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Effect of Wheat Residue Incorporation Along with N Starter Dose on Rice Yield and Soil Health Under Saline Sodic Soil

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Abstract. A field experiment was conducted to determine the effect of crop residue incorporation @ 5 tons wheat straw/ha along with N starter dose (0, 30 kg N/ha, 60 kg N/ha and 90 kg N/ha) on rice (super basmati) production and soil health under saline sodic soils (ECe=5.32 dS/m, pH=8.52 and SAR=18.38) during 2009. Treatments were arranged using randomized complete block design (RCBD) with three replications. The crop was harvested at maturity, data on tillering, plant height, spike length, number of grains/ spike, 1000-grain weight, straw and paddy yields were recorded. Na, K, Ca and N concentration in grain and straw were estimated using atomic absorption spectroscopy. Tillering, number of grains/spike, 1000-grain weight and paddy yield significantly ($P \leq 0.05$) increased by different levels of doses. Maximum plant height (135.66 cm) and numbers of grains/spike (140.33), spike length (24.66 cm), number of tillers/plant (40.33) and 1000-grain weight (23 g) were recorded at the application of 5 tons wheat straw/ha along with 90 kg N/ha. Grain yield was the maximum (3.32 t/ha) at the application of 5 tons wheat straw /ha along with 90 kg N/ha and 26% more than control treatment. Positive correlations ($r = 0.85$) and ($r = 0.96$) was observed between calcium and potassium contents in grain and grain yield of rice. However, negative correlation (-0.92) between Na contents in grain and paddy yield was found. It indicated presence of significantly higher Ca and K contents in grain receiving wheat straw application combined with N starter dose. Its application helped plants to attain more Ca and K to avoid sodium uptake which has been an added advantage to alleviate salinity/sodicity. Economical analysis showed maximum value cost ratio (5.45:1) with the application of 5 tons wheat straw/ha along with 90 kg N/ha.

Keywords: rice, crop residue incorporation, salt affected soil, N starter dose

Introduction

Soil salinization is one of the major factors that contribute to land degradation and decrease in crop yield (Anjum *et al*., 2005; Yassin, 2005). The negative effects of salinization are intensified by the low levels of soil organic matter (Muhammad *et al.,* 2005). Salinity poses threat to crop production in many areas of the world including Pakistan (Ashraf and Foolad, 2007; Hasegawa *et al*., 2000). It has been estimated that almost 40,000 ha of arable land in Pakistan is being lost due to salinity and the area is rapidly increasing each year (Ashraf *et al*., 2008; Ahmad *et al.,* 2006). Rice-wheat is the largest cropping system in the world. Approximately 85% of the rice-wheat area is in the indo-gangatic plains of South Asia covering Nepal, Bangladesh, India and Pakistan (Timsina and Connor, 2001). Rice is highly valued cash crop that earns substantial foreign exchange, grown on an area of 2.96 million hectare with production of 6.952 million tons (GOP, 2009).

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However, the farmers cannot afford chemical fertilizers and pesticides to achieve the potential which is much higher than the national average paddy yield. Hence, there is an urgent need to develop a technology which can fulfill crop production and better utilization of crop residue for soil fertility improvement. As per fertilizer off take data, N: P fertilizer use ratio is 4.67:1, the balance of fertilizer use is in favour of nitrogenous fertilizers (GOP, 2009). Fertilizer off take data showed 5.9% decrease in potassic fertilizer use during 2009 as compared to 2008 which is 25.3 thousand tons. As a result of imbalanced fertilizer use, crop productivity is decreasing. Under present situation the combined use of rice or wheat straw and inorganic fertilizer can, however, increase the yield of rice and wheat in rice-wheat systems (Mahapatra *et al.,*1991) Despite some advantages like killing of deleterious pests and clearing the piles before wheat planting, burning results huge losses of N (up to 80%), P (25%), K (21%) and S (4-60%), air pollution (@ CO_2 13 t/ha) depriving soils of organic matter (SOM). This loss of SOM is one of the

recognized threats to sustainability. Incorporation leads to build up of SOM, soil N, P and K. The major disadvantage of incorporation is the immobilization of inorganic N. However, N at 15-20 kg/ha as starter dose with straw incorporation increases yield of wheat and rice compared to burning (Krishna *et al*., 2004).

