ISSN 0367-6315 (Print) / ISSN 2288-2162 (Online)
Korean J. Soil Sci. Fert. 47(4), 269-274 (2014)
http://dx.doi.org/10.7745/KJSSF.2014.47.4.269

Article

Crop Residues Management for Rice-Wheat Cropping System in Saline-Sodic Soil

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(Received: January 16 2014, Revised: January 22 2014, Accepted: July 5 2014)

Series of field experiments were conducted to evaluate the long term effect of gypsum and crop residue on crop yield and soil health in rice-wheat crop rotation system in salt affected soil. A saline-sodic field having EC_e (electrical conductivity of the saturation extract) 4.77 (dS m^{-1}); pH (H_2O) 8.96; SAR 43.78 (mmol L^{-1}) and gypsum requirement (G.R.) 2.86 (Mg $acre^{-1}$) was selected on Soil Salinity Research Institute Farm. Five treatments consisting of (T_1) control, (T_2) gypsum at 100% G.R., (T_3) gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}, (T_4) gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1}, (T_5) gypsum at 25% G.R.+ rice and wheat straw at 3 Mg ha^{-1} were replicated four times under completely randomized block design. The data indicated that grain and straw yield of rice and wheat was significantly (*$P<0.05$*) increased by all the amendments used either single or in combination. T_2 (gypsum at 100% G.R.) significantly (*$P<0.05$*) increased grain and straw yield of rice and wheat crops followed by T_3 (gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}) when compared with control. Soil properties were also improved by used amendments, pronounced decreased in EC_e, pH_s and SAR were recorded in T_2 followed by T_3. The efficiency of the treatments could be arranged in following order gypsum at 100% G.R.> gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}> gypsum at 25% G.R. + rice and wheat straw at 3 Mg ha^{-1}> gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1}> control.

Key words: Crop residues, Gypsum, Soil amendments, Wheat-rice crop rotation

Effect of gypsum and crop residue on mean rice grain yield (Mg ha^{-1}).

	Treatments	2006	2007	2008	Mean
T_1	Control	1.07 e	1.32 e	1.66 e	1.35 e
T_2	Gypsum at 100% G.R.	3.64 a	3.93 a	3.95 a	3.84 a
T_3	Gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}	3.34 b	3.64 b	3.73 b	3.57 b
T_4	Gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1}	2.25 d	3.13 d	3.27 d	2.88 d
T_5	Gypsum at 25% G.R.+ rice and wheat straw at 3 Mg ha^{-1}	3.24 c	3.33 c	3.52 c	3.36 c

G.R. = gypsum requirement; Means sharing the same small letters are statistically similar at $P \leq 0.05$.

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Introduction

Salinity is an important environmental stress that threatens sustainable production of crops around the world (Munns, 2005). Throughout the world approximately 800 million hectares of land are subjected to salinity (FAO, 2008). Geographically, most of the agricultural land in Pakistan falls in arid and semi-arid regions. According to an estimate by Khan (1998), one third of the total cultivated area of Pakistan (approximately 6.67 million hectares) is subjected to salinity. Several ideas have been put forwarded by the agriculturists to tackle the problem of salinity which includes irrigation management, the cultivation of salt-tolerant species, top-soil replacement, sub-soiling, deep tillage and application of soil amendments (Sarwar et al., 2011; Ibrahim et al., 2012; Sabah et al., 2012; Tahir and Sarwar, 2013).

Crop residues are supposed to play valuable role in maintaining soil fertility and this concept is gaining strength in today's agriculture. It is believed that use of crop residue for improving soil productivity in agriculture system may reduce the use of mineral/chemical fertilizers (Mehdi et al., 2011). Crop residues are easily available on site, and are relatively economical, especially if the crop residues used are of previously harvested crop. Almost 4×10^9 Mg crop residues are produced in the world every year and more than 75% of the residues are derived from cereals crops like corn, rice, wheat etc. (Lal, 2005). Rice straw produced in large quantity and having higher silica contents is rather tedious to manage this much volume of rice straw as it is poor feed for animals (Gaind and Nain, 2007). The common farm practice to get rid of rice straw is burning, which results in losses of nitrogen (80%), phosphorus (25%), potassium (21%), sulfur(4-60%), and air pollution (in the form of CO_2) 13 Mg ha^{-1}subsequently depriving the soil of its precious organic matter (Mandal et al., 2004).

Along with minerals, crop residue is also an important source of soil organic matter, which can improve soil properties such as nutrient availability, water retention, cation exchange capacity, soil reaction, erosion control and pollution remediation (Cooperband, 2002; Ibrahim et al., 2011; Ibrahim et al., 2012), thereby use of crop residue in salt affected soils might be an efficient solution to remove or prevent the salinity problems due to accumulation of soluble salts in the root zone (Sarwar et al., 2008; Ahn et al., 2010; Sarwar et al., 2011). In another study, it was found that EC value of soil amended with rice straw, rye straw and maize stalk was sharply decline when compared with control (Sabah et al., 2012). Rice straw at 5, 10, and 15 Mg ha^{-1} along with fertilizer management practices was beneficial to amend the salt affected soils and growth performance of watermelon plants (Ahn et al., 2010). Application of paddy straw compost in wheat crop was found to increase crop yield as well as soil properties. The ameliorating effect of crop residue (burnt rice husk, rice straw and legume residue) was studied on growth response of rice crop in acidic soil (Gaind and Nain, 2010). Crop residue significantly increased soil organic matter, total nitrogen, available phosphorus, exchangeable potassium, cation exchange capacity of treated plots as compared to control (Sarwar et al., 2008). Growth performance and yield of three rice cultivars were also superior in soil which was treated with crop residue as compared to soil without residue treatments (Sarwar et al., 2010; Sabah et al., 2012). In a rice-wheat cropping system with yield 7 Mg ha^{-1} of rice and 4 Mg ha^{-1} of wheat may remove approximately 300, 30, and 300 kg ha^{-1} of N, P, and K, respectively from the soil (Gaind and Nain, 2011). So, integrated use of organic and inorganic amendments is being currently promoted for economic utilization of the moderately salt affected soils (Haider et al., 2013). It optimizes the use of all available resources which may resolve the practical limitation of input availability and can replenish the soil of its nutrients.

In the present study, the combined effect of gypsum and crop residue on the yield of rice and wheat crops (rice-wheat cropping system in rotation), and soil properties was studied for three years under field conditions. This information would be helpful to researchers and farmers by providing them valuable information and option to utilize undesired crop residue as nutrient source and reclaiming the salt affected soils.

Materials and Methods

These field trials were carried out (Kharif 2006 to Rabi 2008) on a site of Soil Salinity Research Farm. The soil of the experimental farms had EC_e = 4.77 dS m^{-1}; pH_s = 8.96; SAR = 43.78 mmol L^{-1}, and gypsum requirement = 2.86 Mg $acre^{-1}$. Sun dried wheat and rice straw were chopped and mixed to a depth of 20 cm in respective plots and were incubated into soil at water content close to the field capacity for 30 days before transplanting of rice. The gypsum was applied 15 days before transplanting of rice. The experiment was laid out in randomized complete block design with four replicates. The treatment description is presented as under

T_1 = Control
T_2 = Gypsum at 100% G.R.
T_3 = Gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}
T_4 = Gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1}
T_5 = Gypsum at 25% G.R.+ rice and wheat straw at 3 Mg ha^{-1}.

The treatments were replicated on plots with size 6×10 m^2. Twenty five days old rice seedlings of PB-95 were transplanted in July and were fertilized with N (110 kg ha^{-1}), P as P_2O_5 (90 kg ha^{-1}) and K as K_2O (60 kg ha^{-1}). All P and K fertilizers and 50% N were applied at the time of transplanting whereas; remaining 50% N was applied after thirty days of transplanting.

Chemical herbicides were used to control weeds. The $ZnSO_4$ (33%) at 12.5 kg ha^{-1} was also applied 10 days after rice transplanting. Crop was harvested at maturity. After harvesting of rice crop, wheat crop (Inqulab 91) was sown in Rabi season (November) within same layout. Recommended dose of fertilizer for wheat (120-110-70 NPK kg ha^{-1}) were applied. All cultural and management practices were performed uniformly as and when required. The data regarding grain and straw yield for both the crops (wheat and rice) were recorded at maturity.

Composite soil samples were taken from each treatment plot after harvest of each crop throughout study and were analyzed for determination of their chemical properties following the methods as described by US Salinity Lab. Staff (1954). Electrical conductivity of the soil saturation extract (EC_e) was measured with conductivity meter. Soil pH of the saturation extract was measured by using pH meter. Na^+ was determined by flame photometer while Ca^{2+} and Mg^{2+} were determined titrimetrically. Sodium adsorption ratio (SAR) was calculated as follows where ionic concentrations of the saturation extracts are given in m mol L^{-1}.

$$SAR = Na^+/[(Ca^{2+} + Mg^{2+})/2]^{1/2}$$

The data thus collected were subjected to statistical analysis under randomized complete block design and the treatment means were compared by least significance difference (LSD) test as proposed by Steel et al. (1997).

Results and Discussion

Rice grain yield (Mg ha^{-1}) Grain yield depends upon number of productive tillers, number of spikelets per panicle, spikelet sterility and grain weight (Sarwar et al., 2008; Ibrahim et al., 2010). Grain weight is an important yield component in rice production (Atera et al., 2011) which was affected significantly by all the treatments (Table 1). The maximum grain yield (3.84 Mg ha^{-1}) was obtained with T_2 (gypsum at 100% G.R.) followed by 3.57 Mg ha^{-1} with T_3 (gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}) which was significant by T_5 (3.36 Mg ha^{-1}) where gypsum at 25% G.R.+ rice and wheat straw at 3 Mg ha^{-1} was applied. While, the minimum grain yield (1.35 Mg ha^{-1}) was recorded in control (T_1) followed by T_4 (gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1}) which produced grain yield of 2.88 Mg ha^{-1} and all the treatments were statistically different from each other. Management of crop residue is one of the important means of improving soil nutrient contents and which maintain soil productivity (Iwuafor et al., 1991). Ameliorating effect of gypsum and crop residues for reclamation of salt affected soil and enhancement in supply of essential plant nutrients after decomposition of these residues may be contributed to greater production of grain yield in these treatments.

Rice straw yield (Mg ha^{-1}) Data regarding straw yield (Table 2) showed that gypsum at 100% G.R. produced highest straw yield (5.42 Mg ha^{-1}) followed by gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1} which produced (4.88 Mg ha^{-1}) straw yield. The minimum straw yield (1.75 Mg ha^{-1}) was observed in control followed by gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1} obtaining 3.75 Mg ha^{-1} straw yield. Rice crops require 16-17 kg N from soil for the production of each ton of rough rice including straw, so improved straw yield could be due to more leaf area, increased plant height, increased tiller production and increased accumulation of dry matter with those treatments

Table 1. Effect of gypsum and crop residue on mean rice grain yield (Mg ha^{-1}).

	Treatments	2006	2007	2008	Mean
T_1	Control	1.07 e	1.32 e	1.66 e	1.35 e
T_2	Gypsum at 100% G.R.	3.64 a	3.93 a	3.95 a	3.84 a
T_3	Gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}	3.34 b	3.64 b	3.73 b	3.57 b
T_4	Gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1}	2.25 d	3.13 d	3.27 d	2.88 d
T_5	Gypsum at 25% G.R.+ rice and wheat straw at 3 Mg ha^{-1}	3.24 c	3.33 c	3.52 c	3.36 c

G.R. = gypsum requirement; Means sharing the same small letters are statistically similar at $P \leq 0.05$.

Table 2. Effect of gypsum and crop residue on mean rice straw yield (Mg ha^{-1}).

	Treatments	2006	2007	2008	Mean
T_1	Control	1.39 d	1.71 e	2.15 e	1.75 e
T_2	Gypsum at 100% G.R.	5.34 a	5.42 a	5.51 a	5.42 a
T_3	Gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}	4.52 b	4.84 b	5.27 b	4.88 b
T_4	Gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1}	2.91 c	4.09 d	4.27 d	3.75 d
T_5	Gypsum at 25% G.R.+ rice and wheat straw at 3 Mg ha^{-1}	4.44 b	4.50 c	4.97 c	4.64 c

G.R. = gypsum requirement; Means sharing the same small letters are statistically similar at $P \leq 0.05$.

(Sahrawat, 2000). In T_1 (control) there was limited supply of nitrogen and other nutrients which were necessary for tiller production whereas the other treatments supplied it sufficiently rendering the more number of tillers and hence the increased straw yield was produced.

Wheat grain yield (Mg ha^{-1}) Grain yield of wheat crop under salt affected soil was significantly increased with application of gypsum and its combination with different crop residues (Table 3). Gypsum at 100% G.R. (T_2) gave the maximum grain yield of (3.42 Mg ha^{-1}), followed by 3.20 Mg ha^{-1} of (T_3) with application of gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}. T_5 (Gypsum at 25% G.R.+ rice and wheat straw at 3 Mg ha^{-1}) recorded grain yield of 3.00 Mg ha^{-1} followed by T_4 (gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1}) with 2.79 Mg ha^{-1}. The lowest grain yield (1.65 Mg ha^{-1}) was obtained in control. Balance supply of essential plant nutrient is vital for formation and development of grains (Haider et al., 2013). Increased grain yield with amendments application as compared to control may be due to the enhanced growth with increased nutrient uptake, greater translocation of carbohydrates to sink which ultimately increased yield attributes and subsequently produced more grain yield. These findings are in consistence with previous studies (Singh et al., 2001).

Wheat straw yield (Mg ha^{-1}) Our data revealed (Table 4) that the maximum wheat straw (4.52 Mg ha^{-1}) was obtained for T_2 (gypsum at 100% G.R.) followed by T_3 (4.20 Mg ha^{-1}) where gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1} was applied, which was statistically significant (3.95 Mg ha^{-1}) than gypsum at 25% G.R. + rice and wheat straw at 3 Mg ha^{-1} (T_5). Whereas T_1 (control) showed the minimum (2.14 Mg ha^{-1}) straw yield followed by T_4 (gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1}) with straw yield of 3.64 Mg ha^{-1}. All the treatments were significantly different from each other ($P<0.05$). Decomposition of crop residue by soil microorganism transformed it into bio-fertilizer that could improve soil qualities (Tahir et al., 2013). The phosphorus enhanced root growth and uptake of other nutrients which may contribute to better crop growth and straw yield (Sabah et al., 2012). Mehdi et al. (2011) claimed that increased grain and straw yield of rice may be achieved in reclaimed saline-sodic soil with use of farm yard manure (FYM) and sesbania in combination with mineral fertilizers. They also reported the significant residual effect of FYM and sesbania applied to rice crop on the grain and straw production of succeeding wheat crop which reinforced our findings (Ali et al., 2012).

Soil properties Data regarding effect of gypsum alone and its combinations with wheat and rice straw on chemical properties (EC_e, pH_s, and SAR) of salt affected soil after rice and wheat harvest have shown in Table 5. It is evident from the obtained data that pH_s value gradually decreased with application of amendments and after completion of study minimum pH value was recorded with used of gypsum at 100% G.R. in T_2 followed by T_3 and T_5. The maximum pH_s value was noted in T_1 followed by T_4. The sharp decline in soil pH in T_2 was due to release of Ca^{2+} from gypsum which replaces the exchangeable Na^+ (Abdel-Fattah, 2012). As crop residue significantly increased soil organic matter level, so decrease in pH of plots receiving the integrated treatments could be related to release of organic acids and CO_2 during the decomposition of wheat and rice straw (Sarwar et al., 2008). Our findings are in consistence with the previous

Table 3. Effect of gypsum and crop residue on mean wheat grain yield (Mg ha^{-1}).

	Treatments	2006	2007	2008	Mean
T_1	Control	1.22 d	1.75 d	1.97 e	1.65 e
T_2	Gypsum at 100% G.R.	3.12 a	3.34 a	3.80 a	3.42 a
T_3	Gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}	2.90 b	3.12 b	3.57 b	3.20 b
T_4	Gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1}	2.63 c	2.83 c	2.92 d	2.79 d
T_5	Gypsum at 25% G.R.+ rice and wheat straw at 3 Mg ha^{-1}	2.79 bc	2.91 c	3.30 c	3.00 c

G.R. = gypsum requirement; Means sharing the same small letters are statistically similar at $P \leq 0.05$.

Table 4. Effect of gypsum and crop residue on mean wheat straw yield (Mg ha^{-1}).

	Treatments	2006	2007	2008	Mean
T_1	Control	1.59 d	2.28 d	2.56 d	2.14 e
T_2	Gypsum at 100% G.R.	4.29 a	4.33 a	4.93 a	4.52 a
T_3	Gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}	3.85 b	4.07 b	4.66 a	4.20 b
T_4	Gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1}	3.42 c	3.68 c	3.81 c	3.64 d
T_5	Gypsum at 25% G.R.+ rice and wheat straw at 3 Mg ha^{-1}	3.78 b	3.78 c	4.29 b	3.95 c

G.R. = gypsum requirement; Means sharing the same small letters are statistically similar at $P \leq 0.05$.

Table 5. Effect of gypsum and crop residues on selected soil chemical properties after the harvest of rice and wheat.

Treatments	2006			2007			2008		
	pH	EC_e	SAR	pH	EC_e	SAR	pH	EC_e	SAR
T_1 Control	8.92	4.48	40.36	8.80	4.50	30.79	8.62	4.20	24.39
T_2 Gypsum at 100% G.R.	8.59	3.23	23.68	8.31	2.50	16.45	8.17	1.96	14.39
T_3 Gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}	8.68	3.52	27.07	8.52	3.10	17.87	8.35	2.43	16.63
T_4 Gypsum at 25% G.R. + rice straw at 3 Mg ha^{-1}	8.88	3.98	37.53	8.67	3.60	22.41	8.52	3.40	18.82
T_5 Gypsum at 25% G.R.+ rice and wheat straw at 3 Mg ha^{-1}	8.70	3.64	31.11	8.57	3.16	19.08	8.40	3.16	15.91

G.R. = gypsum requirement; EC_e = electrical conductivity of saturated soil paste expressed in dS m^{-1}; SAR = sodium adsorption ratio expressed in (mmol $L^{-1})^{0.5}$.

studies where application of organic amendments (rice straw and farm manure applied with gypsum) positively affected the crop growth and yield (Sarwar et al., 2010; Sarwar et al., 2011; Tahir et al., 2013).

Electrical conductivity was significantly decreased by all the treatments and at the end of experiment sharp decline was noted in T_2 followed by T_3 and T_5. While, the maximum value of EC was noted in control (T_1). Favorable effect of crop residue on decreasing EC of soil could be contributed to the improvement of the soil structure and porosity, thus increasing salt leaching and reducing surface evaporation which inhibits salt accumulation in the surface layers (Wang and Li, 1990; Abdel-Fattah, 2012). These results are reinforced by the findings of Ahn et al. (2010) that rice straw at 5, 10, and 15 Mg ha^{-1} with fertilizer significantly decreased the pH and EC of salt affected soil.

Results regarding SAR indicated that all the amendments significantly decreased the value of SAR. After completion of study, minimum value of SAR was recorded of gypsum at 100% G.R. followed by gypsum at 25% G.R. + wheat straw at 3 Mg ha^{-1}.Organic amendments also significantly decreased SAR when compared with control. Release of organic acids and CO_2 during decomposition of organic material may activate the native $CaCO_3$ of soil which was converted into $CaSO_4$ that reclaimed the soil thus lowering SAR (Sarwar et al., 2008; Sarwar et al., 2011).

Conclusions

From these investigations it may be concluded that crop residues are important resources for soil properties and also contribute towards soil chemical properties. This ultimately results in good and conducive chemical environment for sustainable crop production. Gypsum when used at 100% requirement improved the grain and straw yield during all years. The application of wheat straw and gypsum increased the maximum mean rice grain yield (3.57 Mg ha^{-1}) and rice straw yield (4.88 Mg ha^{-1}). Gypsum and wheat straw also improved the wheat grain yield over gypsum and rice straw treatments. Rice-wheat cropping system is very important in Pakistan and South Asian countries and the integration of crop residues may prove better results on sodic soils under similar ecological conditions.

References

Abdel-Fattah, M.K. 2012. Role of gypsum and compost in reclaiming saline-sodic soils. J. Agric. Vet. Sci. 1(3):30-38.

Ahn, B.K., Y.H. Lee and J.H. Lee. 2010. Fertilizer management practices with rice straw application for improving soil quality in watermelon monoculture greenhouse plots. Korean J. Soil Sci. Fert. 43(1):75-82.

Ali, M., A. Ali, M. Tahir and M. Yaseen. 2012. Growth and yield response of hybrid maize through integrated phosphorus management. Pak. J. Life Soc. Sci. 10:59-66.

Atera, E. A., J.C. Onyango, T. Azuma1, S. Asanuma and K. Itoh. 2011. Field evaluation of selected NERICA rice cultivars in Western Kenya. African J. Agric. Res. 6(1):60-66.

Cooperband, L. 2002. Building Soil organic matter with organic amendments: A resource for urban and rural gardeners, small farmers, turf grass managers and large-scale producers.Center for Integrated Agricultural Systems. University of Wisconsin, Madison, WI.

FAO. 2008. Food and Agriculture Organization (FAO) Land and Plant Nutr. Manag. Service.

Gaind, S. and L. Nain. 2007. Chemical and biological properties of wheat soil in response to paddy straw incorporation and its biodegradation by fungal inoculants. Biodegradation. 18(4): 495-503.

Gaind, S. and L. Nain. 2010. Exploration of composted cereal waste and poultry manure for soil restoration. Bioresource Technol. 101(3):2996-3003.

Gaind, S. and L. Nain. 2011. Soil health in response to bio-augmented paddy straw compost. World J. Agric. Sci. 7(4): 480-488.

Haider, M.S., M. Ibrahim, H.R. Athar, G. Sarwar and M.A. Tahir. 2013. Ability of *Puccinellia ciliata* to grow in a waterlogged saline environment. Agrochimica. 57(3):279-288.

Ibrahim, M., A. Hassan, M. Arshad and A. Tanveer. 2010. Variation in root growth and nutrient element of wheat and rice: Effect of rate and type of organic materials. Soil Environ. 29:47-52.

Ibrahim, M., M. Yamin, G. Sarwar, A. Anayat, F. Habib, S. Ullah, S. Rehman. 2011. Tillage and farm manure affect root growth and nutrient uptake of wheat and rice under semi-arid conditions of Pakistan. Appl. Geochem. 26S:194-197.

Ibrahim, M., K.H. Han, S.K. Ha, Y.S. Zhang and S.O. Hur. 2012. Physico-chemical characteristics of disturbed soils affected by accumulate of different texture in South Korea. Sains Malaysiana. 41(3):285-291.

Iwuafor, E.N.O., B.T. Kang and I.F. Ike, 1991. Effects of different tillage and crop residue management systems on chemical properties of an Alfisol. Proc. International Soil Tillage Research Organization, Ibadan, Nigeria on July 8-12, 1991, pp. 53-62.

Khan, G.S. 1998.Soil salinity/sodicity status in Pakistan. Soil Survey of Pakistan, Lahore, Pakistan.

Lal, R. 2005. World crop residues production and implication of its use as a biofuel. Environ. Intl. 31:575-586.

Mandal, K.G., K. Arun, K. Misra, M. Hati, K. Kali, P. Bandyopadhyay, K. Ghosh and M. Mohanty. 2004. Rice residue-management options and effects on soil properties and crop productivity. Food Agric. Environ. 2(1):224-231.

Mehdi, S.M., M. Sarfraz, S.T. Abbas, G. Shabbir and J. Akhtar. 2011. Integrated nutrient management for rice-wheat cropping system in a recently reclaimed soil. Soil Environ. 30:36-44.

Munns, R. 2005. Genes and salt tolerance: bringing them together. New Phytolog. 167:645-663.

Sabah, N., G. Sarwar, M. Ibrahim, M.A. Tahir, Y. Iftikhar, M.S. Haider, K.H. Han, S.K. Ha, Y.S. Zhang. 2012. Efficiency of various nutritional sources to improve physical properties of saline-sodic soil. Korean J. Soil Sci. Fert. 45:93-97.

Sahrawat, K.L. 2000. Macro and micronutrients removed by upland and lowland rice cultivars in West Africa. Commun. Soil Sci. Plant Anal. 31:717-723.

Sarwar. G., H. Schmeisky, N. Hussain, S. Muhammad, M. Ibrahim and E. Safdar. 2008. Improvement of soil physical and chemical properties with compost application in rice-wheat cropping system. Pakistan J. Bot. 40:275-282.

Sarwar, M.A., M. Ibrahim, M. Tahir, K. Ahmad, Z.I. Khan and E.E. Valeem. 2010. Appraisal of pressmud and inorganic fertilizers on soil properties, yield and sugarcane quality. Pakistan J. Bot. 42:1361-67.

Sarwar, G., M. Ibrahim, M.A. Tahir, Y. Iftikhar, M.S. Haider, N. Sabah, K.H. Han, S.G. Ha and Y.S. Zhang. 2011. Effect of compost and gypsum application on the chemical properties and fertility status of saline-sodic soil. Kor. J. Soil Sci. Fert. 44: 510-516.

Singh, M., V.P. Singh and K.S. Reddy. 2001. Effect of integrated use of nitrogen and farmyard manure or green manure on transformation of N, K and S and productivity of rice-wheat system on a Vertisol. J. Indian Soc. Soil Sci. 49(3):430-435.

Steel, R.G.D., J.H. Torrie and D.A. Dickey. 1997. Principles and procedures of statistic: A Biometrical Approach. 3rd Ed., McGraw Hill book Co. Inc. New York. p. 400-428.

Tahir, M. and M.A. Sarwar. 2013. Plant growth promoting rhizobacteria (PGPR): a budding complement of synthetic fertilizers for improving crop production. Pak. J. Life Soc. Sci. 11:1-7.

Tahir, M.A., M. Ibrahim, G. Sarwar, Y. Iftikhar, S.K. Ha, K.H. Han and Y.S. Zhang. 2013. Impact of indigenous industrial compost on the growth of coarse and fine rice varieties under saline environment. Pertanika J. Trop. Agric. Sci. 36:61-70.

U.S. Salinity Lab. Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Handb.60, Washington, D.C., USA.

Wang Z. Q. and L.Q. Li. 1990.Salinization in china and its prevention, studies on the prevention of land degradation in china. Agricultural Science and Technology Press of China, Beijing.