 c
Crop Residues (wheat/maize)	3.75 c
Municipal Solid Waste	6.00 b
Filter cake	7.75 a
NPK(recommended)	2.76 d
LSD (0.05)	0.79

† = TOC (organic/inorganic fertilizer) – TOC (control)

Table 5: Total organic carbon at 0-15 cm depth as affected by NPK fertilizers after two years of application

Treatment	TOC (t ha^{-1}) †
Farm Yard Manure + full NPK	6.50 c
Wheat Residues + full NPK	4.87 d
Municipal Solid Waste +full NPK	9.46 a
Filter Cake +full NPK	8.37 b
LSD	0.61

† = TOC (Organic waste + full NPK) - TOC (full NPK)

The results are supported by the findings of Rathore *et al.* (1995) who reported that residual effect of organic waste (farmyard manure) in combination with inorganic fertilizers was significant on yield of succeeding wheat crops. Cooke (1970) concluded that farmyard manure showed very good residual effect on following crops as it added residues of soil nutrients required for plant growth. Moreover, comparison of residual effect of organic and inorganic fertilizers revealed that mineral N fertilizer had residual effect only for one growing season whereas manuring with phosphorus and potassium had residual effect that lasts for many years. The reason could be that nutrients present in organic materials are not fully available to the crops in the season of its application (Ramamurthy and Shivashankar, 1996).

wheat straw yield is depicted in Table 7. The data showed that all organic sources applied with NPK had statistically equal significant effect on straw yield.

Among various organic wastes, crop residues used as sole application had the least residual effect on wheat straw yield (8517 kg ha^{-1}). Maximum increase (32.7%) in straw yield over control was obtained by filter cake, followed by 27.9% and 23.2% by MSW and FYM treatments. However the crop residues produced minimum increase (16.9%) over control.

As far as straw yield is concerned, residual effect of organic wastes integrated with full NPK mineral fertilizers was significant as compared with NPK mineral fertilizers application. The plots applied with filter cake gave maximum increase (26.8%) in straw yield over sole NPK fertilized plots and followed by 25% and 14.3% increase by MSW and crop residues.

Planned mean contrast analyses of data showed that residual effect of all the organic wastes alone or in combination with NPK fertilizers resulted in highly significant increase in wheat straw yield over the control treatment (Table 8). All organic wastes (except filter cake) with NPK fertilizers (either half or full) produced significantly higher yield than the organic waste sole

Table 6: Mineral N contents of soil (0-15 cm) after two years application of treatments

Treatments†	Total mineral N	Nitrate-N kg ha^{-1}	Ammonium-N
Control	58.29 l	31.39 f	26.9 bcd
PK	56.93 m	30.65 f	26.3 bcd
NPK	74.36 i	61.23 b	13.1 e
FYM	65.02 k	43.34 e	21.6 d
FYM + half NPK	74.42 i	52.52 d	21.9 d
FYM + full NPK	86.89 d	59.45 b	27.4 bc
Crop Residues	66.47 j	31.02 f	35.4 a
Crop Residues + half NPK	75.83 g	53.53 cd	22.3 cd
Crop Residues + full NPK	84.79 f	53.77 cd	31.0 ab
MSW	75.47 h	48.83 de	26.6 bcd
MSW+ half NPK	84.78 f	53.54 cd	31.2 ab
MSW+ full NPK	91.05 c	69.37 a	21.7 d
Filter Cake	85.18 e	58.28 bc	26.9 bcd
Filter Cake + half NPK	93.69 b	66.92 a	26.7 bcd
Filter Cake + full NPK	97.41 a	72.00 a	25.4 cd
LSD	0.1382	5.48	5.5

†= Where FYM = Farm yard manure, MSW = Municipal solid waste, NPK= Recommended dose; All organic wastes were applied at 3t C ha^{-1}; Means sharing similar letter (s) in a column do not differ significantly at *p=0.05*

Straw yield of wheat

Residual effect of various organic wastes alone and in combination with inorganic NPK mineral fertilizers on

treatments. Integrated effect of organic fertilizers plus half NPK mineral fertilizers showed non-significant results in comparison to inorganic NPK mineral fertilizers (full dose). Residual effects of fertilizers applied on the same site for

consecutive many years, affect soil chemical properties, improving soil quality and crop yields (Ginting *et al*., 2003; Tabibian *et. al.*, 2012). According to Kaushik *et al.* (1984), organic fertilizers (manures) resulted in good residual impact on yield of crop in paddy wheat rotation. In some studies, it has been reported that the residual effect of green manure may double the yield of succeeding cereal crop (Ghosh, 1980).

dose. In addition, crop residues and FYM along with full NPK increased grain yield by 62.5% and 58.4% over NPK fertilizers treatment. One of the major reasons in enhancing crop yield is might be due to addition of nutrients in soil by application of organic fertilizers. The soil analyses after 2 years experiment have proved that MSW+ full NPK and filter cake + full NPK treatments retained higher soil total organic carbon (Table 4 and 5) and total mineral N (Table 6)

Table 7: Residual effect of organic wastes and NPK mineral fertilizers on wheat yield during 2012-13

