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Integrated use of MSWC and phosphorus for improving productivity of rice-wheat rotation in salt affected soils

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Abstract

Salt affected soils are widely spread around the globe and recognized as threat for food security due to low crop productivity. Salts can be ameliorated chemically or biologically. Organic/biological amendments improve the granulation, water holding capacity, infiltration rate and hydraulic conductivity besides leaching salts. Field experiments were carried out to investigate the usefulness of integrated nutrient management approach in moderately salt affected soils. Inorganic and organic sources of plant nutrients were used in rice-wheat cropping system. Comprehensive survey was carried out to select the site for rice-wheat rotation in permanent layout. Results revealed that combined application of municipal solid waste compost (MSWC) with mineral fertilizer i.e. site specific use of mineral fertilizer with MSWC in 80:20 ratio and integrated use of chemical fertilizers with MSWC in 80:20 ratio enhanced paddy / grain yield and improved the fertility status of the soil. Site specific and integrated use of chemical fertilizer with MSWC in 80:20 ratio produced the highest biomass/paddy and biomass/grain yield i.e. 11.73/2.79and 5.48/2.65 Mg ha^{-1}at Jhugian Pir, District Hafizabad, respectively. Pre and post-harvest soil analysis was carried after transplanting / sowing of each crop. Integrated and site specific use of MSWC slightly reduced the $pH_{s,}EC_e$ and SAR compared to the initial status of soil while organic matter, available P, extractable K and Zn was enhanced from the initial values. A slight increase in heavy metals such as Co, Cu and Pb was observed with the application of MSWC.

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Introduction

Soils of arid and semi-arid regions in general and that of salt affected soils in particular are poor in organic matter resulting in poor soil health and reduced crop yields. Situation can be improved by the addition of organic manures along with mineral fertilizers. The mineral fertilizers can only be used effectively if soils have an optimum level of organic matter. The addition of compost especially the municipal solid waste compost (MSWC) to agricultural land has become a global practice to enhance soil organic matter (SOM) and reduce invisible pollution.

The maintenance of optimum soil organic matter is vital to retain favorable soil physical conditions (Ros *et al.*, 2006; Madrid *et al.*, 2007). The burning of municipal wastes for fuel/energy and exploitation of crop residue as animal feed diminished the traditional sources of organic matter (Lal, 2005; Skoulou and Zabaniotou, 2007; Tejada *et al.,* 2008). Intensive profit oriented cropping system reduces the chances of green manuring and minimized the invisible return to farmers (Lal, 2005; Tejada *et al.,* 2008). In developing countries like Pakistan, the huge masses of municipal waste are deposited in the unlined open landfills. This practice of disposal is raising public health concerns due to increase air and water pollution. Composting of MSW can reduce the open landfill disposal and associated environmental impacts (Noble and Coventry, 2005). The application of MSWC to arable land enhances organic matter, improves nutrients status and physical properties (Alvarenga *et al.*, 2007; Jilani, 2007; Weber *et al.*, 2007). Sole use of MSWC to satisfy the crop nutrient needs is impractical and may result in heavy metals accumulation. Combined application of MSWC and chemical fertilizer has proved to be effective, environment friendly and sound nutrient management strategy to uphold crop productivity and SOM level. Application of MSWC reduces the hazardous soil erosion and leaching of nutrients (Blum *et al.,* 2004; Van-Camp *et al.,* 2004). The MSWC can compensate the mineral fertilizers due to presence of nutrients and improve the physical conditions as organic content (Tzortzakis *et al.,* 2012).

