Response of Indigenous Rice Cultivars to Applied Fertilizers in Tidal Floodplain of South Central Coastal Region of Bangladesh

ABSTRACT

Growing rice in tidal floodplain in south central coastal region of Bangladesh is constrained due to uncontrolled floodwater. The area is not suitable for growing high yielding modern varieties of rice and the farmers grow indigenous varieties which are tall and tolerant to tidal floods but with low yield potential. These varieties are usually grown without fertilizer application. Information on the response of these indigenous varieties to fertilizer application is either lacking or inadequate. The present study was conducted to evaluate the fertilizer response of three indigenous rice varieties. On farm trials were carried out for two consecutive growing seasons (2011 to 2013) involving fifteen (15) farmers of five villages representing tidal flood plain. There was significant varietal difference in fertilizer response. Variety Sadumota gave higher yield (3.84 t per ha) than the other two varieties. This was attributed to more panicles per unit area and larger number of spikelets per panicle. Varieties Moulata and Sadumota respectively produced 26 and 21% higher yield when grown with a moderate dose of 40 kg N, 15 kg P and 24 kg K per ha. Fertilizer induced higher yield in Sadumota was associated with greater number of filled spikelets per panicle and larger grain size.

Key words: Indigenous rice, fertilizer response, tiller density, grain yield, tidal floodplain.

INTRODUCTION

South central coastal region of Bangladesh (Jhalakati, Pirojpur, Barguna, Patuakhali and Barisal districts) is criss-crossed with numerous rivers and canals. The region is subjected to seasonal tidal flooding and lands remain inundated from July through October. Depth and duration of inundation, however, varies depending on land topography and distance from the rivers and the sea. Crop production in this tidal floodplain ecosystem is seriously constrained with uncontrolled flood water in the monsoon. High tide followed by low tide twice a day and flooding for about a week around full moon and new moon followed by recession in a fortnightly cycle during lunar month make the coastal tidal floodplain ecosystem unique. Crop production practices in this unfavorable ecosystem evolved following the natural phenomenon. Farmers over ages adapted to the changing pattern of natural ecosystem (Hamid, 2010). Because of land topography and hydrology, lowland rice is the only crop that farmers can grow during monsoon. Climatic conditions of Bangladesh favor growing rice throughout the year.

Farmers generally grow three crops of rice in different seasons- aus (summer), aman (monsoon/autumn) and boro (winter). There are however, spatial and temporal variations in areas rice is planted and cropping intensity. In the tidal flood plain, most lands are planted to aman rice, but ausis also commonly grown. Area where boro rice is planted is gradually expanding. Both aus and aman rice are grown mostly with naturally occurring tidal water. Production of HYVs in aus is a recent phenomenon; local varieties have been almost wholly replaced with modern varieties. But in aman season, farmers grow mostly indigenous rice varieties without fertilizer application. Traditional cultivars are generally tall, have few tillers, and produce low but stable yields under unfavorable environments. Because of low yield potential, indigenous lowland rice in tidal floodplain is generally considered to
be unsuitable for the intensive management practices aimed at high yields.

There has been a dramatic reduction in the cultivation of indigenous local varieties of rice in Bangladesh since the introduction of modern varieties. With the availability of high yielding, fertilizer responsive varieties and rapid expansion of irrigation facilities, Bangladesh farmers increasingly adopted modern rice varieties. Expanding culture of modern varieties led to serious genetic erosion making us reliant on a narrow spectrum of cultivars (Zhu et al., 2003). There had been a wide diversity of rice varieties grown in aman season but over the years the number of varieties has shrunk. Currently, four varieties (land races) - Sadamota, Lalmota, Nakhuchimota and Moulat dominate in tidal floodplain ecosystem of Jhalakati district and adjoining areas. These varieties are of long duration and perceived to be low yielding. Indigenous rice varieties used to be grown both under direct seeding (broadcast) and transplanting methods.

Currently, farmers no longer practice broadcast seeding. Seeds are planted in the nursery seedbed usually by mid-June and seedlings transplanted in the field by end-July or early August. The crop is harvested towards the end of December or early mid-January. It is commonly believed that siltation due to tidal inundation contributes to regeneration of soil fertility, although, the contribution of siltation to soil fertility has not been adequately studied (Hamid, 2010). Barison and Uphoff (2011) observed a total NPK uptake of 63 to 177 kg N, 13 to 36 kg P and 56 to 153 kg K per ha by rice crop. Even with low yield potential (2 to 4 t per ha), indigenous rice cultivars produce biomass to the tune of 10 to 12 t per ha suggesting that a moderate crop with indigenous rice variety may remove 90 kg N, 20 kg P and 100 kg K per ha in a growing season (www.knowledgebank.irri.org). Debnath et al. (2014) obtained significant response of T. Aman rice to fertilizer application in soils of tidal flood ecosystem. Application of fertilizers had been instrumental in introduction and raising yields of high yielding varieties in Bangladesh. Rates of fertilizers and application methods have been recommended targeting variable yield levels in different agro-ecological regions of Bangladesh (BARC, 2012). But no fertilizer recommendation is available for indigenous varieties of rice for tidal floodplain ecosystem (Nath et al., 2012) where continual rice cropping without fertilizer application must have depleted soil fertility leading to a situation that the soil cannot support sustainable crop production (Dobermann and Cassman, 1996).

In view of the increasing demand due to increase of population and income growth and bringing more land under cultivation being extremely limited, rice yield requires to be substantially increased to feed the growing population (Tilman et al., 2011; Ray et al., 2013). Meeting the increasing food demand amidst decline in productive agricultural areas warrants enhancing agricultural productivity of marginal ecosystem like tidal floodplain. Ecological conditions not being favorable for crop growing profitably, yield of indigenous aman rice in tidal floodplain is low. However, moderate to high yield potential of indigenous rice has been reported under good management conditions (Sinha and Misra, 2015). Effective water control is expensive and requires governmental and regional intervention. Improved crop nutrition could be an option for increasing system productivity (Haefele and Konboon, 2009). Several workers attempted to improve yields of indigenous rice but with limited success (Ragland and Boonpuckdee, 1987; Wade et al., 1999; Willet, 1995; Boling et al., 2008).

Rice yield improvement throughout rice growing countries in the world during the past decades was associated with the development and dissemination of high yielding, fertilizer responsive varieties. Indigenous rice varieties are either non-responsive or responds negatively to fertilizer application. Several workers Catling and Islam (1979) and Amin et al. (2006) reported significant response of indigenous rice varieties to fertilizer application. Saito et al. (2006) observed marginal yield increase in traditional upland rice due to fertilizer application. Singh et al. (2012) also reported significant but small increase in grain yield of traditional lowland scented rice varieties. Evaluating 55 landraces of latertic region of West Bengal, Sinha and Mishra (2015) reported that some of the landraces having high yields ranging between 4.653 to 5.665 t ha⁻¹ responded favorably to fertilizer application.

Amarasinghe et al. (2014) reported significant difference in the response of rice cultivars for fertilizer on growth parameters. Varieties also differed in the amount of fertilizers required for obtaining better growth and rice yield. In most cases, the response of both upland and lowland indigenous rice varieties was low or very low or inconsistent. Low response and inconsistent results could be explained by the characteristics of indigenous rice varieties and site-specific differences in soil fertility.

In the present study, we investigated the response of traditional rice cultivars to fertilizer application conducting on-farm trials in unfavorable ecological conditions in tidal floodplain ecosystem in southern Bangladesh.

**MATERIALS AND METHODS**

**Experimental location**

On-farm trials were conducted in two villages in the tidal floodplain for two consecutive aman seasons, 2011 to 2012 and 2012 to 2013. Two villages – North Uttampur in Rajapurupazila, and Kistakati in Jhalakatisadarupazila of Jhalakati district were selected for conducting the trial to evaluate the response of three popular indigenous rice varieties to applied fertilizers. Geographical locations of the villages are 22°33.06’ N and 90°09.70’ E and 22°36.16’ N and 90°09.90’E respectively. Five farmers (3 farmers in
North Uttampur and 2 farmers in Kistakati) participated in running the trial. Same farmers conducted the trials for both the seasons. Each farmer had devoted a plot of 0.134 ha for running the experiment. Plots in Kistakathi are in close proximity with the two rivers, Bishkhali and Dhanshiri on both sides and connected by canals. Plots in North Uttampur are close to the river Jangkali on the west and also not far from the river Bishkhali on the east. All the five trial plots were subject to tidal flooding in high tides at least a week around the lunar events- full moon or new moon. Soils in the study areas are clayey and clay-loam with low N, very low P, medium high K, high S, medium low Zn and very high contents of Ca, Mg, Cu and Fe (SRDI, 2008).

### Treatments

Three popular indigenous rice varieties- Lalmota, Moulata and Sadamota were used in the trial. Seedlings for all the five farmers were raised in a single place on a raised plot in order to avoid damage due to tidal flood. No fertilizer was applied in the nursery bed. 60-day old seedlings were uprooted and transplanted on the same day, 11th August, 2011 and 8th August, 2012 during low tides.

Three fertilizer treatments – (i) transplanting seedling following farmers’ traditional method of using handful of seedlings (>10 seedlings per hill) without fertilizer application (as control), (ii) transplanting of seedlings following farmers’ practice with basal application of 25% recommended rate was for HYVs, that is, 20 kg N, 8 kg P and 12 kg K per hand (iii) transplanting of seedlings in rows, 40 cm × 40 cm configuration with basal application of 50% of recommended rate of 40 kg N, 15 kg P and 24 kg K per ha. The latter two rates are based on the 25 and 50% of recommended rates for HYVs of rice grown under irrigated condition targeting moderate yield (BARC, 2012). NPK was applied in the form of urea, triple superphosphate and muriate of potash fertilizers, respectively. The whole amount of fertilizers was applied one day prior to transplanting seedlings in low tides when fields were not flooded. N fertilizer was not applied in splits because high tides usually do not allow topdressing of N fertilizer after transplanting. Hill density of each individual sub-plots were counted and recorded immediately after transplanting seedlings (Hamid et al., 2015).

### Observation and data analysis

Phenological development of three rice varieties as influenced by fertilizer application was recorded. All the three varieties used in the trial were of long duration. Variety Moulata required 172 days to harvest while Lalmota and Sadamota took 188 days. At maturity, panicles of an area measuring 5m × 2m at the center of each treatment plot was harvested and threshed. The paddy was sun dried for two days and weight recorded adjusting at 13% moisture content (http://wwwknowledgebankirriorg/moisture-content-calculations). Hill density of the harvest area was also recorded. Number of tillers per hill and number of panicles per hill were recorded. Number of tillers per hill was calculated dividing the number of tillers per unit area by the number of hills per unit area. Ten hill samples were collected from each sub-sub plot cutting at the base and plant height and a sub-sample of five panicles from each treatment plot was taken to determine the number of filled spikelets per panicle. Single grain weight was recorded taking samples of 1000 grains for each variety and fertilizer treatment. Results on plant growth, grain yield and yield attributes were subject to statistical analysis and means compared using LSD. A combined analysis of data was performed since the trend of response to fertilizer and variety was similar in both the years. The five locations where the trials were conducted in both the years were taken as replications and thus not considered variable in data analysis.

### Design of experiment

Three indigenous rice cultivars each with three fertilizer doses and planting methods were the treatment variables. Five farmers running the trial were considered replications. Thus, the trial comprising 3 × 3 treatments with 5 replications was set in a split-plot design. Each plot was divided into three sub-plots accommodating rice varieties. Each sub-plot was further sub-divided into three smaller plots to accommodate fertilizer treatment.

### Cultural management

Appropriate management practices were followed for growing the crop under tidal flooded conditions. Measures were taken to control weed growth. Insect pest infestation was minimal and no pesticide spraying was required. Disease infestation was also not noticed. Plants of Lalmota and Sadamota were studied and no lodging observed. Cultivar Moulata tended to lodge partially during maturity stage but that did not affect crop yield.

### RESULTS AND DISCUSSION

#### Morphological characters

#### Variety effect

Three varieties – Moulata, Sadamota and Lalmota were used in the trials. Results on hill and tiller densities at harvest are presented in Table 1. Variety had significant
Table 1. Influence of fertilizer application on hill and tiller densities of three varieties of indigenous rice.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Hills per m²</th>
<th>2011-2012</th>
<th>2012-2013</th>
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<tbody>
<tr>
<td></td>
<td>FP</td>
<td>25% RF</td>
<td>50% RF</td>
</tr>
<tr>
<td>Moulata</td>
<td>6.6</td>
<td>7.0</td>
<td>6.9</td>
</tr>
<tr>
<td>Lalmota</td>
<td>7.5</td>
<td>7.2</td>
<td>6.9</td>
</tr>
<tr>
<td>Sadamota</td>
<td>7.1</td>
<td>6.8</td>
<td>7.2</td>
</tr>
<tr>
<td>Mean</td>
<td>7.1</td>
<td>7.2</td>
<td>7.2</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>0.32</td>
<td>0.36</td>
<td>0.21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variety</th>
<th>Tillers per m²</th>
<th>2011-2012</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moulata</td>
<td>194</td>
<td>207</td>
<td>230</td>
</tr>
<tr>
<td>Lalmota</td>
<td>173</td>
<td>180</td>
<td>178</td>
</tr>
<tr>
<td>Sadamota</td>
<td>169</td>
<td>150</td>
<td>145</td>
</tr>
<tr>
<td>Mean</td>
<td>179</td>
<td>179</td>
<td>184</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>28</td>
<td>42</td>
<td>37</td>
</tr>
</tbody>
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Fertilizer rates: FP – farmers’ practice of usually no use of fertilizers, 25% RF – 20% of fertilizer rate recommended for irrigated HYVs, and 50% RF – 50% of fertilizer rate recommended for irrigated HYVs.

Table 2. Effect of variety and fertilizer application on the number of hills and tillers of indigenous rice per unit area. Mean of two growing seasons.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Hills per m²</th>
<th>Tillers per hill</th>
<th>Tillers m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moulata</td>
<td>6.85</td>
<td>31.6</td>
<td>217</td>
</tr>
<tr>
<td>Lalmota</td>
<td>7.52</td>
<td>23.1</td>
<td>173</td>
</tr>
<tr>
<td>Sadamota</td>
<td>7.22</td>
<td>22.5</td>
<td>162</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>0.31</td>
<td>6.38</td>
<td>32</td>
</tr>
</tbody>
</table>

Fertilizer rates: FP – farmers’ practice of usually no use of fertilizers, 25% RF – 20% of fertilizer rate recommended for irrigated HYVs, and 50% RF – 50% of fertilizer rate recommended for irrigated HYVs.

influence on the number of hills and tillers per m². The number of hills retained per m² at the time of harvest varied between 6.4 and 8.6 across varieties, fertilizer treatments and growing seasons. Averaged over growing seasons and fertilizer treatments, cultivar Lalmota displayed more hills per unit area (7.85) than the other two varieties while Moulata showed the lowest hill density (6.85). Variety, Sadamota ranked intermediate (7.22) hill density. Seedlings of all the three varieties were transplanted uniformly in the experimental plots regardless of treatment differences. Therefore, the difference in tiller density as displayed at harvest might have been due to differential response of varieties to tidal flood and its consequential effect on hill mortality during the growing season (Catling et al., 1983). Variety and spatial position also might have contributed to the difference in hill density.

The experimental crop experienced repeated cycles of tidal floods following transplanting. