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Rice straw incorporation: its impact on potassium supply and soil fertility in rice-rice cropping pattern in saline areas of Bangladesh

M R Khan, M A Tarafder, M H Rahman, M F Islam and S Das

Soil Science Division, Bangladesh Institute of Nuclear Agriculture, **Bangladesh**

***Correspondence:** binamunna@yahoo.com_ **Received 14-07-2021, Revised: 24-11-2021, Accepted: 29-11-2021 e-Published: 05-12-2021**

This study carried out to investigate the bestowed of potassium (K) from rice straw and its higher use in rice production at southern coastal saline region of Bangladesh during July-October, 2018 and January-May, 2019. The different dose of potassium fertilizers were the treatments with rice straw. Saline tolerant rice variety Binadhan-8 used as test crop and six treatments designed for the study. The different treatments expressed significant difference among the treatments due to the different K fertilization along with the rice straw incorporation. The rice straw incorporation recovered the reduced K fertilizer in which higher amount of rice straw added. Treatments T_4 and T_6 receive same amount of K fertilizer but amount of rice straw addition different. The highest grain yield produced from treatment $T_{6,}$ which was 75% K fertilizer with 2.5 t ha^{-1} rice straw incorporation revealed higher amount of K was available from rice straw mineralization. In fact, there were positive trend changes occurs in soil pH, Om, N, P S contents and K content has very noticeable change observed due to the rice straw addition although some portion of chemical fertilizer was reduced as well as one year cultivation. Rice straw can supply K that can reduce chemical fertilizer as well as increase organic matter and reduce adverse effect of salinity to some extent.

Keywords: Salinity, rice straw, yield, Transplanted aman rice and Boro rice

INTRODUCTION

The coastal area is about 2.85 million hectare in deltaic Bangladesh of which cultivable land cover 0.83 million hectare which is 30% of total arable land (BBS 2018). About 90% of the arable land in the area remains fallow for 6-7 months after the Aman rice harvest because of the shortage of fresh water, salinity of the soil and late draining condition (SRDI, 2010). The rice based cropping patter is prime factor for food supply in Bangladesh (Kabir et al. 2015).

Among the main nutrients for rice are nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) of which on yield potentials depends (Kamrunnahar, et al. 2017).

A major abiotic problem in agriculture is salinity that will appears as an immense difficulty in next decades. The coastal areas of Bangladesh is affected by salinity is different level which make low land use in crop cultivation is averagely 50%. In the coastal areas tidal flooding in the rainy season (June-October) inundate the areas by saline sea water which increase the salinity of the soil and on the other hand, during dry season (November to May) high temperature enhance upward movement of the saline water. The salinity effects on plant deleteriously in the whole plant part which result reduce yield and leads to even plant death (Parida & Das, 2005). Among the limiting factor in agriculture, salinity on the top that effect from germination, physiological growth and total yield (Munns R & Tester, 2008). There are water stress occurs within the root zone resulted ion toxicity and nutritional disorders and thus creates oxidative stress, alteration of metabolic processes and physiological disorder occurs due to high salinity (Munns, 2002; Zhu, 2007).

The plant nutrient K is known as the “quality element” for the plant growth and yield (Haque and Rahman, 2004). The judicial use of potassium is very important for higher crop production with higher quality as well as decrease cost of production and increase farmer’s income. In Bangladesh, emphasis on K nutrition to crops has been laid mainly on inherent supply of K from soil to plant. The amount of potassium uptake by the plant needs to fulfill by the external addition which does not always appropriately done resulted there are a gap. During rice harvesting, straw has been removed from the field which is widespread in India, Bangladesh and Nepal, that is the reason for K depletion in many areas. The K demand for rice production is higher than N and P (Islam et al. 2015; Islam et. al. 2016) and about 103 kg potassium is required to produce 7.0 t ha^{-1} yield (BARC, 2012) never-the-less K demand differ with the rice variety as well (Islam &Muttaleb, 2016). The demand of K fertilizer increasing with a growth rate of 6.15 per annum and will be 361.32 thousand metric tons in 2020 (Naher et al. 2015). The potassium mining takes place when the rate of application is often less than 100 kg ha^{-1} in the rice field and it is obviously a limited factor that a soil does not have the ability to supply K for a long time.