Wheat is the principal crop grown over an area of 9.05 million hectares with 24.032 million tons yield in Pakistan (GOP, 2009). Wheat grain is consumed as major staple food in the country. Approximately 25 million tons wheat straw is produced annually. Major proportion of wheat straw is being consumed by livestock. No doubt wheat straw is being considered more precious than paddy straw. However, considerable area under wheat is being harvested by combined harvester. The combined harvester leaves behind a large amount of loose straw in the field whose disposal or utilization is difficult, time consuming and laborious. So farmers are compelled to burn the crop residues causing major environmental threat whereby application of N 15-20 kg/ha as starter dose with straw incorporation increases yields of wheat and rice compared to burning of straw (RWC-CIMMYT, 2003).

As compared to paddy straw, wheat straw is relatively easier to manage than rice crop residue because time between wheat harvesting and rice transplantation is relatively more than time available between rice harvesting and wheat plantation. Temperature, moisture and microbial population are also more conducive for decomposition of wheat residue and C: N ratio of wheat straw is closer than rice residue. C:N ratio is an index to visualize how early the material is likely to decompose. The ideal C:N ratio is 20:1. However, wheat straw C:N ratio is wider like 40:1. To bring this ratio closer, N fertilizer is added to boost up decomposition process so that early mineralization of the straw can contribute nutrients for plant growth. Moreover, the availability of K and Ca reduces the Na uptake from solution root interface. Therefore the study has been designed to investigate the viability of incorporating wheat straw along with N starter dose and its impact on paddy yield and soil health under saline sodic soils.

Materials and Methods

A field experiment was conducted to determine the effect of crop residue incorporation along with N starter dose on rice (super basmati) production and soil health at SSRI, Pindi Bhattian, Pakistan under saline sodic soils during Kharif season 2009 (Table 1). Treatments were arranged using randomized complete block design (RCBD) with three replications. The treatments were: Control, 5 tons wheat straw/ha, T2+30kg N/ha, T2+60 kg N/ha and T2+90 kg N/ha. The wheat straw was incorporated in all treatments except control. The soil was prepared by puddling and a recommended dose of P_2O_5 and K_2O @ 80 and 50 kg/ha, respectively to all treatments. Full dose of P and K were applied at the time of rice transplantation. The crop was irrigated with tube well water throughout the growth period. Tubewell water applied during growth of rice crop has high residual sodium carbonate (RSC). However, ECw is marginally higher than salinity threshold value of 1.5 dS/m (Table 2). Necessary plant protection measures were taken whenever required. Data on tillers, plant height, panicle length, number of grain/panicle, 1000 grain weight, straw and paddy yields were recorded at the time of crop harvest. Plant samples were oven dried at 60 °C to a constant weight and recorded dry matter yield. Grain and straw samples were ground using Wiley mill then digested in perchloric-nitric diacid (2:1 1N) mixture (Rhoades, 1982) to estimate Na, K, Ca and Mg by atomic absorption spectroscopy. The data thus obtained were analyzed using MSTATC and treatment means were separated using LSD test.

Results and Discussion

Growth and yield. Salt-affected soils are characterized by high concentrations of soluble salts and low organic matter and nitrogen content (Asma *et al*., 2009).

Table 1. Physico-chemical analysis of the soil at SSRI Farm, Pindi Bhattian

Parameters	Value before residue incorporation	Value after residue incorporation
pH (1:1)	8.52	8.28
ECe (1:1) dS/m	5.32	5.74
SAR $(m.mole_c /L)^{1/2}$	18.38	17.13
$CaCO_3$ (%)	21	20
OM (%)	0.8	1.02
Sand (%)	63	63
Silt (%)	17	17
Clay (%)	20	20
Textural class -	Sandy loam	Sandy loam
Available N (mg/kg)	6.5	9.5
Available P (mg/kg)	4.3	7.1
Available K (mg/kg)	23	32

SAR = sodium adsorption ratio; OM = organic matter

Table 1 indicates that the soil pH was lowered and SAR decreased due to acidic effect of wheat straw incorporation combined with N starter dose. It helped acids release of Ca and leaching of Na. There was a slight increase in ECe of the soil. The available amount of all the major plant nutrients (N, P, K) and organic matter content increased in the soil. These results are in consonance to the findings of Sarwar *et al.* (2008). Data in Table 3 indicates that crop residue incorporation alone and with N starter dose significantly affected plant height, number of tillers, panicle length, number of grains/panicle, straw and paddy yield. Maximum plant height (136.66 cm), maximum numbers of tillers (40.33) and maximum panicle length (28.66 cm) were recorded in treatment receiving straw incorporation @ 5 ton/ha along with 90 kg N/ha. The highest number of grains per panicle (140.33) was recorded in treatment receiving wheat straw incorporation @ 5 ton/ha along with 90 kg N/ha and the lowest in control treatment. Thousand grain weight is an important index of grain health. Treatments receiving residue incorporation along with 30, 60 and 90 kg N/ha as starter dose produced healthy grain comparing with control treatment just receiving chemical fertilizer at recommended rate. Straw yield (24.46 t/ha) and grain yield (3.32 t/ha) were the highest in treatment receiving 5 tons wheat straw along with 90 kg N/ha and the lowest paddy yield (2.53 t/ha) was recorded in control. By the comparison of different treatments, it can be concluded that residue incorporation enhanced yield over control to a variable degree. This is the second crop in field receiving residue incorporation along with starter N dose. With the passage of time, soil fertility is improving as is evident from grain yield and resultantly less fertilizer addition will be needed. Microbial activity would have increased due to residue incorporation and N addition helping rapid decomposition. N starter application influence crop residue decomposition, nutrient release, and crop yields (Bijay and Bronson, 2001).

