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Phosphorus Use Efficiency and Yield of Direct Seeded Rice and Wheat Influenced by Residues Incorporation and Phosphorus Application under Saline Soil

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Abstract. A two years field study according to split plot design was conducted to investigate the impact of crop residue (CR) incorporation and P application (0, 40, 80, 120 kg P_2O_5/ha) on P use efficiency and yield of direct seeded rice (DSR) and wheat grown under saline soil (EC_e = 4.59 dS/m; pHs = 8.38; SAR = 6.57 $(mmol_c/L)^{1/2}$; extractable P = 4.07 mg/kg; texture = sandy clay loam), during the years 2011 and 2012. Planting of DSR (with and without crop residue incorporation @ 2 tonnes/ha) were placed in main plots and P application was in sub plots. Data on tillering, plant height, panicle length, 1000 grain weight, paddy and straw yields were collected. On an average of two years, maximum tillers (18), panicle length (33), grain/panicle (121) and paddy yield (3.26 t/ha) were produced with P application @ 80 kg P_2O_5/ha along with CR incorporation. Similarly in case of wheat grown after DSR, maximum tillers (17), spike length (17), grains/panicle (66) and grain yield (3.56 t/ha) were produced with P application @ 80 kg P_2O_5/ha along with CR incorporation. Although, the growth and yield contributing parameters with this treatment (80 kg P_2O_5/ha + CR) performed statistically equal to 120 kg P_2O_5/ha without CR incorporation during both the years, but on an average of two years, grain yield of DSR and wheat was significantly superior (22 and 24%, respectively) than that of higher P rate (120 kg/ha) without CR. Overall, continuous two years CR incorporation further increased (17%) paddy yields during the follow up year of crop harvest. Higher P use efficiency and concentrations of P, K^+ and Ca^{2+} in both DSR and wheat plant tissues was found where 80 kg P_2O_5/ha was applied along with CR incorporation or 120 kg P_2O_5/ha alone while Na^+ and Mg^{2+} concentration decreased with CR incorporation and increasing P rate. An increasing trend in DSR paddy and wheat grain yields was observed with increasing the rate of P application without CR incorporation, however, it was not as much as that of 80 kg P_2O_5/ha application with CR incorporation and found to be superior than rest of the treatments during both study years.

Keywords: direct seeded rice, wheat, saline soil, crop residues, P application

Introduction

Soil salinity is a major problem in boosting up agricultural production throughout the world due to which million hectares of agricultural land are unable to produce potential crop yields. In regions such as Pakistan, over a quarter of the cultivatable land is occupied by medium to high salinity (Ahmad, 2002; Qureshi and Qadir, 1992). The problem is going faster because of heavy irrigations with brackish water which further decline the fertility of culturable lands and crop yields (Qadir, *et al*., 2003; Ahmad, 2002; Minhas, 1996; Ghafoor *et al*., 1992; Ahmad *et al*., 1990). Saline soils contain surplus soluble salts (Cl^- and SO_4^{--} of Na^+, Ca^{2+} and Mg^{2+}) which cause high osmotic pressure and compound interactions of Na, Ca and K (Maser *et al*., 2002). These salts disturb the equilibrium in rhizosphere and affect crop productivity. Adequate plant nutrition may reduce ill effects of these ions thereby helping plants to improve their growth and productivity under such situations (Mahmood *et al*., 2013; Aslam *et al*., 2008; Ghafoor *et al*., 2004; Mahmood *et al*., 1994). Phosphorus availability in problem soils is affected by anion competition (PO_4^{--} and Cl^-) and many other interactions. In calcareous soils, applied P almost instantaneously gets fixed with lime due to the formation of insoluble dibasic calcium phosphate compounds. Much work has been reported regarding nutrient management for conventional crops to enhance their yields under unfavourable situation but much less exertion is reported on direct seeded rice under saline soils. Optimised P nutrition is critical for producing potential yields because it encourages healthy growth, such as development of strong root system,

