CROP RESIDUES AND PHOSPHORUS EFFECT ON YIELD AND ECONOMICS OF DIRECT SEEDED RICE AND WHEAT GROWN UNDER SALINE-SODIC SOIL

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ABSTRACT:- A field study on saline-sodic sandy loam soil (EC_e =6.6 dS m^{-1}; pH =8.31; SAR =17.4 ($m.mol_c\ L^{-1})^{1/2}$; $CaCO_3$ =3.5% and available P=3.9 mg kg^{-1}) was conducted on direct seeded rice and wheat for two consecutive years at Soil Salinity Research Institute (SSRI) Farm, Pindi Bhattian, Pakistan to investigate the yield and economics of direct seeded rice and wheat under crop residue incorporation and phosphorus applications. Split plot design (crop residue in main plots and P application in sub plots) was followed with three replications. Biomass yields were collected at maturity of each crop. Maximum straw and grain yields of both crops were harvested with the application of P_2O_5 @ 80 kg ha^{-1} along with crop residues incorporations. Overall 2.75 and 2.89 t ha^{-1} of paddy and wheat, respectively were obtained with P_2O_5 @ 80 kg ha^{-1} under crop residue incorporation. Although, the yields produced with the treatment, 80 kg $P_2O_5 ha^{-1}$ + crop residue, performed similar to P_2O_5 @ 120 kg ha^{-1} without crop residues incorporation during both the years. However, on average, grain yield of direct seeded rice and subsequent wheat was significantly superior (22 % and 19%, respectively) than that of higher P_2O_5 application (120 kg ha^{-1}) without crop residues incorporation. As a whole, constant two years crop residues incorporation further improved the paddy yield (9%) during the following years of crop harvesting. Economic analysis of both the crops was carried out to see the best treatment with sufficient economic benefits as compared to without crop residues incorporation. Maximum net benefit of Rs. 92754 for direct seeded rice and Rs. 69558 for wheat grown with 80 kg P_2O_5 ha^{-1} application under crop residues incorporation was determined. Among P application treatments under no crop residues incorporation, the maximum net benefit (Rs. 75874 and Rs. =65725) and the highest residual values (Rs. 49809 ha^{-1} and Rs 39160 ha^{-1}) for direct seeded rice and wheat, respectively, were attained with 120 kg P_2O_5 ha^{-1} which were not again as much as that of 80 kg P_2O_5 ha^{-1} application with crop residues incorporation.

Key Words: Direct Seeded Rice; Wheat; Crop Residues Incorporation; P Application; Saline-Sodic Soil; Economic Analysis; Pakistan.

INTRODUCTION

In Pakistan, the rice crop occupies approximately 2.58 mha with 5.54 mt paddy production and 2.7% of the value added in agriculture and 33 m US $ foreign exchange earnings (GoP, 2014) that is much lower than developed

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countries. In rice-wheat cropping system, the world famous fine rice cultivars are grown on about 1.5 mha of the Punjab known as "Kallar tract" which have nearly one mha moderate to high salinity/sodicity (Mahmood et al., 2013). Usually, crop grown on such soils produces inadequate paddy due to toxic effects of specific ions on growth and ultimately reduced yields. Population growth and economic burden are exerting the pressure on arable lands. Intensive cropping are exhausting nutrients from soil equilibrium gradually, which is among the major constraints to get optimum yields. The consistent increase in population imposes a significant economical pressure; an intensive land use which degrade soil environment gradually and are the severe matter for apprehension. Rice and wheat both are nutrient-exhaustive crops and are mining the soils gradually. During the last decade, cultivated area has decreased realistically (~1.25%) owing to urbanization, industrialization and soil degradation due to salinity/sodicity problems (GoP, 2014). In fact, there are many problems facing resource poor farmers of salt-affected lands such as high costs of fertilizers, shortage of good quality irrigation water and electricity to pump the under ground water. Besides, high prices of fuels to operate machinery tools for land preparation and the harvest of crops are other constraints, which discourage badly the source restricted farmers. To overcome the problems of small farmers, efforts should be made to consolidate their income through natural resources management for maximizing crop productivity. Improvement in agricultural production is possible only through either managing natural resources or by diversification in cultivation techniques. Enhanced productivity per unit of land, water and labour is cost effective to increase agricultural production. Given the substantial gap between average farmer's and progressive farmer's yield per acre, there are intermediate opportunities to increase production through improved cultural practices such as good quality certified seed, balanced fertilizer use, improved soil resource management.