Treatment †	Dry matter yield	Straw yield	Grain yield
	kg ha^{-1}		
Control	9750 h	7283 h	2466 g
PK	10500 h	7750 gh	2750 g
NPK	13350 cde	10083 abcd	3266 def
FYM	12167 fg	8977 ef	3190 f
FYM+ half NPK	13533 bcde	10017 abcd	3516 bcde
FYM+NPK	14000 abc	10267 abc	3733 ab
Crop Residues	11750 g	8517 fg	3233 ef
Crop Residues +half NPK	13000 def	9467 cde	3533 bcd
Crop Residues + full NPK	14250 ab	10483 ab	3766 ab
MSW	12750 ef	9317 def	3433 cdef
MSW+ half NPK	14250 ab	10617 a	3633 bc
MSW+ full NPK	14750 a	10783 a	3966 a
Filter Cake	13167 cde	9667 bcde	3500 bcde
Filter Cake + half NPK	13750 bcd	10017 abcd	3733 ab
Filter Cake + full NPK	14767 a	10833 a	3933 a
LSD	836.87	903.79	294.97

†= Where FYM = Farm yard manure, MSW = Municipal solid waste, Crop residues (wheat, maize). All organic wastes were applied at 3t C ha^{-1}, Means sharing similar letter (s) in a column do not differ significantly at p=0.05

Grain yield of wheat

The data revealed that overall, MSW + full NPK and filter cake + full NPK treatments resulted in the highest residual impact on grain yield of 3966 kg ha^{-1} and 3933 kg ha^{-1} followed by crop residues in combination with full NPK, FYM with full NPK and filter cake with half NPK treatments (Table 7).

Residual impact of various organic wastes alone showed that filter cake and MSW resulted in higher grain yield (3500 and 3433 kg ha^{-1}) with 41.9% and 39.2% increase over control. However, crop residues and FYM increased grain yield by 31% and 29.3% over control. Mehdi *et al*. (2011) reported that among organic manures as sole treatments, FYM applied at 20 t ha^{-1} to rice had better residual impact on wheat grain yield.

Residual effect of organic wastes after addition of half and full NPK fertilizers for preceding crops improved wheat grain yield. Maximum increase of 87.5% in grain yield was recorded by MSW plus NPK fertilizers (full dose) followed by 83.4% by filter cake with NPK over NPK recommended that enhanced the wheat yield. Bharadwaj and Omanwar (1994) reported that organic fertilizer (manures) addition increased the soil nutrients including available N, P, K in soil, increased in organic matter content (Tabibian *et al*., 2012), soil fertility and other properties (Mkhabela and Warman, 2005; Karami *et al*., 2009).

MSW showed a better residual response in increasing wheat yield as it contains a wide range of macro and micro nutrients required for plant growth (Shah and Anwar, 2003). In addition, it improves the physical, chemical and biological properties of the soil by supplying organic matter (Roca-Pérez *et al*., 2009).

Planned mean contrast analyses (Table 8) indicated that grain yield was improved significantly higher by organic wastes plus NPK mineral fertilizers (half +full) in contrast with organic wastes alone. The data further revealed that the residual impact of organic and inorganic sources on wheat grain yield was statistically equivalent. The integration of organic fertilizers with half and full NPK fertilizers produced highly significant impact on grain yield as compared to NPK mineral fertilizers (full dose).

Table 8: Planned mean contrasts of residual effect of organic and inorganic sources on wheat yield (kg ha^{-1})

Treatment †	D.M.Y.	S.Y.	G.Y.	Planned mean comparisons
Control	9750 **	7283**	2466**	Control vs. Rest
Rest	13285	9771	3514	
FYM sole	12166**	8976**	3190 **	FYM alone vs. FYM with NPK (half + full)
FYM +NPK	13767	10142	3625	
Crop Residues sole	11750**	8516**	3233**	C.R alone vs. C.R with NPK (half + full)
Crop Residues + NPK	13625	997	3650	
MSW sole	12750**	9316**	3433**	MSW alone vs. MSW with NPK (half + full)
MSW + NPK	14500	10700	3800	
Filter Cake sole	13166**	9666 ns	3500*	Filter cake alone vs. Filter cake with NPK (half + full)
Filter Cake + NPK	14258	10425	3833	
Organic	12458*	9119*	3339 ns	Organic vs. Inorganic
Inorganic	13350	10083	3267	
Organic + full NPK	14441*	10591 ns	3850 **	Organic + full NPK vs. Inorganic
Inorganic	13350	10083	3267	
Organic + half NPK	13633 ns	10029 ns	3604**	Organic + half NPK vs. Inorganic
Inorganic	13350	10083	3267	

† Where FYM = Farm yard manure, MSW = Municipal solid waste, C.R = Crop Residues (wheat, maize), DM.Y= Dry matter yield, S.Y = Straw Yield, G.Y = Grain Yield. , ** = highly significant at 1%, * = significant at 5%, ns = non significant.

The results are in line with Talathi (2001) who reported that the residual effects of 50% NPK mineral fertilizers (recommended dose) + 50% N received through FYM was more effective, resulting in increased dry matter yield, grain and kernel, as well as stover yield of a succeeding maize and groundnut crop.

According to Iqbal *et al*. (2008) the residual effect of the poultry litter applied to wheat was significant on the subsequent maize crop as application of poultry litter had a good residual effect on soil fertility resulted in enhanced nutrients uptake by maize crop.

Conclusion

The data have shown that combined use of organic wastes with chemical fertilizers exhibited comparatively higher residual effect on wheat yield than sole organic wastes treatments. Among organic wastes, municipal solid waste and filter cake integrated with full NPK mineral fertilizers were outstanding in terms of residual effect enhancing wheat productivity under irrigated conditions. Moreover, these treatments also have retained higher soil total organic carbon and total mineral N after 2 years long experiment that enhanced the wheat yield.

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