

EFFECT OF WHEAT RESIDUE INCORPORATION ALONG WITH N STARTER DOSE ON RICE YIELD AND SOIL HEALTH UNDER SALINE SODIC SOIL

M. Arshadullah, A. Ali, S. I. Hyder and A. M. Khan

Land Resources Research Institute, National Agricultural Research Centre, Islamabad, Pakistan

Corresponding author's email: arshad_pk2002.@yahoo.com

ABSTRACT

A field experiment was conducted to determine the effect of crop residue incorporation @ 5 tons wheat straw ha⁻¹ along with N starter dose (0, 30kg N ha⁻¹, 60kg N ha⁻¹ and 90kg N ha⁻¹) on rice (supper basmati) production and soil health at Soil Salinity Research Institute (SSRI) Farm, Pindi Bhattian, district Hafizabad under saline sodic soils (ECe=5.32 dS m⁻¹, 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⁻¹, 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⁻¹, 1000- grain weight and paddy yield significantly (P≤ 0.05) increased by different levels of doses. Maximum plant height (135.66 cm) and numbers of grains spike⁻¹ (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⁻¹ along with 90 kg N ha⁻¹. Grain yield was the maximum (3.32 t ha⁻¹) at the application of 5 tons wheat straw ha⁻¹ along with 90 kg N ha⁻¹ and 26% more than control treatment. Positive correlations (r= 0.85) and (r=0.96) 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⁻¹ along with 90 kg N ha⁻¹.

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 (Yassin, 2005; Anjum et al, 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 (Hasegawa et al., 2000; Ashraf and Foolad, 2007). 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 (Ahmad et al., 2006; Ashraf et al., 2008). 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. Rice is grown on an area of 2.96 million hectare with production of 6.952 million tons (GOP, 2009).

However, the resource poor 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 favor 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 (@ CO₂ 13 t ha⁻¹) 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⁻¹ as starter dose with straw incorporation increases yield of wheat and rice compared to burning (Krishna G 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, labour intensive. So farmers are compelled to burn the crop residues causing major environmental threat whereby application of N 15-20 kg ha⁻¹ as starter dose with straw incorporation increases yields of wheat and rice compared to either burning of straw (RWC-CIMMYT. 2003).

As compared to paddy straw, wheat straw is relatively easier to manage than rice crop residue due to the time between wheat harvesting and rice transplantation is relatively more than time available between rice harvesting and wheat plantation. Since fortunately, 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 reduce 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 soil.

MATERIALS AND METHODS

A field experiment was conducted to determine the effect of crop residue incorporation along with N starter dose on rice (supper basmati) production and soil health at SSRI, Pindi Bhattian, under saline sodic soils (Table-1) during Kharif season 2009. Treatments were arranged using randomized complete block design (RCBD) with three replications. The treatments were: Control, 5 tons wheat straw ha⁻¹, T2+30kg N ha⁻¹, T2+60kg N ha⁻¹ and T2+90kg N ha⁻¹. The wheat straw was incorporated in all treatments except control. The soil was prepared by puddling and a recommended dose of P₂O₅ and K₂O @ 80 and 50 Kg ha⁻¹, 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, EC_w is marginally higher than salinity threshold value of 1.5 dS m⁻¹ (Table 2). Necessary plant protection measures were taken whenever required. Data on tillers, plant height, panicle length, number of grain panicle⁻¹, 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. Ground plant samples were 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.

Table 1: Physico-Chemical Analysis of the Soil at SSRI farm, Pindi Bhattian.

Parameters	Unit	Value before residue incorporation	Value after residue incorporation
pH (1:1)		8.52	8.28
ECe (1:1)	dS m ⁻¹	5.32	5.74
SAR	(m.mole _c L ⁻¹) ^{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 ⁻¹	6.5	9.5
Available P	mg Kg ⁻¹	4.3	7.1
Available K	mg Kg ⁻¹	23	32

Table 2 : Water analysis of Tubewell

Parameters	Unit	Value
pH		8.1
ECe	dSm ⁻¹	1.7
RSC	meq L ⁻¹	15.2
HCO ₃	meq L ⁻¹	17.5