Phosphorus is the second most essential crop nutrient and generally deficient in most of Pakistani soils due to its ready fixation. It has been reported that about 75-90% of added P-fertilizer is precipitated/fixed the 80% of added P fertilizer is fixed with metal complexes in calcareous soils like Pakistan (Hinsinger, 2001).The traditional application of P-fertilizer results in more P losses (precipitated/fixed) due to anion reactivity. Site specific nutrient management is a strategy adopted for sustainable agriculture and to lessen the nutrient losses. Phosphorus fixation tendency of soils is highly varied due to spatial availability of cations responsible of P-fixation. The variation of available P and P-fixation tendency of soil should be addressed before fertilizer application to minimize the P losses from soil. Site-specific application of phosphorus should be carried out to sustain the crop yields and to improve the P-use efficiency (McLean *et al.,* 1982; Juang *et al.,* 2002).

Soil P level based determination of fertilizer requirement is considered an economically and environmentally efficient method to maintain the appropriate P level in the soil (Mc Lean *et al.,* 1982; Juang *et al.,* 2002). Furthermore, recent studies also suggested that MSWC application rates should be formulated on the basis of crop P requirements rather than on N requirement of crop. Field experiments are conducted to investigate the usefulness of site-specific nutrient management approach for moderately salt affected soils under rice-wheat cropping system.

Materials and methods

For sites selection, comprehensive soil survey was carried out and soil was selected at Jhugian Pir District Hafizabad. A permanent layout was framed for rice-wheat cropping system following randomized complete block design (RCBD). The initial soil status of the selected site is given in Table 1. The recommended standard test phosphorus (STP) target value of 16 mg kg^{-1} was adjusted from McLean *et al.* (1982) considering the P fixation capacity of soil. The P fixation factor was used as multiplier of differences to calculate the amount of P fertilizer for the respective target sufficiency levels of P i.e. 16 mg kg^{-1}.

Recommended dose of fertilizers applied to rice and wheat were 110-90-75 and 130-110-90 kg ha^{-1}, respectively.

The treatment details are, control (T_1), recommended sole use of chemical fertilizers (T_2), site specific use of chemical fertilizer (T_3), Integrated use of chemical fertilizers with MSWC in 80:20 ratio (T_4), Site specific integrated use of chemical fertilizer with MSWC in 80:20 ratio (T_5).

Data on yield parameters like biomass and paddy yield/grain yield were recorded of rice and wheat. Soil samples (pre and post) for chemical analyses were randomly collected from 0-15 cm and 15-30 cm soil layer from each treatment. Soil analysis for pH_s, EC_e, SAR, and O.M was carried out according to the methods described in U.S. Salinity Lab. Staff (1954) and Tandon, (2005), while soil texture was determined as described by Bouyoucos (1962). Soil bulk density was measured by core sampler from 10-15 and 20-25 cm soil depths (Blake and Hartge, 1986). Water analysis was carried out by the methods described by U. S. Salinity Lab. Staff (1954).

Available P from soil samples was determined by Watanab and Olsen (1965). DTPA extractable Zn, Cu, Co, Cd and Pb were determined following the method described by Lindsay and Norvell, (1978). Data are subjected to statistical analysis following RCBD using (Statistix v. 8.1) standard procedures (Steel *et al.,* 1997). The differences among the means are compared by applying the Duncan's multiple range tests (DMR) (Duncan, 1955).

Results and discussion

Three year field experiments on rice and wheat were conducted at 'mouza' JhugianPir District Hafizabad to investigate the site-specific nutrient management of P using MSWC. Initial soil status of site before onset of experiments is given in Table 1.

Table 1. Initial Soil Status at JhugianPir.

Parameters	Units	Soil Depth (0-15 cm)	Soil Depth (15-30 cm)
Soil Texture		Loam	Loam
Bulk density	(Mg m^{-3})	1.61(10-15 cm)	1.58(20-25 cm)
pH_s		8.68	8.45
EC_e	(dS m^{-1})	4.98	4.77
SAR	(mmol L^{-1})$^{1/2}$	29.37	26.35
Organic Matter	(%)	0.46	0.29
Available P	(mg kg^{-1})	8.46	7.12
Extractable K	(mg kg^{-1})	95.30	88.46
DTPA Extractable			
Zn	(mg kg^{-1})	0.80	0.38
Cu	(mg kg^{-1})	0.36	0.26
Co	(mg kg^{-1})	0.20	0.16
Cd	(mg kg^{-1})	0.20	0.16
Pb	(mg kg^{-1})	0.46	0.32

The MSWC isanalyzed by Tandon (2005) and the chemical composition is given in Table 2.