Nutrient mining due to intensive cropping and practice of imbalance fertilizer applications are the main examples of soil resources degradation. This results in 68% and 64%, reduction in the yield of rice and wheat, respectively, causing a loss estimate from 0.3 to 1.0 billion dollar per annum (Abbas, 2009). In the rice-wheat cropping system, a major limitation is the short time for wheat cultivation after the harvest of rice as well and further delay in planting affects the crop yield. A large area under rice and wheat crops is being harvested with combined harvester, which leaves behind a massive loose straw whose removal or exploitation in a short time period is not so easy. The situation compels farmers to burn that for preparing their lands for timely sowing of subsequent crops. Crop residues are rich source of plant nutrients that farmers demolish through burning which not only cause nutrient losses but also pollute the environment (Gupta et al., 2003; Ali et al., 2012; Mahmood, et al., 2013). In addition to these restrictions, the problem of P fixation in our soils due to high pH (Ghafoor et al., 2004) is another constraint considerably reducing crop yields. Under calcareous alkaline soils, its availability is further reduced owing to the formation of insoluble phosphate compounds. The growing crop plants under such environment demands relatively higher nutrition to produce the potential yields. The left over residues could be recycled if their burning is discouraged. Generally, a huge quantity of mineral nutrients utilized by the plant remains within residues which can be utilized for the growth of succeeding crops through their incorporation (Byous et al., 2004; Danga and Wakindiki, 2009; Mahmood et al., 2013). In many other studies by previous researchers (Eagle et al., 2000; Saha and Mishra. 2009; Anjum et al., 2013; Rath et al., 2005; Danga and Wakindiki, 2009; Ali et al., 2012; Shaaban et al., 2013) had reported that crop residues recycling definitely improved soil health in terms of enhanced nutrient status and hence crop productivity.

Traditional transplanting of rice is a very difficult process of cultivation which requires expensive labour and machinery tools for puddling rice fields. Consequently, direct sowing of rice is an option which saves all these expenses and complexities. The present field study was thus conducted under a permanent layout in naturally saline-sodic soil to explore economics of the crop residue incorporations as well as different rates of P application and their impact on direct seeded rice paddy and wheat grain yields.

MATERIALS AND METHOD

A field study was conducted for continuous two years in a constant layout under saline-sodic soil (EC_e= 6.6 dSm^{-1}, pH= 8.3, SAR=17.4 $(m.mol_c\ L^{-1})^{1/2}$, $CaCO_3$ =3.5% and available P =3.9 mg kg^{-1}; sandy loam) at Soil Salinity Research Institute (SSRI) Farm, Pindi Bhattian, Pakistan during 2011 and 2012. The experiments were planned following split plot design with three replications. Direct seeding of rice with and without crop residues incorporation (2 t ha^{-1}) was placed in main plots and different P rates (0, 40, 80 and 120 kg P_2O_5 ha^{-1}) were applied in the sub-plots.

Recommended basal dose of N @ 100 kg ha^{-1} (half at sowing time and remaining half at tillering initiation) and 50 kg K ha^{-1} as SOP were applied to all the plots at the time of sowing. Soaked seed (for 24 h) of rice cv. Basmati-2000 and wheat cv. Inqlab @ 40 kg ha^{-1} was broadcasted uniformly. 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. Each crop was harvested at maturity and the data on paddy/grain yields of direct seeded rice and wheat were collected to compute the economic analysis. The economic analysis of crop residues incorporation and four P fertilizer rates applied to direct sowing of rice and wheat crops grown under saline-sodic soil was computed (CIMMYT, 1998).

