RICE PRODUCTIVITY AND SOIL HEALTH AS AFFECTED BY WHEAT RESIDUE INCORPORATION ALONG WITH NITROGEN STARTER DOSE UNDER SALT-AFFECTED SOIL

Arshad Ali, Muhammad Arshadullah, Syed Ishtiaq Hyder, Imdad Ali Mahmood and Badar-uz-Zaman*

ABSTRACT:- A field experiment was conducted to determine the effect of wheat straw incorporation @ 5 t ha^{-1} along with different N starter doses (0, 30, 60 and 90 kg N ha^{-1}) on rice (Supper basmati) production and soil health at MK Farm, Farooqabad, district Sheikhupura under saline sodic soil (ECe=5.65 dS m^{-1}, pH=8.57and SAR=19.38) during 2010. Treatments were arranged in 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. Plant samples collected at maturity were analyzed for K, Ca and Na concentration in grain and straw. Tillering, grains spike^{-1}, 1000-grain weight and paddy yield significantly ($P \leq 0.05$) increased with different levels of N doses. Maximum tillers plant^{-1} (27.66), plant height (138.33 cm), spike length (28.33 cm), and grains spike^{-1} (175), 1000-grain weight (28.66 g) and paddy yield (4.25 t ha^{-1}) was harvested with 5 t ha^{-1} wheat straw incorporation plus 60 kg N ha^{-1}. The paddy yield was 19% more than control treatment. Positive correlations (r= 0.74) and (r=0.73) between Ca^{2+} and K^{+} contents in grain and its yield were calculated. However negative correlation (-0.85) between Na^{+} content in grain and paddy yield was noticed. Data indicates presence of significantly higher Ca^{2+} and K^{+} contents in grain receiving wheat straw incorporation along with N starter dose (30 kg ha^{-1}). Economical analysis showed that maximum value cost ratio (4.1:1) was determined with incorporation of 5 t ha^{-1} wheat straw plus 60 kg N ha^{-1}.

Key Words: Rice; Wheat Straw Incorporation; Saline Sodic Soil; N Starter Dose; Paddy Yield; Yield Components; Pakistan.

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 (Greenway and Munns, 1986; Hasegawa et al., 2000; Ashraf and Foolad, 2007). It has been estimated that almost 40,000 ha of arable land in Pakistan has been 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

*Land Resources Research Institute, National Agricultural Research Centre, Park Road, Islamabad-45500, Pakistan.
Corresponding author: arshad_pak786@yahoo.com

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 over 2.96 mha with production of 6.952 mt (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 fullfil crop production and better utilization of crop residue for soil fertility improvement. As per fertilizer off take data, N: P fertilizer used 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 was 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 13tha^{-1}) depriving soils of organic matter (Byous et al., 2004). Incorporation of crop residues leads to build up of soil organic matter and plant nutrients (N, P, K and Ca). 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 et al., 2004).

Wheat is the principal crop grown over 9.05 mha with 24.032 mt yield in Pakistan (GoP, 2009). Wheat grain is consumed as major staple food in the country. Approximately 25 mt 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 combine harvester. This 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 burning of straw (RWC-CIMMYT, 2003).

Compared to paddy straw, wheat straw is relatively easier to manage the rice crop residue due to the following reason:

i. Time between wheat harvesting and rice transplantation is relatively more than time available between rice harvesting and wheat plantation.
ii. Fortunately, temperature, moisture and microbial population are also more conducive for decomposition of wheat residue.
iii. C:N ratio of wheat straw is closer than rice residue.

The C:N ratio is an index to visualize how early the material is likely to decompose. 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, present study was planned to investigate the viability of wheat straw incorporating along with different N starter doses and their impact on paddy yield and soil health in salt-affected soil.

MATERIALS AND METHOD

A field experiment was conducted to determine the effect of crop residue incorporation alongwith N starter dose on rice (Supper basmati) production and soil health at MK Farm, Farooqabad, district Sheikhupura under saline sodic soils (Table 1) during *kharif* 2010. Treatments were arranged using randomized complete block design (RCBD) with three replications. The treatments were:

T_1 = Control
T_2 = Wheat straw @ 5 t ha^{-1}
T_3 = Wheat straw @ 5 t ha^{-1} + 30 kg N ha^{-1}
T_4 = Wheat straw @ 5 t ha^{-1} + 60 kg N ha^{-1}
T_5 = Wheat straw @ 5 t ha^{-1} + 90 kg N ha^{-1}

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^{-1}, were added in soil 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. Necessary plant protection measures were applied 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 ^oC 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. 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).

Table 1. Physico-chemical analysis of the soil at MK Farm, Farooqabad, Sheikhupura, Pakistan

Parameters	Value without crop residue before sowing	Value with crop residue after harvest
pH	8.57	8.32
ECe (dS m^{-1})	5.65	5.84
SAR(m.mole$_c$ L^{-1})$^{1/2}$	19.38	17.38
$CaCO_3$ (%)	7.00	7.00
Organic mater (%)	0.90	1.33
Total N (%)	0.03	0.04
Available P (mg kg^{-1})	4.07	5.11
Available K (mg kg^{-1})	39.12	42.37
Sand (%)	33.00	33.00
Silt (%)	42.00	42.00
Clay (%)	25.00	25.00
Textural Class	Loam	Loam

Table 2. Water analysis of tubewell

Parameters Unit	Value
pH	8.3
ECw dS m^{-1}	1.6
RSC me l^{-1}	14.7
HCO_3 me l^{-1}	16.3

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). Soil pH was lowered and SAR decreased due to acidic effect of wheat straw incorporation combine with N starter dose (Table 1). It helps in 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 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 (Table 3). Maximum plant height (138.33 cm), numbers of tillers (27.66) and panicle length (28.33 cm) were recorded in treatment receiving straw incorporation @ 5 t ha^{-1} along with 60 kg N ha^{-1}. The highest number of grains per panicle (175.66) was recorded in treatment receiving wheat straw incorporation @5 tha^{-1} along with 60 kg N ha^{-1}. The lowest in control treatment. 1000-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 compared with control treatment just receiving chemical fertilizer at recommended rate. Maximum straw yield (22.6 tha^{-1}) was attained @ 5 tha^{-1} straw incorporation. Grain yield (4.25 tha^{-1}) was the highest in treatment receiving 5 t wheat straw along with 60 kg N ha^{-1}. The lowest paddy yield (3.57 t ha^{-1}) was recorded in control. By comparing different treatments, it can be concluded that residue incorporation significantly enhanced paddy yield over control (Table 3). With the passage of time, soil fertility

Table 3. Growth and yield of rice influenced by wheat straw incorporation and N application at MK Farm, Farooqabad, Sheikhupura, Pakistan (average 2009 and 2010)

Treatment	Plant height (cm)	Tillers plant^{-1}	Panicle length (cm)	Grain panicle^{-1}	1000-grain weight (g)	Straw yield (t ha^{-1})	Grain yield (t ha^{-1})
T_1	129.33 d	16.00 c	27.66 a	129.66 c	26.00 b	16.39 e	3.57 d
T_2	136.00 b	21.33 b	25.33 b	132.33 c	25.66 b	22.63 a	3.70 c
T_3	131.33 c	21.33 b	24.33 b	120.00 d	27.66 a	19.63 c	4.09 b
T_4	138.33 a	27.66 a	28.33 a	175.66 a	28.66 a	21.48 b	4.25 a
T_5	136.33 b	15.33 c	28.00 a	167.00 b	28.33 a	19.13 d	4.10 b
LSD	1.141	1.14	1.418	5.219	1.141	0.197	0.119

Means followed by same letter do not differ significantly at P = 0.05 was improved (Table 1) and resultantly increased crop yield with less fertilizer addition (Table 3). Nitrogen deficiency is one of the most important limiting factors for crop productivity and yield (Shah et al., 2003). Organic N decomposes to inorganic ammonium-N (NH_4-N) which further oxidizes to nitrate (NO_3-N) via nitrification. These two are the ionic forms of nitrogen that are taken up by the most of plants (Ghosh and Kashyap, 2003). Residues with wider C:N immediately undergo immobilization and subsequent crop suffers nutrient deficiency. The problem is mostly handled by application of mineral N fertilizers that basically reduces the C:N and helps in sufficient nutrient supply needed for the plant.