Ionic concentration. Ionic concentration in straw and paddy was found to be statistically significant except Mg and Na in straw and paddy (Table 4). Sodium uptake was higher in rice grain in control and the lowest where wheat straw @ 5 t/ha along with 90 kg N/ha was applied. This showed that crop residue incorporation alone and along with N as starter dose reduced sodium uptake in rice grains. Ca and K uptake by grain was relatively more where wheat straw was applied along with N starter dose. It can be concluded that incorporation of residue enhanced the availability of K and Ca to plant roots. Under saline conditions, plant can better cope with salinity in the presence of calcium and K. The presence of calcium also enhances rehabilitation of sodic soils which is prevalent in rice-wheat growing area. Furthermore with the continuous addition of crop residue, the availability of K and Ca is likely to increase. As a result, rate of rehabilitation of sodic soil will take place.

Data in Fig. 1 indicates significant positive correlation ($r = 0.85$) between calcium contents in grain and paddy

Table 2. Water analysis of tubewell

Parameters	Unit	Value
pH	-	8.1
ECe	dS/m	1.7
RSC*	meq/L	15.2
HCO_3	meq/L	17.5

*residual sodium carbonate

Table 3. Effect of wheat straw incorporation supplemented with N as starter dose

Treatment	Plant height (cm)	No. of tillers	Panicle length (cm)	No. of grain/ panicle	Straw yield (t/ha)	Grain yield (t/ha)	1000 grain weight (g)
T1=Control	126.00 b	28.66 d	24.33 c	88.00 d	14.76 e	2.53 d	20.66 bc
T2= Straw incorporation @ 5 tons/ha	128.66 b	32.66 c	27.66 a	93.66 c	16.13 d	2.64 d	21.66 ab
T3=T2+ 30kg N/ha	136.00 a	38.33 b	25.33 bc	98.66 c	20.96 c	2.86 c	19.33 c
T4=T2+60kg N/ha	133.00 a	40.33 a	26.33 b	122.33 b	22.23 b	3.14 b	22.33 a
T5=T2+90kg N/ha	135.66 a	40.33 a	28.66 a	140.33 a	24.46 a	3.32 a	23.00 a
LSD	4.294	1.031	1.031	5.168	0.1684	0.1191	1.375

Similar letters do not differ significantly at ($P<0.05$)

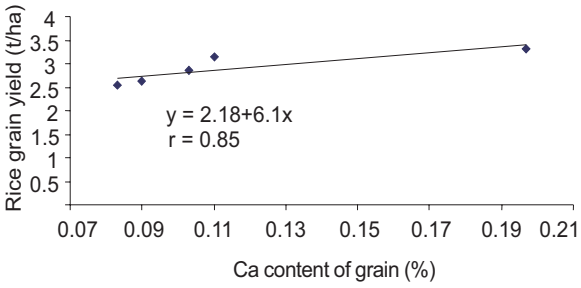

Fig. 1. Correlation Ca content of grain and rice yield.

yield. It indicates presence of significantly higher calcium contents in grain receiving residue incorporation combined with N starter dose. Its application help plants to attain more calcium and K to avoid sodium uptake which has been an added advantage to alleviate salinity/sodicity using crop residue incorporation apart from enhancing soil fertility and physical properties. Data in Fig. 2 indicates significant negative correlation (r = -0.92) indicating more sodium uptake where calcium and K uptake was the lowest in control treatment. Data

Table 4. Effect of wheat straw incorporation along with N as starter dose on Na, K, Ca and Mg uptake % by paddy grain and straw