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maximum tillering, upholds more flowering and seed formation (Sainio *et al*., 2006). Often P deficiency in rice is referred to as "hidden hunger" which causes poor tillering, slow leaf canopy expansion, poor grain formation and delayed maturity. In Pakistan, more than 90% soils are deficient in P (NFDC, 2012; 2010). Farming community in rice-wheat cropping system is facing water shortage, escalating fuel and high fertilizer cost (particularly of P fertilizers) and labour shortage during rice transplanting. About half of the rice cultivated area (~ 1.0 Mha) in Punjab province is salt-affected which has moderate to high salinity, high pH and shortage of good quality ground water causing 30-70% paddy yield reduction (Qayyum and Malik, 1988). Moreover, P availability in soluble orthophosphate form is a prevalent limitation under calcareous soils because it makes insoluble compounds and does not release plant available P even upon heavy irrigations. A large proportion of applied P in the soil becomes immobile due to this process (Mahmood *et al*., 2013; Rahmatullah *et al*., 1994;) however, the plants readily utilize only 8-33% of applied P in the first growing season (Saleem *et al*., 1986). Hence, there is a need to increase the use of P fertilizers in order to guarantee food security for ever increasing populations.

Most of the farmers of rice-wheat cropping system burn wheat crop residues to prepare their lands for timely rice transplanting. This practice not only despoil the environment but also the precious source of plant nutrients (main source of organic material and the important constituent for soil health) are being smashed on large scale in this agricultural ecosystem. About 25% of N and P, 50% of S and 75% of K uptake by cereal crops are retained in crop residues, making them valuable nutrient sources. Since large portion of nutrients taken up by plants remains in the straw, much of this can be recycled for subsequent crop growth after its decomposition (Mahmood *et al*., 2013; Byous *et al*., 2004). In many studies, impact of residues incorporation on soil health had been reported to increase the organic matter and nutrient status and hence crop yields improvement (Ali *et al*., 2012; Krishna *et al*., 2004; Eagle *et al*., 2000; Misra *et al*., 1996). Direct seeding of rice is a new and the most suitable technology for resource poor community of salt-affected lands for which transplanting labour cost, water and machinery tools expenses required during puddling and transplanting could be saved in addition to timely sowing of rice. Weedicide application can be done to control weeds at early stages of growth. The crop matures early as compared to traditional transplanting which further makes possible sowing of wheat crop well in time after the harvest of rice. Besides these benefits, there is much more plant population under direct seeded rice as compared to traditionally transplanted rice for which nutrients requirement could also be higher to produce potential yields.

A little work is reported regarding nutrient management particularly of P application for direct seeded rice in salt-affected soils of Pakistan. Therefore, keeping all these factors in mind, a long term field study was planned to investigate appropriate P dose for direct seeded rice along with wheat straw incorporating and their impact on paddy yield in a slightly saline soil of district Hafizabad, Pakistan.

Materials and Methods

A two year study using a permanent layout was conducted under marginal saline soil of rice-wheat cropping system at farmers field in Wachhoki Kalan, Kankah Dogran-Hafizabad Road, district Hafizabad, Pakistan (EC_e = 4.59 dS/m; pH_s = 8.38; SAR = 6.57 $(mmol_c/L)^{1/2}$; extractable P = 4.07 mg/kg; texture = sandy clay loam) during 2011 and 2012. The experiment was laid out according to split plot design with three replications. Planting methods; direct seeding with and without crop residue (wheat) incorporation @ 2 t/ha were kept in main plots and various P doses (0, 40, 80 and 120 kg P_2O_5/ha) were applied in sub plots.