Now-a-days, high yielding rice varieties has been intensively cultivated resulted higher uptake K from the soil which is responsible for K depletion. The nitrogen and potassium is required higher amount for rice cultivation and is negative balance in Bangladesh soil and it range from 0 -50 kg/ha/yr for N and -100 to -225 kg/ha/yr for K (Rijmpa and Islam, 2002). Continuous use of synthetic fertilizer deteriorate soil physiochemical characteristics and decrease fertility (Ali, Islam, &Jahiruddin, 2009; Singh et. al. 2014).

The K depletion is getting higher due to less use of K addition (Biswas et al. 2004) and high yielding variety rather enhance especially soils with light textured (Saha et. al. 2009) which is responsible for K depletion which results 100–225 kg^{-1} ha^{-1} yr^{-1} potassium losses (Rijmpa& Islam, 2002; Zhang et al. 2010). The rice cropping field is in high K depletion areas in agriculture crop production and it might be up to 60 Kg/ha. It is estimated that 61 kg/ha of K is needed for maintain soil potassium status in rice field (Ahsan et al. 1997).

Binadhan-8 with feather of saline tolerances and high yielding variety and released in 2010 which can be cultivated both saline and non-saline areas of Bangladesh. This rice variety has the ability to tolerant salinity up to 10 dSm^{-1} for the whole growing season. The farmers of Bangladesh have huge quantity of rice straw which they can use as organic matter to incorporate in the crop field. About 40% of N, 30 - 35 % P, 80 - 85 % K and 40 - 50 % S is taken up by rice straw at crop maturity (Dobermann and Fairhust, 2002). The rice straw has higher K among the other nutrient and this K can be used as a source of K when rice straw is applied to soil as organic matter. Hence, experiments were conducted with different levels of K along with rice straw and other fertilizers rates to evaluate the impact of rice straw incorporation to the K contribute for rice production.

MATERIALS AND METHODS

2.1 Experimental Site

This study was conducted at the southern coastal saline region at Debhataupazilla under Satkhira district of Bangladesh, during the period from July-October, 2018 and January-May, 2019. The purpose of the study was to determine the contribution of rice straw to K supply and K-use efficiency in rice production. The soil of the experimental field was saline with a pH value of 7.2-7.5 and the nutrient status of nursery bed soil and initial soil of experiment plot was shown in Table 2.

2.2 Treatments and Experimental Design

A rice variety (Binadhan-8) and six experimental treatments consisting of different rates and sources as follows: For T. aman rice T_1 Control (no fertilizer), T_2 ($N_{90}P_{12}K_{36}S_{10}$), T_3 (NPS + K_{18} + RS @ 1.25 t), T_4 (NPS + K_{27} + RS @ 1.25 t), T_5 (NPS + K_{18} + RS @ 2.50 t) and T_6 (NPS + K_{27} + RS @ 2.50 t). Regarding Boro rice, T_1 Control (no fertilizer), T_2 ($N_{160}P_{30}K_{60}S_{18}$), T_3 (NPS + K_{30} + RS @ 1.25 t), T_4 (NPS + K_{45} + RS @ 1.25 t), T_5 (NPS + K_{30} + RS @ 2.50 t) and T_6 (NPS + K_{45} + RS @ 2.50 t). The randomized complete block design (RCBD) is used with three replications.