The biomass and paddy yield of rice is given in Table 3. Results revealed that site specific integrated use of chemical fertilizer with MSWC in 80:20 ratio (T_5) produced significantly higher biomass and paddy yield i.e. 11.73 and 2.79 Mg ha^{-1}as compared to integrated use of chemical fertilizers with MSWC in 80:20 ratio(T_4) i.e. 11.03 and 2.67 Mg ha^{-1}, respectively. Site specific use of chemical fertilizers enhanced the biomass and paddy yield (10.39 and 2.59 Mg ha^{-1}) than recommended sole use of chemical fertilizers (9.58 and 2.47 Mg ha^{-1}) as compared to control i.e. 4.61 and 1.08 Mg ha^{-1}, respectively.

Results regarding biomass and wheat grain yield (Table 3)clearly demonstrated that site specific integrated use of chemical fertilizer with MSWC in 80:20 ratio (T_5) produced significantly higher biomass and wheat grain yield i.e. 5.48 and 2.65 Mg ha^{-1} to integrated use of chemical fertilizers with MSWC in 80:20 ratio(T_4) i.e. 5.03 and 2.61 Mg ha^{-1}, respectively. Site specific use of chemical fertilizers (T_3) produced more biomass and grain yield (5.15 and 2.48 Mg ha^{-1}) than recommended chemical fertilizers (4.78 and 2.33 Mg ha^{-1}) as compared to control (1.79 and 0.83 Mg ha^{-1}), respectively.

Table 2. Chemical composition of Municipal Solid Waste Compost.

Parameters	Units	Value
Total N	%	0.470-0.630
Total P	%	0.330-0.380
Total K	%	1.02-1.15
Total Zn	mg kg^{-1}	320-520
Total Cu	mg kg^{-1}	86-109
Total Cd	mg kg^{-1}	0-2.80
Total Co	mg kg^{-1}	3.80-12.50
Total Pb	mg kg^{-1}	120-462

Post-harvest soil analysis of rice and wheat (0-15 and 15-30 cm) are presented in (Table 4 and 5). Results demonstrated that salinity/sodicity parameters of the soils were reduced considerably. The reduction in values of pH_s, EC_e and SAR of soils was more in the upper depth (0-15 cm) than lower depth (15-30 cm). Increase inorganic matter, available P and extractable K contents was observed in integrated use of chemical fertilizers with MSWC (T_4) and at site specific integrated use of chemical fertilizer with MSWC (T_5).

Table 3. Integrated Application of P on Biomass and Paddy / Grain Yield of rice and wheat at Jhugian Pir. (Mean of three years).

Treatments	Rice Yield (Mg ha^{-1})		Wheat Yield (Mg ha^{-1})	
	Biomass	Paddy	Biomass	Grain
T_1- Control	4.61 D*	1.08 D	1.79 C	0.83 C
T_2- Recommended sole use of chemical fertilizers	9.58 C	2.47 C	4.78 B	2.33 B
T_3-Site specific use of chemical fertilizers	10.39 BC	2.59 BC	5.15 AB	2.48 AB
T_4- Integrated use of chemical fertilizers with MSWC in 80:20 ratio	11.03 AB	2.67 AB	5.03 AB	2.61 AB
T_5-Site specific integrated use of chemical fertilizer with MSWC in 80:20 ratio	11.73 A	2.79 A	5.48 A	2.65 A
LSD	0.934	0.149	0.605	0.188

*Means sharing the same letter(s) in a column do not differ significantly at $p<0.05$ according to Duncan's Multiple Range Test.