RESULT AND DISCUSSION

Yield of Direct Seeded Rice and Wheat Crop

Maximum paddy (2.75 t ha^{-1}) and wheat grains yields (2.89 t ha^{-1}) were produced with P application @ 80 kg P_2O_5 ha^{-1} along with crops residues incorporation which was considerably better (8% and 6%, respectively) than that of 120 kg P_2O_5 ha^{-1} without crops residues incorporation (Tables 1 and 2). On an average of two years yield data, a significant increase (22% and 19%) over control in paddy and wheat grain yields, respectively, was observed with 80 kg P_2O_5 ha^{-1} application along with crop residues incorporation. Overall, continuous two year crop residues incorporation further increased 6% paddy during the follow up year of crop harvest as compared to without crops residues incorporation. Crop residues incorporation appreciably contributed to growth and yield of wheat grown after directly sowing of rice. Crop residues incorporation might have contributed to growth and paddy yield of direct seeded rice planted in saline-sodic soil which upon decomposition substantially changed the nutrient balance and reduced the adverse effect of salinity /sodicity (Ali et al., 2012; Mahmood et al., 2013). This was probably due to the release of carbon that increased partial pressure of CO_2 and thus formation of H_2CO_3 which enhanced the mitigating effect against salinity/sodicity (EC_e =6.6 dS m^{-1}, pH =8.6, SAR =17.9 (m.mol_c $L^{-1})^{1/2}$ that fell down to EC_e =4.0 dS m^{-1}; pH =8.1; SAR =13.5 (m.molc $L^{-1})^{1/2}$ after harvest of final crop and increased solubility of added P (from 3.9 to 9.5 mg kg^{-1}) for plant uptake resulting in better growth and yield. Generally, the rice crop requires more P at early growth stage for stronger root and shoot development and thus boost up paddy yield (Mishra et al., 2006; Danga and Wakindiki, 2009; Mah-mood et al., 2013). The growth and yield increase due to crop residues incorporation (Eagle et al., 2000; Slaton et al., 2002; Sharma and Sharma, 2004 and Krishna et al., 2004) as well as P application (Aslam et al., 2008). Further, crop residues incorporation might have increased soil microbial activities that enhanced residues decomposition and avail-ability of released nutrients for healthy plant growth (Ali et al., 2012). Microorganisms form symbiotic associations with plant roots that increased the surface area of roots and their access to P. Some micro-organisms discharge acids into the soil which can help to solubilize little P minerals. Increased nutrients in rhizosphere and their rapid availability to growing plants upon complete disintegration of added crop residues provided favorable environment for healthy root

Table 1. Partial budget analysis for direct seeded rice grown with and without crop residues under saline-sodic soil

	P_2O_5			
	0	40	80	120
With crop residues				
Paddy yield (kg ha^{-1})	2258	2408	2754	2592
Straw yield (kg ha^{-1})	5852	6047	6134	6148
TCV	26625	27105	27585	28065
10 % less paddy yield	225.8	240.8	275.4	259.2
10 % less straw yield	585.2	604.7	613.4	614.8
Adjusted grain yield	2032	2167	2479	2333
Adjusted straw yield	2926	5442	5521	5533
Income (grain)	71127	75852	86751	81648
Income (straw)	14630	27211.5	27603	27666
Gross income (paddy + straw)	85757	103064	114354	109314
Net benefit (Rs ha^{-1})	59132	75959	86769	81249
Without crop residues				
Paddy yield (kg ha^{-1})	1346	168	2163	2437
Strawyield (kg ha^{-1})	3641	4538	5347	5594
TCV	24625	25105	25585	26065
10 % less paddy yield	134.6	168.2	216.3	243.7
10 % less Straw Yield	364.1	453.8	534.7	559.4
Adjusted paddy yield	1211	1514	1947	2193
Adjusted straw yield	3277	4084	4812	5035
Income (paddy)	42399	52983	68135	76766
Income (straw)	16385	20421	24062	25173
Gross income (paddy + straw)	58784	73404	92196	101939
Net benefit (Rs ha^{-1})	34159	48299	66611	75874

system of growing crops and thus improved their yield. This could be supported by the findings of Haq et al. (2001), Rath et al. (2005), Danga and Wakindiki (2009) and Mahmood et al. (2013) who reported that crop residues incorporation increased nutrients availability in soil and plants with well developed roots that explore more soil volume for better crop stand.

Table 2. Partial budget analysis for wheat grown with and without crop residues under saline-sodic soil

	P_2O_5			
	0	40	80	120
With crop residues				
Grain yield (kg ha^{-1})	2392	2551	2894	2842
Straw yield (kg ha^{-1})	4351	4522	4674	4719
TCV	27125	27605	28085	28565
10 % less grain yield	239.2	255.1	289.4	284.2
10 % less straw yield	435.1	452.2	467.4	471.9
Adjusted grain yield	2153	2296	2605	2558
Adjusted straw yield	3916	4070	4207	4247
Income (grain)	53820	57398	65115	63945
Income (straw)	31327	32558	33653	33977
Gross income (grain + straw)	85147	89956	98768	97922
Net benefit (Rs ha^{-1})	58022	62351	70683	69357
Without crop residues				
Grain yield (kg ha^{-1})	1691	1963	2524	2624
Straw yield (kg ha-1)	2959	3817	4583	4618
TCV	25125	25605	26085	26565
10 % less grain yield	169.1	196.3	252.4	262.4
10 % less Straw Yield	295.9	381.7	458.3	461.8
Adjusted paddy yield	1522	1767	2272	2362
Adjusted straw yield	2663	3435	4125	4156
Income (grain)	38048	44168	56790	59040
Income (straw)	21305	27482	32998	33250
Gross income (grain + straw)	59352	71650	89788	92290
Net benefit (Rs ha^{-1})	34227	46045	63703	65725