Table 1: Nutrient status of nursery bed soil and initial soil of experiment plot

Soil	pH	OM (%)	Total N (%)	Available (ppm)		Exchangeable K (meq %)	EC (dS m^{-1})
				P	S		
Nursery bed soil	7.2	1.90	0.10	12.2	21.11	0.23	1.12
Initial soil	7.5	1.81	0.11	14.6	18.43	0.19	1.2

OM: Organic matter, EC: Exchange capacity, dsm^{-1}: decisiemens per meter

Table 2: Yield and yield attributes of T.aman rice (var. Binadhan-8) at farmers field Debhata, Satkhira

Treatments	Plant height(cm)	Panicle length (cm)	Tillers $hill^{-1}$ (no.)	1000 seed weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
T_1	89b	19.4c	8.6c	23.1	2.65c	3.80d
T_2	93ab	23.93ab	10.3bc	25.1	4.76b	6.66ab
T_3	97a	22.56b	9.6bc	24.4	4.03b	5.86c
T_4	95a	25.4a	12.3ab	26.0	5.16ab	7.20a
T_5	95a	22.53b	10.1bc	23.0	4.18b	6.23bc
T_6	94ab	25.4a	13.4a	26.2	5.36a	7.26a
CV%	2.84	4.05	15.7	6.25	7.00	6.23

Mean with common letter(s) in a column are not significantly different at the 5% level by DMRT. CV: Coefficient of Variation

2.3 Soil analysis

The initial and post- harvest soil samples of every plot and after two crop cultivation were collected from the experiment's field. The samples were taken at 0-15 cm depth and air dried, ground sieve for chemical analysis. The processed soil were examine for pH, total organic carbon, total N, exchangeable K, and available S with the standard method described by Jacson (1973), Black (1965), Olsen, Calc, Watanabe, and Dean (1954) and Page, Miller, and Keency (1982).

2.4 Methods of cultivation

Seeds of T. aman (transplanted aman) and Boro rice cv. Binadhan-8 were sown in seed bed on June 22, 2018 and January 7, 2019 respectively, which were transplanted in the main field on July 25, 2018 and January, 27, 2019 respectively. The planting distance was maintained at 20 × 15 cm. Fertilizer was applied to the plots as through urea, triple super phosphate, murate of potash and gypsum, respectively. According to the treatments PKS and 1/3rd of N were applied as basal in the soil before transplanting. The rest dose of urea fertilizer was broadcast in two equal splits as top dressing, at 25 and 50 (T. aman rice), and 30 and 55 (Boro rice) days after transplanting respectively. Potassium fertilizer was applied according with the treatment to each unit plot. After transplanting, all required intercultural operations like thinning, weeding, irrigation and pest control were done as per treatment. The crop was harvested on October 27, 2018 and, May 15, 2019 respectively.

Rice straw incorporation supply K

2.5 Data collection and Statistical analysis

The rice was harvested when it reached to maturity. The data was recorded in for yield and yield contributing characters as plant height, panicle length, effective tillers $hill^{-1}$, 1000-grain weight, grain and straw yield. The yields (grain & straw) were adjusted with 14% moisture. Salinity ranged from 2.19 – 4.53 (dSm^{-1}) in T.aman season (July to October) and 4.26 – 9.69 (dSm^{-1}) in Boro season (February to May), respectively. The salinity record was done at every fifteen days interval. To notice the significance of variance of the recorded data, statistically analyses were done and the mean differences were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

RESULTS

Effect on plant characters and yield of T.aman and Boro rice were significantly influenced by the different treatments with K fertilizer along with residual effect of rice straw incorporation of T.aman and Boro rice. K created an environment to induce the growth of plant height rapidly in rice and which might be occurred due to its adaptation to the environment.

3.1 Grain yield

The ultimate goal of higher grain yield varied with the different treatments combination of rice residue and inorganic potassium significantly. Among the different treatments highest grain yield (5.36 t ha^{-1}) was produced from treatment T_6 which was statistically identical to treatment T_4 (5.16 t ha^{-1}) in first crop. Treatment T_4, 27 kg ha^{-1}(75% of recommended dose) potassium fertilizer was added along with 1.25 t ha^{-1} rice straws and in treatment T_6 same amount of potassium fertilizer was applied with 2.5 t ha^{-1} rice straws which seems supplied sufficient amount of K and treatment T_6 gave the highest yield. The treatment T_5 received higher dose of rice straw compare to but less potassium fertilizer produce grain yield less from T_4 yield. It revealed that rice straw can compensate the K nutrient from the soil as well as could save potassium fertilizer by 25% of recommended dose.