RESULTS AND DISCUSSION

Growth and yield: Salt-affected soils are characterized by high concentrations of soluble salts and low organic matter and nitrogen content (Asmalodhi *et al.*, 2009). Table-1 indicated 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 the table 3 indicated that crop residue incorporation alone and with N starter dose significantly affected plant height, number of tillers, panicle length, number of grains

panicle⁻¹, 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⁻¹ along with 90 kg N ha⁻¹. The highest number of grains per panicle (140.33) was recorded in treatment receiving wheat straw incorporation @ 5 ton ha⁻¹ along with 90 kg N ha⁻¹ 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⁻¹ as starter dose produced healthy grain comparing with control treatment just receiving chemical fertilizer at recommended rate. Straw yield (24.46 t ha⁻¹) and grain yield (3.32 t ha⁻¹) were the highest in treatment receiving 5 tons wheat straw along with 90 kg N ha⁻¹ and the lowest paddy yield (2.53 t ha⁻¹) 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-Singh *et al.*, 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⁻¹ along with 90 kg N ha⁻¹ 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.

Table 3 : Effect of wheat straw incorporation supplemented with N as starter dose on tillers, plant height, panicle length, number of grain/panicle, straw and grain yield of rice at SSRI, Pindi Bhattian (2009)

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 ⁻¹	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 ⁻¹	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 ⁻¹	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 ⁻¹	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

Means sharing same letters in a column did not differ with each other

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 at SSRI, Pindi Bhattian (2009)

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 ⁻¹	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 ⁻¹	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 ⁻¹	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 ⁻¹	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

Means sharing same letters in a column did not differ with each other.

Data in Fig 1 indicate significant positive correlation ($r = 0.85$) between calcium contents in grain

and paddy yield. It indicates presence of significantly higher calcium contents in grain receiving residue

incorporation combine 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 indicate significant negative correlation ($r= -0.92$) indicating more sodium uptake where calcium and K uptake was the lowest in control treatment. Data in Fig 3 indicate 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.

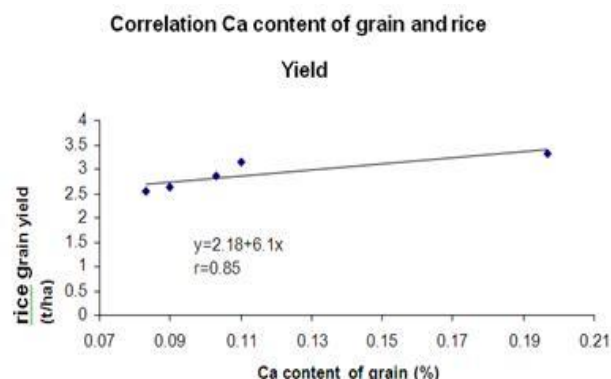


Fig-1:

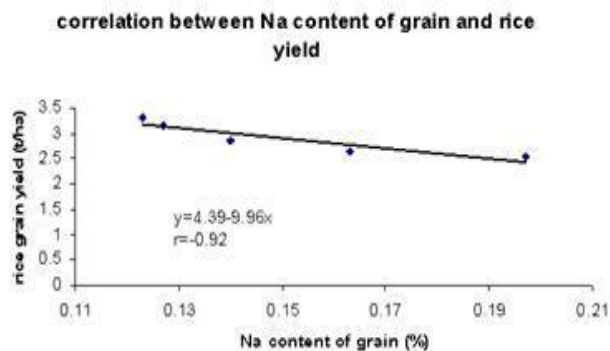


Fig-2:

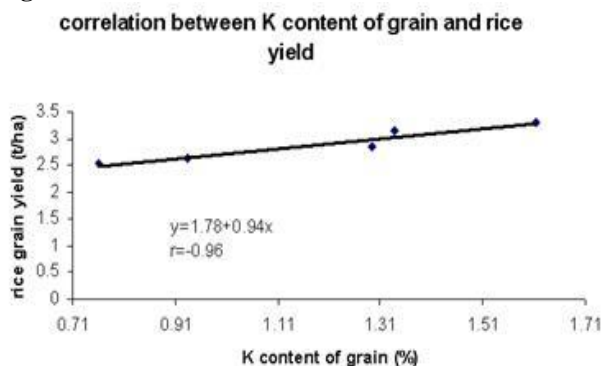


Fig-3:

Table 5: Economic analysis, partial budget analysis and dominance analysis of crop residue management with N on rice productivity, SSRI FARM, Pindi Bhattian.

	T1	T2	T3	T4	T5
	Control	Straw incorporation @ 5 tons ha ⁻¹	T2+ 30Kg N ha ⁻¹	T2+60Kg N ha ⁻¹	T2+90Kg N ha ⁻¹
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⁻¹	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⁻¹	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)		NB		VCR
T1	0		67932		
T2	2500		69041		0.44
T3	3000		77640		3.24
T4	3500		84331		4.68
T5	4000		89726		5.45

* Value Cost Ratio between values of additional crop produce to the additional money spent on straw incorporation and N fertilizer.