The higher values of soil organic matter, available P, extractable K and heavy metal contents was observed in the upper depth of soil (0-15 cm) than the lower depth of soil (15-30 cm) in treatments where MSWC was added i.e. T_4 and T_5.The EC_e and SAR were decreased in T_4 (integrated use of chemical fertilizers with MSWC) after harvest of rice (0-15 cm) i.e. 3.58 and 20.99followed by T_5 (site specific integrated use of chemical fertilizer with MSWC) i.e. 3.59 and 21.18 than control i.e. 4.57 (dS m^{-1}) and 22.11 (mmol L^{-1})$^{1/2}$, respectively. Whereas after harvest of wheat (0-15 cm), the EC_e and SAR were decreased in T_4 (integrated use of chemical fertilizers with MSWC) i.e. 3.59 and 20.61 as compared to control i.e. 4.51 (dS m^{-1}) and 21.34 (mmol $L^{-1})^{1/2}$, respectively.

Table 4. Soil analysis after harvest of rice (0-15 cm) and (15-30 cm) at JhugianPir. (Mean of three years).

Treatments	pH_s	EC_e	SAR	O.M.	Available P	Extractable K	Zn	Cu	Cd	Co	Pb
		(dS m^{-1})	(mmol $L^{-1})^{1/2}$	(%)	----------mg kg^{-1}----------						
					(0-15 cm)						
T_1	8.463 A*	4.57	22.11 A	0.33 B	5.38 B	74.92 B	0.61 B	0.24 C	0.140 AB	0.140 B	0.32 B
T_2	8.453 AB	4.54	21.31 AB	0.58 A	13.38 A	136.27 A	0.73 B	0.27 BC	0.137 AB	0.137 B	0.32 B
T_3	8.457 AB	3.62	21.60 AB	0.59 A	12.26 A	135.65 A	0.72 B	0.27 BC	0.130 B	0.150 B	0.33 B
T_4	8.450 AB	3.58	20.99 B	0.61 A	12.97 A	140.43 A	0.99 A	0.40 A	0.173 A	0.253 A	0.62 A
T_5	8.447 B	3.59	21.18 B	0.62 A	12.49 A	141.18 A	0.98 A	0.39 AB	0.170 AB	0.243 A	0.60 A
LSD	0.017	1.43	0.89	0.111	4.12	20.37	0.205	0.12	0.04	0.07	0.17
	(15-30 cm)										
T_1	8.48	4.61 A*	24.58 A	0.20 B	4.68 B	70.46 B	0.27 C	0.17 C	0.120 A	0.113	0.233 B
T_2	8.48	4.14 AB	22.78 B	0.31 A	8.18 A	89.85 A	0.34 B	0.18 C	0.110 AB	0.110	0.227 B
T_3	8.49	4.02 B	22.99 AB	0.31 A	8.43 A	89.92 A	0.33 B	0.21 BC	0.106 B	0.127	0.233 B
T_4	8.49	3.98 B	22.57 B	0.34 A	8.52 A	91.36 A	0.39 A	0.27 AB	0.113 AB	0.127	0.327 A
T_5	8.48	4.0 B	23.41 AB	0.33 A	8.49 A	91.58 A	0.39 A	0.28 A	0.110 AB	0.130	0.320 A
LSD	NS	0.478	1.799	0.075	2.52	13.47	0.047	0.062	0.0106	0.023	0.05

*Means sharing the same letter(s) in a column do not differ significantly at $p<0.05$ according to Duncan's Multiple Range Test.

The increase in organic matter content was 87.8% with T_5 (site specific integrated use of chemical fertilizer with MSWC) and 84.8% with T_4 (integrated use of chemical fertilizers with MSWC) than control i.e. 0.33%. Increase in available P and extractable K was observed with all treatments as compared to control. Highest available P was observed with T_2 (recommended sole use of chemical fertilizers) i.e. 13.38 mg kg^{-1} than control i.e. 5.38 mg kg^{-1}.Increase in available P and extractable K with all treatments was observed after harvest of rice and wheat as compared to control.