Recommended basal dose of N @ 100 kg/ha (half at sowing time and remaining half at tillering stage) and K @ 50 kg/ha as SOP were applied to all the plots at the time of sowing. Soaked seed (for 24 h) of rice cv. Basmati-2000 @ 40 kg/ha was broad-casted uniformly. The same inputs were applied to intermediate wheat crop. Effective weedicides were used to control weeds and the crop was grown to maturity. All agronomic requirements and plant protection measures were met throughout the growth period whenever required. Presowing soil samples (0-15 cm depth) were collected for the analysis of general soil characteristics (Table 1) according to the methods suggested by Ryan *et al*. (2001). Plant samples were collected at maturity for the determination of ionic concentration in tissues.

Table 1. General characteristics of saline soil before initiation and after the study during 2011 and 2012 (Average of three repeats)

P_2O_5	EC_e			SAR			pH			OM			P			K		
(kg/ha)	+CR	–CR	Mean	+CR	–CR	Mean	+CR	–CR	Mean	+ CR	–CR	Mean	+CR	–CR	Mean	+CR	–CR	Mean
Before sowing																		
0	4.59^{NS}	4.58^{NS}	4.58^{NS}	6.57^{NS}	6.56	6.57^{NS}	8.38^{NS}	8.38^{NS}	8.38^{NS}	0.52^{NS}	0.54^{NS}	0.54^{NS}	4.08^{NS}	4.07^{NS}	4.07^{NS}	78.03^{NS}	77.05^{NS}	77.02^{NS}
40	4.57	4.57	4.58	6.56	6.57	6.57	8.39	8.37	8.38	0.54	0.52	0.54	4.06	4.08	4.07	77.10	76.49	77.02
80	4.58	4.59	4.58	6.57	6.56	6.57	8.38	8.38	8.38	0.53	0.54	0.54	4.07	4.07	4.07	79.09	77.02	77.02
120	4.58	4.58	4.58	6.56	6.57	6.57	8.38	8.39	8.38	0.54	0.53	0.54	4.07	4.07	4.07	76.62	77.00	77.02
Mean	4.58^{NS}	4.58	-	6.57^{NS}	6.57	-	8.38^{NS}	8.38	-	0.54^{NS}	0.54	-	4.07^{NS}	4.07	-	77.02^{NS}	77.02	-
After harvest of final crop																		
0	3.87d	4.58a	4.22A	4.92d	6.57a	5.74A	8.18c	8.38a	8.28A	0.68^{NS}	0.49^{NS}	0.59^{NS}	2.99ef	1.28f	2.13D	95.26a	78.86d	87.06A
40	3.84d	4.51b	4.17B	4.87de	6.45b	5.66B	8.16c	8.37a	8.27B	0.69	0.52	0.61	8.26cd	3.89e	6.08C	93.46b	75.73e	84.60B
80	3.69f	4.42c	4.06C	4.82e	6.42bc	5.62BC	8.11e	8.34b	8.23C	0.71	0.53	0.62	11.23b	6.86d	9.05B	88.48c	73.86e	81.17C
120	3.77e	4.38c	4.08C	4.85de	6.36c	5.61C	8.14d	8.32b	8.23C	0.70	0.54	0.62	14.57a	9.56bc	12.06A	91.75b	70.82f	81.29C
Mean	3.79B	4.47A	-	4.87B	6.45A	-	8.15B	8.35A	-	0.69A	0.52B	-	9.26A	5.40B	-	92.24A	74.82B	-
Texture	sandy clay loam																	

SAR = sodium adsorption ratio; OM = organic matter (%); Means followed by same letter (s) do not differ significantly at $P \leq 0.05$ NS = non-significant.

Dried and ground samples were digested in perchloricnitric acid (2:1 1N) mixture (Rhoades, 1982) to estimate P, K^+, Na^+, Ca^{2+} and Mg^{2+} concentrations by spectronic-20 and atomic absorption spectrophotometer. At maturity, the crops were harvested and agronomic data on fertile tillers, plant height, panicle length, grains/panicle, 1000-grain weight, paddy and straw yields were recorded. Phosphorus use efficiency (PUE) was computed by using the following formula as suggested by Fageria *et al*., (1997):

$$\text{PUE (\%)} = \frac{(TPU_F) - (TPU_C)}{\text{P dose (kg/ha)}} \times 100 \quad \text{.............. (1)}$$

where:

TPU_F = total P uptake (kg/ha) in fertilized plots and TPU_C = total P uptake (kg/ha) in control plots.