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⁻¹ along with 90 kg N ha⁻¹ was applied and that was higher than control treatment. 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 that is 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⁻¹) at the application of 5 tons wheat straw ha⁻¹ along with 90 kg N ha⁻¹ 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.

REFERENCES

- Ahmad, M. S. A., Q. Ali, R. Bashir, F. Jved and A. K. Alvi. (2006). Time course changes in ionic composition and total soluble carbohydrates in two barley cultivars at seedling stage under salt stress. *Pakistan J. Bot.*, 38: 1457-1466.
- Anjum, R., A. Ahmed, Rahmatullah, M. Jahangir and M. Yousif (2005). Effect of soil salinity/sodicity on the growth and yield of different varieties of cotton. *Int. J. Agri. Biology*, 4: 606–608.
- Ashraf, M. and M. R. Foolad. (2007). Role of glycine betaine and praline in improving plant abiotic stress resistance. *Environ. Exp. Bot.*, 59: 206-216.
- Ashraf, M., H. R. Athar, P. J.C. Harris. and T.R. Kwon. (2008). Some prospective strategies for improving crop salt tolerance. *Adv. Agron.* 97: 45-110.
- Asmalodhi, M. Arshad, F. Azam and M.H. Ssajjad (2009). Changes in mineral and mineralizable N of soil incubated at varying salinity, moisture and temperature regimes. *Pakistan J. Bot.*, 41(2),pp: 967-980.
- Bijay-Singh, K.F. Bronson 2001. Nitrogen-15 balance and use efficiency as affected by rice residue management in a rice-wheat system in northwest India. *Nutr. Cycl. Agroecosyst.* 59:227–237
- GOP. (2009). Agricultural Statistics of Pakistan. Ministry of Food, Agriculture and Livestock. Economic Wing. Government of Pakistan, Islamabad
- Greenway, J. and R. Munns. (1980). Mechanisms of salt tolerance in non- halophytes. *Ann. Rev Plant Physiol.*, 31: 149-190.
- Hasegawa, P. M., R. A. Bressan, J. K. Zhu and H. J. Bohnert. (2000). Plant cellular and molecular responses to high salinity. *Ann. Rev Plant Physiol. Plant Mol. Biol.*, 51: 463-499.
- Krishna G. Mandal*, Arun K. Misra, Kuntal M. Hati, Kali K. Bandyopadhyay, Prabir K. Ghosh and Manoranjan Mohanty, (2004). Rice residue-management options and effects on soil properties and crop productivity. *Food, Agri. & Environ.* 2 (1): 224-231.
- Muhammad, S., T. Müller and R. G. Joergensen (2005). Relationships between soil biological and other soil properties in saline and alkaline arable soils from the Pakistani Punjab. In. Muhammad, S. Microbial use of organic substrates and maize growth, especially in saline and alkaline soils of the Pakistani Punjab. PhD thesis, Department of Soil Biology and Plant Nutrition, Faculty of Organic Agricultural Sciences, University of Kassel. pp:48-71
- Mahapatra, B. S., G. L. Sharma and N. Singh (1991). Integrated management of straw and urea nitrogen in low land rice under a rice- wheat rotation. *J. Agric. Sci., Camb.* 116:217-222
- Rhoades, J. D. (1982). Cation Exchange Capacity. *In: Methods of Soil Analysis. Part 2. Chemical and microbiological properties.* A.L. Page, (ed.). Amer. Soc. Agron., Madison, Wisconsin, USA. pp. 149-158.
- RWC-CIMMYT. (2003). Addressing Resource Conservation Issues in Rice-Wheat Systems of South Asia: A Resource Book. Rice-Wheat Consortium for the Indo-Gangetic Plains-International Maize and Wheat Improvement Centre, New Delhi, India.
- Sarwar, G., H. Schmeisky, N. Hussain, S. Muhammad, M. Ibrahim and Ehsan Safdar (2008). Improvement of soil physical and chemical properties with compost application in rice-wheat cropping system. *Pakistan J. Bot.*, 40(1): 275-282.
- Timsina J. and D. J. Connor, (2001). Productivity and management of rice±wheat cropping systems: issues and challenges. *Field Crops Research* 69 93-132.
- Yassin, A. (2005). Adverse effects of salinity on citrus. *Int. J. Agri. Biology*, 4: 668–680.