Partial/Budget Analysis of Direct Seeded Rice and Wheat Crops

Partial budget analysis for P application rates (Tables 1 and 2) showed that all P application rates under crop residues incorporation gave higher benefit than that without crop residues incorporation. However, maximum net benefit for direct seeded rice and wheat crops was calculated from P application 80 kg P_2O_5 ha^{-1} with crop residues incorporation under saline-sodic soil. This treatment for direct seeded rice and wheat again was superior as compared to elevated P application rates (120 kg P_2O_5 ha^{-1}) without crop residues incorporation. Whereas, among the P application treatments, minimum net benefit (Rs. 48299 for direct seeded rice and Rs. 46045 for wheat) were attained with the application of 40 kg P_2O_5 ha^{-1} without crop residues incorporation. Correspondingly, the P application 80 kg P_2O_5 ha^{-1} alongwith crop residues incorporation also demonstrated their highest Cost Benefit Ratio (CBR) for direct seeded rice and wheat. The results of present study was supported by Nagappa and Biradar (2002) who reported that directly sowing of rice is feasible and economical technique to get comparatively higher net income.

Cost Benefit Ratio (CBR) and Net Benefit (NB) of Direct Seeded Rice and Wheat Crops

The data indicates that maximum CBR (4.1) for direct seeded rice was calculated with the application of 80 kg P_2O_5 ha^{-1} under crop residues incorporation and it was 3.9 with elevated rate of P_2O_5 (120 kg ha^{-1}) without crop residues incorporation (Table 3). Similarly, the highest CBR of 3.5 for

Table 3. Cost benefit ratio for direct seeded rice grown under saline-sodic soil

Treatments	Gross income (Paddy + Straw)	Total cost that vary	Net benefit	Cost benefit ratio
With crop residue				
T_1 (0 kg P_2O_5 ha^{-1})	85757	26625	59132	3.2
T_2 (40 kg P_2O_5 ha^{-1})	103064	27105	75959	3.8
T_3 (80 kg P_2O_5 ha^{-1})	114354	27585	92754	4.1
T_4 (120 kg P_2O_5 ha^{-1})	109314	28065	81249	3.9
Without crop residue				
T_1 (0 kg P_2O_5 ha^{-1})	587	24625	34159	2.4
T_2 (40 kg P_2O_5 ha^{-1})	73404	25105	48299	2.9
T_3 (80 kg P_2O_5 ha^{-1})	92196	25585	66611	3.6
T_4 (120 kg P_2O_5 ha^{-1})	101939	26065	75874	3.9

wheat (Table 4) was calculated alongwith 80 kg P_2O_5 ha^{-1} under crops residues incorporation which was significantly at par (3.5) with higher rate of P_2O_5 (120 kg ha^{-1} without crop residues incorporation). Generally, all P application rates along with crop residues incorporation showed much higher NB being maximum (Rs. 86769 and Rs. 70683) with 80 kg P_2O_5 ha^{-1} application alongwith crop residues incorporation direct seeded rice and wheat crops, respectively. Among P application treatments without crop residues incorporation, the maximum NB (Rs. 75874 and Rs. 65725) for direct seeded rice and wheat, respectively, were obtained with higher P application rates (120 kg P_2O_5 ha^{-1}) which were not again as much as that of 80 kg P_2O_5 ha^{-1} application alongwith crop residues incorporation.

Residual Analysis for Direct Seeded Rice and Wheat Crops

The residual analysis was computed to confirm the results of marginal analysis. These results regarding

Table 4. Cost Benefit Ratio (CBR) for wheat grown under saline-sodic soil

Treatments	Gross income (Paddy + Straw)	Total cost that vary	Net benefit	Cost benefit ratio
With crop residue				
T_1 (0 kg P_2O_5 ha^{-1})	85147	27125	58022	3.1
T_2 (40 kg P_2O_5 ha^{-1})	89956	27605	62351	3.3
T_3 (80 kg P_2O_5 ha^{-1})	98768	28085	70683	3.5
T_4 (120 kg P_2O_5 ha^{-1})	97922	28565	69357	3.4
Without crop residue				
T_1 (0 kg P_2O_5 ha^{-1})	59352	25125	34227	2.4
T_2 (40 kg P_2O_5 ha^{-1})	71650	25605	46045	2.8
T_3 (80 kg P_2O_5 ha^{-1})	89788	26085	63703	3.4
T_4 (120 kg P_2O_5 ha^{-1})	92290	26565	65725	3.5