Treatment	Ca% grain	Na% grain	K% grain	Mg% grain	Ca% straw	Na% straw	K% straw	Mg% straw
T1=Control	0.083 b	0.197 a	0.760 d	0.130	0.217 bc	0.320 d	1.827 a	0.637 d
T2= Straw incorporation @ 5 tons/ ha	0.090 b	0.163 ab	0.933 c	0.130	0.327 a	0.933 a	1.780 a	1.057 a
T3=T2+ 30kg N/ha	0.103 b	0.140 ab	1.293 b	0.123	0.323 a	0.263 d	1.627 b	0.827 c
T4=T2+60kg N/ha	0.110 b	0.127 b	1.337 b	0.127	0.173 c	0.590 b	1.830 a	0.683 d
T5=T2+90kg N/ ha	0.197 a	0.123 b	1.613 a	0.117	0.260 b	0.430 c	1.057 c	0.930 b
LSD	0.05954	0.05954	0.05954	NS	0.05954	0.05954	0.05954	0.05954

Similar letters do not differ significantly at (P>0.05).

Table 5. Economic analysis, partial budget analysis and dominance analysis of crop residue management with N on rice productivity

	T1 Control	T2 Straw incorporation @ 5 tons/ha	T3 T2+30 kg N/ha	T4 T2+60 kg N/ha	T5 T2+90 kg N/ ha
Dose					
Input cost Rs.	0	2500	3000	3500	4000
Application cost	0	0	0	0	0
Total cost that vary	0	12,500	14,000	15,000	16,325
Yield grain (kg/ha)	2530	2640	2860	3140	3320
Yield adjusted (10% Low)	2277	2376	2574	2826	2988
Output price (Rs./kg)	24	24	24	24	24
Yield straw (kg/ha)	14760	16130	20960	22230	24460
Yield adjusted (10% Low)	13284	14517	18864	20007	22014
Output price (Rs./kg)	1	1	1	1	1
Gross field benefits (Rs.)	67932	71541	80640	87831	93726
Net benefits (Rs.)	67932	69041	77640	84331	89726
Dominance Analysis					
TCV (Total cost that vary)	0	2500	3000	3500	4000
NB (net benefit)	67932	69041	77640	84331	89726
VCR (value cost ratio)	-	0.44	3.24	4.68	5.45

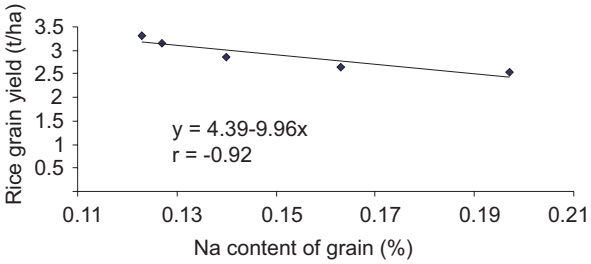

Fig. 2. Correlation between Na content of grain and rice yield.

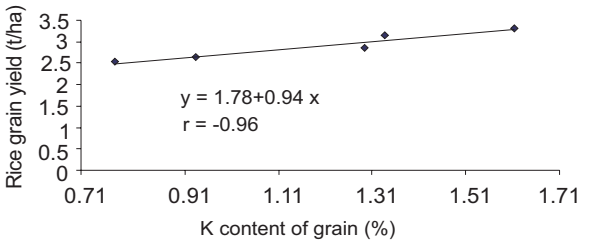

Fig. 3. Correlation between K content of grain and rice yield.

in Fig. 3 indicates significant positive correlation (r = 0.96) again indicating more potassium uptake as compared to control treatment. Chemical data indicates that application of residue incorporation along with N starter combats salinity sodicity by enhanced uptake of calcium and K.

Economic analysis. All the agronomic practices and plant protection measures were same except crop residue incorporation alone and with N as starter dose. The maximum net benefit was gained when wheat straw incorporation @ 5 ton/ha along with 90 kg N/ha was applied and that was higher than control treatment (Table 5). Presently N starter dose seems to be necessary for timely decomposition of crop residues. However, with the continuous input of crop residue and enhanced microbial population, starter dose may not be required in future. Dominance analysis is carried out for VCR (Value Cost Ratio) i.e. values of additional crop produce to the additional money spent on straw incorporation and N fertilizer.

Conclusion

Paddy yield was the maximum (3.32 t/ha) at the application of 5 tons wheat straw/ha along with 90 kg N/ha and 26% more than control treatment. Residue incorporation along with N application help plants not only to attain more Ca and K to avoid sodium uptake to alleviate salinity/sodicity but also help mineralization and mobilization of essential nutrients to plant apart from adding organic matter, therefore enhancing fertility and productivity of soil through improving the soil physical, chemical and biological properties. N starter dose helps in timely decomposition of wheat straw. Moreover, it is against the iconoclastic practice of burning crop residue and unleashing atmospheric pollution rather it saves the tremendous natural resource a step towards sustainable environmental development.

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