Regarding Boro rice, the total grain production between the treatments found alike and the maximum grain yield (5.76 t ha^{-1}) was produced from treatment T_6 which was statistically identical to treatment T_4 (5.63 t ha^{-1}) as well. The higher amount of rice straw contribute higher amount of K which interns can compensate to the reduced rate of chemical fertilizer added. The added rice straw can reduce 25% synthetic potassium fertilizer which is very noticeable. From the findings of the experiments, it can be designated that the highest grain yield found from treatment T_6 and all other yield contributing characters observed better among the treatments (Table 2 & 3).

3.2 Straw yield

The straw incorporation with soil in rice field contributed major participatory role for straw production in the paddy rice and significant difference observed among the treatments. The maximum straw yield (7.26 t/ha) was observed in treatment T_6 in T.aman rice. Regarding Boro season, the maximum straw (7.16 t/ha) produced from treatment T_4 followed by T_6 and the lowest straw yield produced from control treatment T_1 in both T.aman and Boro rice, respectively (Table 2 & 3). Won et al. (2015) also reported similar findings.

3.3 Salinity and Fertility

The salinity status is very important throughout the growing season. During the T.aman rice growing period, it is known as wet season in Bangladesh and due to rainfall salinity situation remain favorable for crop production. The salinity ranged from 2.19 to 4.53 (dS/m) during the July to October (T.aman rice) which is not high salinity for rice cultivation (Fig. 4). Likewise, Boro rice cultivation season (January to April) is considered as dry season in Bangladesh and almost no rainfall occurred that creates unfavorable condition of high salinity in saline areas for crop growth. The salinity ranged from 3.81 to 10.32 (dS/m) during the whole growing season (Fig. 1). The coastal regions of Bangladesh are quite low in soil fertility. The levels of soil pH, organic matter (OM), nitrogen (N), phosphorus (P), sulphur (S) and potassium (K) content prior to and after completion of T. aman and Boro rice are presented in Table 4and 5

Table 3: Yield and yield attributes of Boro rice (Binadhan-8) at farmers field Debhata, Satkhira

Treatments	Plant height(cm)	Panicle length (cm)	Tillers $hill^{-1}$ (no.)	1000 seed weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
T_1	84.53d	22.1b	13.83b	22.0b	2.93d	3.76c
T_2	91.56bc	23.86a	17.53a	24.16a	5.1abc	6.7ab
T_3	89.86c	23.2ab	17.1a	23.5a	4.73c	6.13b
T_4	93.66ab	24.6a	17.46a	24.36a	5.63ab	7.16a
T_5	92.26b	24.13a	17.53a	24.06a	4.83bc	6.2b
T_6	94.80a	24.53a	17.93a	24.5a	5.76a	7.13a
CV%	1.45	3.79	6.74	3.42	9.62	8.33
LSD	2.281	1.548	1.962	1.399	0.8006	0.886

Mean with common letter(s) in a column are not significantly different at the 5% level by DMRT, CV: Coefficient of Variation, LSD: least significance difference.

Table 4: Soil Nutrient status of post-harvest of T.aman rice growing season

Treatments	T. aman rice 2014					
	pH	OM (%)	N (%)	P (ppm)	K(meq%)	S (ppm)
Initial	7.5	1.81	0.11	14.6	0.19	18.43
T_1	7.5	1.80	0.09	14.0	0.18	16.85
T_2	7.4	1.78	0.08	14.4	0.20	17.75
T_3	7.3	1.80	0.11	14.2	0.20	19.50
T_4	7.6	1.83	0.12	14.1	0.24	19.70
T_5	7.2	1.90	0.12	14.6	0.22	19.00
T_6	7.3	1.90	0.11	13.8	0.23	19.40
Range	7.2-7.6	1.78-1.90	0.08-0.12	13.8-14.6	0.18-0.24	16.85-19.70