Total PU was calculated as:

$$\text{TPU (kg/ha)} = \frac{\text{P contents (\%) in plant tissues (dry matter)} \times \text{yield (kg/ha)}}{100} \quad \text{........ (2)}$$

The Eq. 2 was used to calculate TPU_F and TPU_C separately for putting in Eq. 1.

The data thus, collected were subjected to statistical analysis using software package MSTAT-C and treatment means were compared using least significant difference (LSD) at 5% probability level (Gomez and Gomez, 1984).

Results and Discussion

Growth and yield of DSR. On an average of two years DSR crop data, maximum fertile tillers (19), panicle length (34 cm), grain/panicle (121) and paddy yield (3.26 t/ha) were produced with 80 kg P_2O_5/ha application along with CR incorporation (Table 2). Paddy yield obtained from the plots fertilized with 80 kg P_2O_5/ha under CR incorporation was statistically similar to paddy yield obtained under higher P application rate (120 kg P_2O_5/ha) with no CR incorporation, however, paddy yield obtained from the plots fertilized with rate of 80 kg P_2O_5/ha under CR incorporation was otherwise superior (6%) than that of obtained under higher P rate (120 kg P_2O_5/ha) without CR. Overall, paddy yield produced by this treatment (80 kg P_2O_5/ha) showed 22% additional yield over control (0 kg P/ha + CR). During second year of DSR, the lower dose of P (40 kg P_2O_5/ha + CR) performed statistically equal to higher P rate (120 kg P_2O_5/ha) without CR incorporation. On the average, continuous two year CR incorporation further increased 17% paddy yield during the follow up year of crop harvest as compared to previous crop harvest under CR incorporation.

Growth and yield of wheat crop. Minimum number of productive tillers (9), spike length (12 cm), grain/spike (33) and grain yield (2.87 t/ha) were produced from the plots where no P was applied under CR incorporation however, these parameters were significantly higher than that of control treatment (0 kg P_2O_5/ha) without CR incorporation (Table 3). A considerable increase in growth and yield contributing parameters was observed with P fertilization and CR incorporation. Maximum fertile tillers (17), spike length (17 cm), grain/panicle (56) and grain yield (3.56 t/ha) was produced with P application (@ 80 kg P_2O_5/ha) along with CR incorporation. Grain yield harvested with 80 kg P_2O_5/ha application and CR incorporation was 7% higher than extended P application rate (120 kg P_2O_5/ha) without CR incorporation. Wheat grain yield harvested with 40 kg P_2O_5/ha application and CR incorporation was also statistically similar to higher P rate (120 kg P_2O_5/ha) without CR incorporation. When P was applied without CR incorporation, maximum grain yield was obtained with higher rate of P (120 kg P_2O_5/ha) but was not again as much as harvested @ 80 kg P_2O_5/ha under CR incorporation. From our data, it can be seen that the paddy yield was 2.9 t/ha during the first year of experimentation while it was 3.5 t/ha during second year (Table 2). In comparison to regular practice of transplanting where the national yield is 2.4 t/ha on normal soils (GOP, 2014), yield data of present study is promising with the yield increase of 21% for first year and 45% for second year.

Ionic concentration and PUE of DSR and wheat. It is evident from the data in Table 4-5 that high Na^+ and Mg^{2+} while low K^+ and Ca^{2+} concentrations were determined from both DSR and wheat plant tissues where no P was applied without CR incorporation. Phosphorus application and CR incorporation significantly reduced saline ions (Na^+ and Mg^{2+})

Table 2. Growth and yield of direct seeded rice (DSR) influenced by P application and crop residues (CR) incorporation under saline soil (Average of three repeats)

P_2O_5	Tillers		Plant height (cm)		Panicle length (cm)		Grain/panicle		Paddy yield (t/ha)		Straw yield (t/ha)	
(kg/ha)	+ CR	– CR	+ CR	– CR	+ CR	– CR	+ CR	– CR	+ CR	– CR	+ CR	– CR
2011												
0	13.67bc	8.00d	126.33a	118.00b	26.00bc	17.67d	108.67bc	78.33d	2.497cd	1.887e	6.430ab	4.760c
40	14.00bc	12.33c	129.00a	119.67b	27.00bc	22.00c	110.67b	99.33c	2.637bc	2.215d	6.590a	5.657b
80	17.67a	15.67ab	130.00a	120.67b	30.67a	24.67bc	119.33a	105.67bc	2.987a	2.707abc	6.980a	6.523ab
120	16.00ab	16.00ab	130.00a	120.67b	28.00ab	27.00ab	115.67a	114.33ab	2.852ab	2.817abc	6.830a	6.737a
LSD	2.8362		4.6787		3.1727		8.3600		0.2639		0.9532	
2012												
0	14.67bc	9.33d	125.67b	98.00d	29.33bc	17.00e	105.67de	86.00f	2.873bc	1.560e	7.223b	5.090d
40	15.00bc	13.00c	127.00ab	114.00c	31.00b	24.00d	113.33bc	99.00e	3.103abc	2.127d	7.313b	5.750c
80	18.67a	15.67ab	133.67a	115.33c	35.67a	25.33cd	122.67a	109.00cd	3.537a	2.723c	7.913a	6.542b
120	16.33ab	16.33ab	129.00ab	116.33c	31.67b	26.67bcd	118.67ab	115.00ab	3.308ab	3.307ab	7.510ab	6.730b
LSD	2.4983		7.7940		3.7621		5.6257		0.5246		0.5817	

Means followed by same letter (s) do not differ significantly at $P \leq 0.05$.

Table 3. Growth and yield of wheat influenced by P application and CR incorporation under saline soil (average of three repeats)

P_2O_5	Tillers		Plant height (cm)		Spike/length (cm)		Grain/spike		Grain yield (t/ha)		Straw yield (t/ha)	
(kg/ha)	+ CR	– CR	+ CR	– CR	+ CR	– CR	+ CR	– CR	+ CR	– CR	+ CR	– CR
0	9.33d	6.67e	81.00ab	71.00b	12.67cd	9.67e	33.00c	20.67d	2.652c	1.591e	5.936ab	3.476d
40	12.33c	8.67de	88.33a	74.33b	14.33bc	11.00de	46.67b	42.67b	3.194abc	2.054d	6.314ab	4.433c
80	17.00a	14.00bc	89.67a	78.67ab	17.33a	12.67cd	56.33a	43.67b	3.560a	2.877bc	6.676a	5.447b
120	14.33bc	16.33ab	89.33a	79.00ab	15.33ab	16.33ab	48.33b	46.00b	3.259ab	3.320ab	6.377ab	6.547a
LSD	2.4807		9.2534		2.5848		6.2967		0.4200		0.9954	

Means followed by same letter (s) do not differ significantly at $P \leq 0.05$.

concentration and improved K^+ and Ca^{2+} in both DSR and wheat crop plants. The data indicated that P application particularly with CR incorporation considerably decreased Na^+ concentration and increased K^+ and Ca^{2+} concentration in plant tissues. Phosphorus application still at lower rate (40 kg P_2O_5/ha) along with CR incorporation performed better or even statistically equal to higher dose of P (120 kg P_2O_5/ha) without CR incorporation.

Maximum PUE in case of DSR (26%) and wheat (23%) was reflected from the plots treated with 80 kg P_2O_5/ha application under CR incorporation (Fig. 1) which was comparable with higher P dose (120 kg P_2O_5/ha) under no CR incorporation. Under CR incorporation, further increase in P application (120 kg P_2O_5/ha) did not show significant difference in PUE by both the crops. On the other hand, when P was applied without CR incorporation, maximum PUE was determined from the treatments

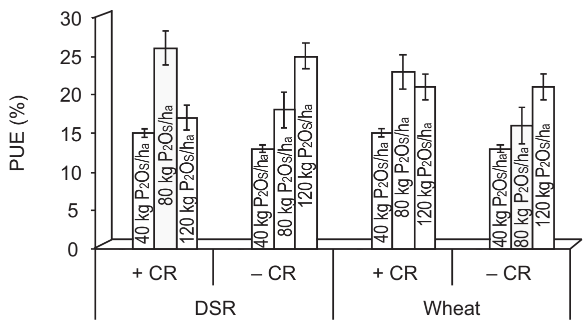

Fig. 1. PUE (%) of direct seeded rice and wheat as influenced by crop residues incorporation and P application under saline soil.

Table 4. Ionic concentration (%) in DSR plant tissues affected by P application and CR incorporation under saline soil (Average of three repeats)

P_2O_5 (kg/ha)	K^+		Na^+		Ca^{2+}		Mg^{2+}	
	+ CR	– CR	+ CR	– CR	+ CR	– CR	+ CR	– CR
				2011				
0	1.906e	1.827e	0.276bc	0.459a	0.196c	0.091d	0.196b	0.389a
40	2.268de	2.167de	0.266bc	0.315b	0.234c	0.212c	0.195b	0.374a
80	3.445a	2.555cd	0.144e	0.230cd	0.322a	0.247bc	0.141b	0.390a
120	2.920b	2.992b	0.178de	0.209cde	0.298ab	0.320a	0.135b	0.355a
LSD	0.4237		0.0473		0.0618		0.0738	
				2012				
0	2.016de	1.666e	0.225bc	0.419a	0.126d	0.085e	0.120c	0.215a
40	2.748bc	2.044de	0.178cd	0.290ab	0.197c	0.116de	0.115cd	0.174b
80	3.645a	2.289cd	0.138d	0.228bc	0.291a	0.196c	0.094d	0.143c
120	3.053b	2.739bc	0.184cd	0.199cd	0.249b	0.276ab	0.107d	0.106d
LSD	0.4977		0.0734		0.0331		0.0275	

Means followed by same letter (s) do not differ significantly at $P \leq 0.05$.

Table 5. Ionic concentration (%) in wheat plant tissues influenced by P application and crop residues (CR) incorporation under saline soil (Average of three repeats)

P_2O_5 (kg/ha)	K^+		Na^+		Ca^{2+}		Mg^{2+}	
	+ CR	– CR	+ CR	– CR	+ CR	– CR	+ CR	– CR
Straw								
0	1.249c	1.163c	0.136bc	0.221a	0.124d	0.105d	0.143bc	0.216a
40	1.896ab	1.148c	0.104de	0.207a	0.211b	0.177c	0.135bcd	0.198a
80	2.100a	1.800b	0.089e	0.169b	0.293a	0.205bc	0.106cd	0.149b
120	1.923ab	1.874ab	0.097e	0.135cd	0.219b	0.222b	0.121bcd	0.102d
LSD	0.2321		0.0310		0.0329		0.0403	

Means followed by same letter(s) do not differ significantly at $P \leq 0.05$.

where P was applied at higher rate (120 kg P_2O_5/ha) and was not as much of P application @ 80 kg P_2O_5/ha under CR incorporation.

Effect of CR on fertility status and saline soil amelioration. The data in Table 1 shows that at the end of study, there was a significant improvement in organic matter content as well as P and K availability owing to continuous CR incorporation and P fertilization. Maximum SOM and P, K contents were recorded with increased P application rate under CR incorporation in saline soil.

After the harvest of final DSR crop, overall 21% decline in ECe with CR incorporation was observed as compared to before the sowing of DSR with CR incorporation (Table 1). Increasing the rate of P application under CR incorporation also caused a significant reduction in ECe being the maximum decline with higher rates of P_2O_5 (80 and 120 kg/ha) after completion of study. Overall, ECe fell down to 3.79 dS/m from 4.58 dS/m due to continuous CR incorporation and was fairly below the permissible limit. Similarly, under CR incorporation, there was also a considerable reduction in the value of SAR from 6.57 before crop sowing to 4.87 $(mmol_c/L)^{1/2}$ after the harvest of third season DSR crop. A minimum mean value of pH (8.15) was observed from the plots incorporated with CR. Decrease in pH value under CR incorporation along with P application was slightly higher as compared to control (0 kg P_2O_5/ha) plots.

Growth and yield of DSR and wheat. Improved growth and yield of DSR and wheat with adequate P application and CR incorporation was possibly as a result of CR incorporation that positively contributed in growth and yield of DSR particularly during second year. This was apparently due to complete decomposition and mineralization of added CR which provided healthy environment owing to perfect soil physical condition by ameliorating the adverse effects of hazardous ions (Table 1). Moreover, water and P retention capacity might have also been improved due to added CR that retained comparatively excess moisture and P availability for a longer time. Besides, fabrication of acid farming substances by microbial activities and partial pressure of CO_2 released during CR decomposition decreased soil pH and enhanced P availability and other necessary plant nutrients which encouraged healthy plant growth and hence yields. Similar observations have also been documented by Mahmood *et al*. (2013), Danga and Wakindiki, (2009), Mishra *et al*. (2006) and Rath *et al*. (2005). Further, adequate P fertilization promoted vigorous early plant growth, improved tillering and increased number of grains per panicle which eventually produced better yield of DSR (Arshadullah *et al*., 2012; Sainio *et al*., 2006). The increase in yield due to CR incorporation as well as P application have also been well documented by Ali *et al*. (2012), Aslam *et al*. (2008), Krishna *et al*. (2004), Sharma and Prasad, (2003), Slaton *et al*. (2002), Eagle *et al*. (2000).

A significant increase in growth and yield contributing parameters of wheat grown after DSR was observed with P fertilization and CR incorporation. This was definitely attributable to CR incorporation that improved fertility status (Table 1) and consequently enhanced PUE (Fig. 1). Besides, adequate P application and its judicious utilization further facilitated to improve growth and yield. As it has been discussed earlier, that CR incorporation upon decomposition substantially changed the nutrient balance in rhizosphere which facilitated the plant roots to access the nutrients especially phosphorus. Growing plant roots and some microorganisms involved in decomposition of plant residues also discharge acid farming substances in the vicinity which could increase P solubility and its availability (Mahmood *et al*., 2013; Rehim *et al*., 2010).

Conversely, minimum number of productive tillers, panicle and spike lengths, DSR grains/panicle, wheat grains/spike and yields in case of control (0 kg P_2O_5/ha) of both DSR and wheat crops were due to P deficiency that directly distorted the normal tillering and grain formation by inhibiting their materialization and hence reduced yields (Rehim *et al*., 2010; Delgado *et al*., 2002). When P was applied without CR incorporation, higher grain yield was obtained with increasing P rate and was maximum where P was applied @ 120 kg P_2O_5/ha. Better crop growth and yield with maximum P application (120 kg P_2O_5/ha) under no CR incorporation could be due to the reason that crops grown under salt-affected soils demands relatively higher nutrition to reach the potential yields (Aslam *et al*., 2008; Mahmood *et al*., 1994). However, this yield harvested with 120 kg P_2O_5/ha under no CR incorporation was 6% less than that obtained from 80 kg P_2O_5/ha with CR incorporation. It is obvious from the data in Table 2 that during second year of DSR grown under CR incorporation, even lower P rate (40 kg P_2O_5/ha) performed statistically equal to higher P rate (120 kg P_2O_5/ha). This was most probably due to enhanced P availability in acidified rhizosphere as a result of microbial activities during CR decomposition. Moreover, fully decomposed CR and mineralization during subsequent wheat and DSR growing season presumably enriched the soil with mineral nutrients that contributed to a large extent in producing the maximum grain yields. Further, the longer root system in wheat crop might have absorbed nutrients from deeper soil layers to ensure healthy crop growth and hence yield. There are several reports that signify the role of P application in the enhancement of crop yields (Rehim *et al*., 2010; Danga and Wakindiki, 2009; Van der Eijk *et al*., 2006). Advantages of crop residue incorporation in soil and integrated nutrient management have been widely discussed by Ali *et al*. (2012); Shiva *et al*. (2012), Byous *et al*. (2004). Similar conclusions have also been reported by Yadvinder *et al*. (2004), Kharub *et al*. (2004), Sharma and Prasad (2003), Abid *et al*. (2002). Consequently, a substantial amount of P requirement for crop growth could be met by the incorporation of CR. Adequate P application approach on problem soils within the rice-wheat cropping system have to guarantee high and sustainable food grain production, high net profit and build-up of native soil P in available form.

Ionic concentration in plant tissues, PUE and soil physical status. The higher concentrations of P, K^+ and Ca^{2+} in CR treated plots could be due to enhanced mineral nutrition in soil through complete decomposition and mineralization of incorporated CR and P application further facilitated their intake by crop (Mahmood *et al*., 2013; Ali *et al*., 2012; Danga and Wakindiki, 2009). In particular, P application with CR incorporation considerably decreased Na^+ contents and increased K^+ and Ca^{2+} concentrations in wheat tissues (Table 5). Ali *et al*. (2003) have reported that in rhizosphere with higher nutrients concentration, plants absorbed and translocated relatively more K^+ and less Na^+ than at lower concentrations. The data indicated that, P application still at lower rate (40 kg P_2O_5/ha) along with CR incorporation performed better or even statistically equal to higher dose of P without CR incorporation. These findings could also be supported by the results of Mahmood *et al*. (2009), Delgado *et al*. (2002), Haq *et al*. (2001) and Kinraide (1999; 1998) who reported that salinity interferes with the absorption and translocation of K^+ and Ca^{2+} by plants.

It has been reported earlier that enhanced CO_2 partial pressure in the rhizosphere during the processes of CR decomposition and microbial respiration increased the availability of P and other essential nutrients (Mahmood *et al*., 2013; Ali *et al*., 2012; Qadir *et al*., 2003). Crop residues incorporation upon decaying also modified the environment by adding organic matter and nutrients, supporting by the data in Table 1. Improved soil physical conditions owing to CR incorporation also enhanced P uptake.

Further increase in P application (120 kg P_2O_5/ha) did not show significant difference in PUE by both (DSR and wheat) crops. On the other hand, under no CR incorporation, maximum PUE was determined from the treatments where P was applied at higher rate (120 kg P_2O_5/ha) and was not as much as of 80 kg P_2O_5/ha application with CR incorporation. This was most probably due to excessive uptake of saline ions in the absence of CR that reduced crop biomass ultimately resulting in less PUE. Many studies have investigated the effects of pH variation on P retention and availability, but reliable enhancement in soil P availability has not yet been obtained. However, minor changes may be achievable. For example: evidences from many detailed studies show that the more organic matter there is in soil, the more the amount of very readily available plant P (Rehim *et al*., 2012; Leytem and Mikkelsen, 2005; Delgado *et al*., 2002; Manske *et al*., 2000).

Conclusion

Results of the present study of two years (2011 and 2012) indicated that P application @ 80 kg P_2O_5/ha alongwith CR incorporation (2 t/ha) was found to be superior than rest of the treatments in terms of producing maximum grain yields of both DSR and wheat crops grown under saline soil. During second year of DSR grown under CR incorporation, the lower P application rate (40 kg P_2O_5/ ha) performed slightly better and produced comparable paddy yield as that of higher P application rate (120 kg P_2O_5/ha) without CR incorporation. Therefore, continuous CR incorporation is worth recommended to restore soil fertility as well as productivity.

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