Table 5. Analysis using residual for direct seeded rice grown under saline-sodic soil

Treatments	1 Total cost that vary	2 Net benefit	3 Returned required by farmer (100% *1) Rs ha^{-1}	4= [2-3] Residual (Rs ha^{-1})
With crop residue				
T_1 (0 kg P_2O_5 ha^{-1})	26625	59132	26625	32507
T_2 (40 kg P_2O_5 ha^{-1})	27105	75959	27105	48854
T_3 (80 kg P_2O_5 ha^{-1})	27585	92754	27585	65169
T_4 (120 kg P_2O_5 ha^{-1})	28065	81249	28065	53184
Without crop residue				
T_1 (0 kg P_2O_5 ha^{-1})	24625	34159	24625	09534
T_2 (40 kg P_2O_5 ha^{-1})	25105	48299	25105	23194
T_3 (80 kg P_2O_5 ha^{-1})	25585	66611	25585	41026
T_4 (120 kg P_2O_5 ha^{-1})	26065	75874	26065	49809

residual analysis (Tables 5 and 6) demonstrate that the highest residual values of direct seeded rice and wheat were observed with 80 kg P_2O_5 ha^{-1} and crop residues incorporation followed by 120 kg P_2O_5 ha^{-1} without crop residues incorporation. The improvement in their economics is definitely attributed to continuous P application and crop residues incorporation that might have altered the soil physical conditions due to which P availability and its utilization was enhanced. Consequently, the nutrient utilization efficiency positively affects healthy growth and yields of directly cultivated rice and wheat crop in adverse soil condition. This corroborates with the findings of Ali et al. (2012); Gillani et al. (2014); Nagappa and Biradar (2002); Mehdi et al. (2003); Saha et al. (2014);

Table 6. Analysis using residual for wheat grown under saline-sodic soil

Treatments	1 TCV	2 NB	3 Returned required by farmer (100% *1) Rs ha^{-1}	4= [2-3] Residual (Rs ha^{-1})
With crop residue				
T_1 (0 kg P_2O_5 ha^{-1})	27125	58022	27125	30897
T_2 (40 kg P_2O_5 ha^{-1})	27605	62351	27605	34746
T_3 (80 kg P_2O_5 ha^{-1})	28085	69558	28085	41473
T_4 (120 kg P_2O_5 ha^{-1})	28565	67798	28565	39233
Without crop residue				
T_1 (0 kg P_2O_5 ha^{-1})	25125	34227	25125	09102
T_2 (40 kg P_2O_5 ha^{-1})	25605	46045	25605	20440
T_3 (80 kg P_2O_5 ha^{-1})	26085	63703	26085	37618
T_4 (120 kg P_2O_5 ha^{-1})	26565	65725	26565	39160

Ramzan et al. (2014). Khan (2004) reported similar trend in economic analysis of mungbean cultivars and P application rates. Similarly, the influence of various levels of N and P on green grams and its good response was reported by Srinivas and Shaik (2002). The results of Shaaban et al. (2013) showed that application of inorganic fertilizers integrated with farm yard manure enhanced nutrient availability as well as improved economical production of mungbean. Nadeem et al. (2010) and Ayyaz et al. (2014) also supported these findings. On the basis of all economic analyses of the study over two years (2012-2013), 80 kg P_2O_5 ha^{-1} could be recommended to farmers to get maximum return by directly sowing of rice and subsequent wheat crop on marginally salt-affected soils.

Thus on the basis of this investigation, it is concluded that crop residues incorporation is the best choice rather its burning to improve direct seeded rice and wheat yields with 80 kg P_2O_5 ha^{-1} application under slightly saline-sodic soil.

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AUTHORSHIP AND CONTRIBUTION DECLARATION

S. No	Author Name	Contribution to the paper
1.	Mr. Imdad Ali Mahmood	Conceived idea and expermentation Introduction, Materials and Method
2.	Dr. Arshad Ali	Results and discussion
3.	Dr. Armghan Shahzad	References
4.	Mr. Muhammad Asif Masud Ghumman	Statistical and economic analysis
5.	Dr. Muhammad Arshad Ullah	Help in write up abstract and Result and discussion
6.	Dr.Tariq Sultan	Experimentation
7.	Dr.Badar-u-Zaman	Soil and plant analysis

(Received April 2015 and Accepted January 2016)