The increase in available P and extractable K after harvest of rice with T_4(integrated use of chemical fertilizers with MSWC) was observed i.e. 12.97 and 140.43 mg $kg^{-1}$and with site specific integrated use of chemical fertilizer with MSWC i.e. 12.49 and 141.18 mg kg^{-1} while after harvest of wheat, the values with T_4 were (13.91 and 147.88) and with T_5 (12.86 and 147.76 mg kg^{-1}). The contents of heavy metals viz. Zn, Cu, Cd, Co and Pb were more in integrated use of chemical fertilizers with MSWC (T_4) than site specific integrated use of chemical fertilizer with MSWC in (T_5) while rest of the treatments exhibited less concentration of these metals.

Similarly, the lower layer (15-30 cm) after harvest of rice and wheat showed less value of the discussed parameters than upper layer (0-15 cm). Heavy metal contents increased in integrated use of chemical fertilizers with MSWC in 80:20 ratio (T_4) compared with site specific integrated use of chemical fertilizer with MSWC (T_5) while in the remaining treatments there was decrease in concentration of metals.

Application of MSWC in combination with inorganic fertilizer especially(T_5) site specific integrated use of chemical fertilizer with MSWC produced significantly higher biomass/paddy and wheat grains than(T_4) integrated use of chemical fertilizers with MSWC in 80:20 ratio (Ribeiro *et al.,* 2000;Singer *et al.,* 2004; Montemurro *et al.,* 2005a; Akram *et al.,* 2007; Kasthuri *et al.,* 2011). Site specific application of fertilizer with compost on soil need basis increases the crop productivity, reduces the fertilizer loss and input cost (Montemurro *et al.,* 2005a; Akram *et al.,* 2007; Kasthuri *et al.,* 2011).

The flooding of alkaline soils resulted in decrease of soil pH after rice harvest. The decrease in soil salinity and sodicity after rice harvest might be the reason that flooding resulted in leaching of soluble salts.

Improvement in organic matter after the application of MSWC might be due the fact that a considerable amount of organic content was incorporated in soil (Akram *et al.,* 2007; Qazi *et al.,* 2009).

Highest available P and extractable K was observed in the treatments where MSWC was added with chemical fertilizer i.e. integrated use of chemical fertilizers with MSWC in 80:20 ratio and site specific integrated use of chemical fertilizer with MSWC in 80:20 ratio (T_4 and T_5). Increase in available P and extractable K with the combined application of mineral fertilizer and MSWC were confirmed by many researchers (Rodd *et al.,* 2002; Zhang *et al.,* 2006; Akram *et al.,* 2007; Qazi *et al.,* 2009; Kasthuri *et al.,* 2011).

Table 5. Soil analysis after harvest of wheat (0-15 cm) and (15-30 cm) at JhugianPir. (Mean of three years).