Table 5: Soil Nutrient status of post-harvest of Boro rice growing season

Treatments	Boro rice 2015					
	pH	OM (%)	N (%)	P (ppm)	K(meq%)	S (ppm)
T_1	7.6	1.76	0.09	13.6	0.16	16.12
T_2	7.8	1.76	0.09	14.5	0.19	17.35
T_3	7.5	1.95	0.10	14.1	0.20	19.65
T_4	7.4	1.98	0.12	15.1	0.22	20.15
T_5	7.2	2.00	0.13	14.8	0.21	19.10
T_6	7.2	2.00	0.12	14.7	0.21	19.96
Range	7.4-7.8	1.76-2.00	0.09-0.12	13.6-15.0	0.16-0.22	16.12-20.15

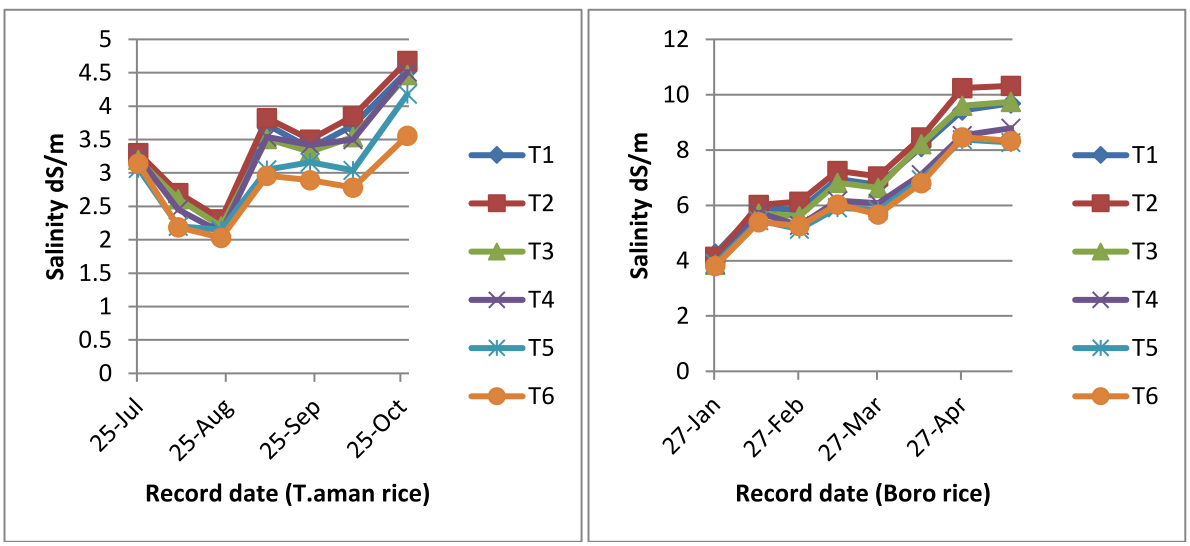

Figure1: Salinity record of both T.aman and Boro rice during the growing season under different treatments.

3.4 Consequence of rice straw incorporation in soil

3.4.1 Soil organic matter and pH

The soil organic matter (OM) status is low in saline soil but there are increasing trend observed in treatment with rice straw. The highest increase of OM was found in treatment T_5 and T_6 where 2.5 t ha^{-1} rice straws were applied (Table 4). The soil pH decreased slightly after consecutive two season's addition of rice straw. The treatment which received highest rice straw (2.5 t ha^{-1}) show a slightly decreased pH value. A slight decreasing trend of soil pH is observed within the rice straw received plots (Table 4).

3.4.2 Macro nutrients (N, P, K & S) content in soil

The soil nitrogen content was increased when higher amount of rice straw was added to soil. The highest increase of nitrogen was observed in treatment T_5 followed by T_6, which received the higher rice straw (Table 4). The soil available phosphorus was increased slightly due to the treatments with rice straw incorporation. The highest available of phosphorus was increased in treatment T_4 which received 1.25 t ha^{-1} rice straw never-the-less, the available phosphorus decrease when highest addition of rice straw treatment. Similarly, soil potassium and sulphur was increased in every treatment which received rice straw and the highest potassium and sulphur content was found in treatment T_4 and T_5 respectively.