Ionic Concentration

In straw and paddy ionic concentration was statistically significant except for Mg^{2+} and Na^+ in straw (Table 4). Sodium concentration was higher in rice grain harvested from control and the lowest where wheat straw @ 5 t ha^{-1} plus 90 kg N ha^{-1} was applied. This showed that crop residue incorporation alone and along with N application reduced Na^+ concentration in rice grains. This was presumably due to dilution factor resulting in more K^+ uptake released from decomposed organic residues which suppressed Na^+ concentration in plant tissues as a result of antagonistic effect (Table 4). Generally it is assumed that reduced growth of plants in saline environment is not only due to decreased water potential but is also due to ion excess in the shoot caused by enhanced Na^+ and Cl^- uptake (Yeo and Flowers, 1986; Maser et al., 2002). Kupier (1984) reported that the root medium NaCl salinity interferes with the absorption and translocation of K^+ by plants. Similar findings have also been reported by Ali et al. (2003).

Ca^{2+} 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^{2+} to plant roots. Under saline conditions, plant can better cope with salinity in the presence of Ca^{2+} and K^+. The presence of Ca^{2+} also enhances rehabilitation of sodic soils which is prevalent in

Table 4. Effect of wheat straw incorporation along with N application on Na, K, Ca and Mg concentration (%) by paddy grain and straw at MK farm, Farooqabad in district Sheikhupura, Pakistan

Treatment	Grain				Straw			
	Ca^{2+}	Na^+	K^+	Mg^{2+}	Ca^{2+}	Na^+	K^+	Mg^{2+}
T_1	0.10 d	0.17 a	0.12 d	0.16	0.43 ab	0.24	2.50 b	0.92
T_2	0.13 c	0.13 b	0.15 c	0.15	0.34 c	0.19	2.66 a	0.83
T_3	0.25 b	0.11 c	0.19 b	0.13	0.27 d	0.17	2.47 b	0.94
T_4	0.33 a	0.10 c	0.23 a	0.17	0.47 a	0.22	2.35 c	0.97
T_5	0.11 c	0.07 d	0.13 d	0.16	0.37 bc	0.26	2.10 d	1.04
LSD	0.018	0.018	0.019	NS	0.059	NS	0.059	NS

Means followed by same letter do not differ significantly at P = 0.05 rice-wheat growing area. Furthermore with the continuous addition of crop residue, the availability of K^+ and Ca^{2+} is likely to be increased.

Data also indicate significant positive correlation (r= 0.74) between Ca^{2+} contents in grain and paddy yield. It denotes presence of significantly higher Ca^{2+} contents in grain receiving residue incorporation combine with N starter dose (Figure 1). Its application help plants to attain more Ca^{2+} and K^+ to avoid Na^+ uptake which has been an added advantage to alleviate salinity/ sodicity using crop residue incorporation apart from enhancing soil fertility and physical properties. Data showed significant negative correlation (r= -0.85) indica-ting more Na^+ uptake whereas Ca^{2+} and K^+ uptake was the lowest in control treatment (Figure 2). Signi-ficant positive correlation (r= 0.73) again indicating more K^+ uptake as compared to control treatment is well evident (Figure 3) . Chemical data (Table 4) indicated that residue incorporation along with N application ameliorate salinity / sodicity by enhancing Ca^{2+}, K^+ and suppressing Na^+ ion accumulation which in turn improve the K:Na apart from consolidating the soil structure by flocculation. It helps better off fertility because of N, P mineralization and K^+ availability. It is finally concluded that mitigating the salinity status and alleviating water

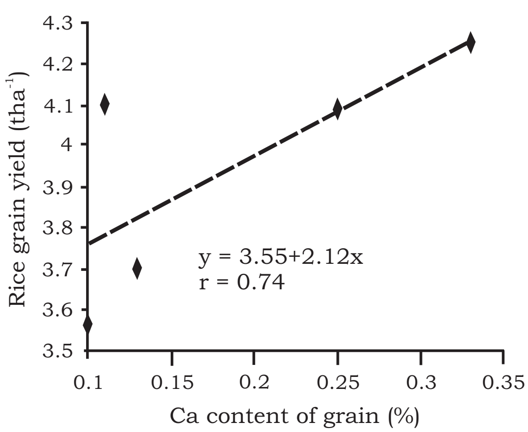

Figure 1. Correlation between Ca content of grain and rice yield

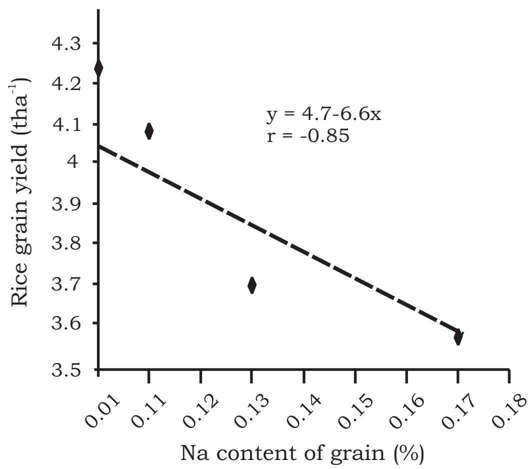

Figure 2. Correlation between Na content of grain and rice yield

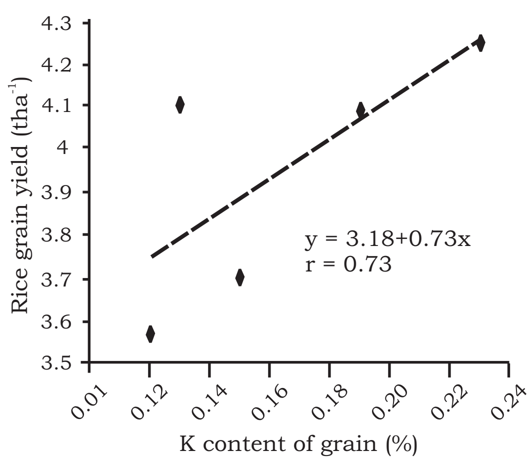

Figure 3. Correlation between K content of grain and rice yield

and nutrients stress not merely improve the soil health but also the paddy yield.

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 tha^{-1} along with 60 kg N ha^{-1} was applied and that was higher than control treatment. Marginal rate of return of treatment receiving straw incorporation along with 30 kg N ha^{-1} is 0.22 higher than treatment receiving 5t wheat straw alone (Table 5 and 6). 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.

It is thus concluded that the paddy yield was the maximum (4.25 t ha^{-1}) with the application of 5t wheat straw ha^{-1} along with 60 kg N ha^{-1} that was computed to be 19% more than control treatment. Residue incorporation along with N application help plants not only to attain more Ca^{2+} and K^{+} to avoid Na^{+} 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

Table 5. Economic, partial budget and dominance analysis of crop residue management with N on rice productivity, MK Farm, Farooqabad in district Sheikhupura, Pakistan

Particular		T_1	T_2	T_3	T_4	T_5
Input cost	(Rs)	0	6500	8,000	9,000	10,325
Total cost that vary	(Rs)	0	6500	8,000	9,000	10,325
Yield grain	(kg ha^{-1})	3570	3700	4090	4250	4100
Yield adjusted	(10% low)	3213	3330	3681	3825	3690
Output price	(Rs kg^{-1})	24	24	24	24	24
Yield straw	(kg ha^{-1})	16390	22630	19630	21480	19130
Yield adjusted	(10% low)	14751	20367	17667	19332	17217
Output price	(Rs kg^{-1})	1	1	1	1	1
Gross yield benefits	(Rs)	91863	100287	106011	111132	105777
Net benefits	(Rs)	91863	93787	98011	102132	95452

Table 6. Marginal Analysis on rice productivity, at MK Farm Farooqabad, Sheikhupura , Pakistan

(Rs)

Treatment	Total cost	Marginal cost that vary	Net benefit	Marginal net benefit	Marginal rate of return
T_1	0	0	126492		
T_3	14000	14000	129578	3085.6	0.2204

dose helps in timely decomposition of wheat straw. Moreover, it is beside the traditional 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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