Treatments	pH_s	EC_e	SAR	O.M.	Available P	Extractable K	Zn	Cu	Cd	Co	Pb
		(dS m^{-1})	(mmol $L^{-1})^{1/2}$	(%)	------------------------------------mg kg^{-1}	----------------------------------					
	(0-15 cm)										
T_1	8.45 AB*	4.51 A	21.34	0.30 B	4.35 B	70.62 B	0.55 B	0.19 B	0.123 BC	0.123 B	0.267 B
T_2	8.440 B	3.50 C	20.38	0.60 A	14.64 A	144.22 A	0.61 B	0.22 B	0.117 C	0.113 B	0.277 B
T_3	8.453 A	3.61 B	21.22	0.62 A	12.86 A	143.21 A	0.60 B	0.22 B	0.110 C	0.123 B	0.283 B
T_4	8.447 AB	3.59 B	20.61	0.65 A	13.91 A	147.88 A	1.03 A	0.42 A	0.183 A	0.270 A	0.657 A
T_5	8.443 AB	3.60 B	20.82	0.62 A	12.86 A	147.76 A	1.00 A	0.41 A	0.177 AB	0.253 A	0.607 A
LSD	0.013	0.043	1.006	0.126	3.95	16.46	0.106	0.093	0.055	0.068	0.123
	(15-30 cm)										
T_1	8.46	4.54 A	21.68	0.17 B	4.02 B	66.72 B	0.240 C	0.150 C	0.103	0.097 AB	0.200 C
T_2	8.45	3.78 B	20.97	0.34 A	8.35 A	92.76 A	0.303 B	0.153 BC	0.097	0.093 B	0.197 C
T_3	8.46	3.68 B	21.94	0.32 A	8.60 A	92.38 A	0.296 B	0.183 B	0.097	0.110 A	0.200 C
T_4	8.45	3.64 B	21.21	0.37 A	8.73 A	93.85 A	0.383 A	0.267 A	0.097	0.110 A	0.313 A
T_5	8.46	3.65 B	21.24	0.35 A	8.55 A	93.37 A	0.363 A	0.257 A	0.097	0.100 AB	0.297 B
LSD	0.015	0.346	1.28	0.069	2.425	13.08	0.0299	0.033	0.008	0.0165	0.015

*Means sharing the same letter(s) in a column do not differ significantly at $p<0.05$ according to Duncan's Multiple Range Test.

Addition of organic content in the soil improves soil quality and microbial population and thus soil health. Incorporation of MSWC into the agricultural soils improves the soil organic matter (SOM) and improves the soil physical properties like hydraulic conductivity and infiltration rate resultantly crop productivity (Blum *et al.,* 2004; Van-Camp *et al.,* 2004; Chitravadivu *et al.,* 2009).

Composting of municipal solid wastes provides an excellent mean to add processed organic content into the agricultural fields and can be used as soil conditioner and crop substrate instead of dumping wastes to landfills and thus protect the environment (Han *et al.,* 2000; Parnaudeau *et al.,* 2004; Van-Camp *et al.,* 2004; Gigliotti *et al.,* 2005; Spargo *et al.,* 2006). Application of MSWC to agricultural soils promotes crop production, improves soil properties, enhances water retention/water holding capacity (Franzluebbers, 2002a, b), provides essential nutrients (Tejada *et al.,* 2001; Zhang *et al.,* 2006; Alvarenga *et al.,* 2007; Weber *et al.,* 2007) and augments mineral fertilizers (Sterrett, 2001).

Incorporation of MSWC to agricultural fields provides logical solution but the main hitch arises with the accumulation of heavy metals into the soil (Zhang *et al.,* 2006). The source of wastes should be addressed like MSWC formed from the industrial wastes. The chemical composition of MSWC should be checked before application and permissible limits of heavy metals (EPA, 1995) must be kept in mind and after application soil analysis also be carried out (Weber *et al.,* 2007).

The DTPA extractable Zn, Cu, Co, Cd and Pb was observed higher in treatments where MSWC was applied i.e. (integrated use of chemical fertilizers with MSWC) and (site specific integrated with MSWC) while minor decrease in DTPA extractable Zn, Cu, Co, Cd and Pb was observed in T_2 and T_3. Increase in DTPA extractable heavy metals with MSWC was observed by Qazi *et al.* (2009).Hargreaves *et al.* (2008) reported an increase in DTPA extractable Pb with MSWC application. Increase in metal concentration (Fe, Mn and Zn) due to sewage water irrigation was observed by Ghafoor *et al.* (1995). Decrease in DTPA extractable Zn, Cu, Co, Cd and Pbin treatments with no MSWC was observed because of fixation with anions like carbonates/sulphidesor interactions of metals with other metals, clay or organic matter (Murtaza *et al.*, 2010).

Field experimentations validated that site specific use of mineral fertilizer with MSWC and integrated use of chemical fertilizers with MSWC in 80:20 ratio enhanced paddy/grain yield and slight increase in the Zn, Cu, Co, Cd and Pb concentrations in rice-wheat rotation.

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