DISCUSSION

4.1 Rice straw decrease salinity

Saline soil is reluctant for crop production but suitable management practices of reducing salinity along with saline tolerant rice variety (Binadhan-8) are a suitable option. Rice straw incorporation increase soil organic matter content and can alleviate salt effect from the saline soil. The results showed that rice straw incorporation improves the physiological growth of rice which thus reflects that rice straw reduce adverse effect of salinity. Rice straw amendment to the field increase organic matter content and play important role to decrease unfavourable situation of salinity. Among the different organic amendment (rice hull, rice straw & saw dust), rice straw found best to improve nutrition supply in rice cultivation in coastal saline soil of Bangladesh (Kaniz and Khan, 2013).

4.2. Reduces bulk soil pH and increases nitrogen

Rice straw addition to soil is very beneficial to soil physicochemical properties and increase organic matter content as well as is important in soil remediation. There is great influence of crop residue on soil pH. The mineralization process increased which thus reduces soil pH, thus influences in availability of plant nutrients in saline condition. Rice straw incorporation can alleviate the harmful situation of saline soil for plant growth (Bin et al. 2021). Among the treatments, 0.3 units of soil pH reduction were observed in highest rice straw addition plots. The soil pH of the different treatments reduces with the incorporation of rice straw (Table 4). Decomposition of organic matter decrease the soil pH thus increases nitrogen availability (Wang et al. 2015). The changes in pH are related to the excess cation concentration, C and N cycles, types of crop residues and soil (Butterly et al. 2012, Shen et al. 2015).

4.3. Rice straw increase potassium availability

There is variation observed in the treatments considering exchangeable potassium in soil. The treatments combination with the rice straw and inorganic K fertilizer improves soil K availability to plant (Table 4). Rice residue increase soil fertility and helps tp produce higher crop by improve nutrient supply (Singh and Reddy 2001).The rice straw addition helps to escalate soil available K which increase physiological growth of the rice plant and improve both grain and straw production (Dobermann*et al.* 1998). The potassium helps plant to combat with the stress condition which thus improve dry matter yield of paddy rice (Reyhaneh *et al*. 2012). The rice straw addition helps to increase readily available K (water-soluble K + exchangeable K) and suitable for K uptake by rice. Moreover, the rice residue has impact on increasing non-exchangeable K content due to the fixation process for all soils (Timtong D and Wittaya J., 2021)

4.4 Rice straw influences Grain yield

Rice straw incorporation helps to creates a suitable environmental for crop growth within the soil and add organic matter and supply nutrient elements. The decomposition of rice straw supplies some nutrients element that helps to improve the balance of nutrient availability when inorganic fertilizer was added in the field. Rice straw contribute to maintain soil N, P, K, and S reserves and sometimes it might improve (Dobermann and Fairhurst, 2002).

In the different physiological stage and plant body, K availability engageS in development which helps in crop growth. This finding as well authenticate, the greatest yield was produced from treatment which received the highest rice straw in both T.aman and boro rice. The residual nutrients for the succeeding crop of Boro rice avail better root zone condition in terms of nutrient to make use of them. The soil productivity and crop yield further improve due to the residues remain in the field from the preceding crop as well as rice straw incorporation and seems to remain minimum level of compensation for threshold necessity of soil organic matter. The effect of rice straw application may not be prominent in first crop T.aman rice due to less decomposition rate in organic matter. The high C:N ratio in rice straw might sometimes consequential low nutrient availability in the early stage (Rautaray, Ghosh, & Mittra, 2003), but chemical fertilizer enhance the starvation.

CONCLUSION

Rice straw contains more potassium compared to the other nutrients, which can be used as a source of K supply to crops. This rice straw is abounded for rice growing farmer which they can easily use as organic matter in rice field. Our study suggests that rice straw application could play an important role as a source of potassium as well as organic matter to improve nutrient status of the soil and enhance the fertility of the coastal saline areas for rice production in Bangladesh.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

MRK and MAT designed and performed the experiments. MRK and MHR wrote the manuscript. MAT, MFI and SD performed data analysis. All authors read and approved the final version.

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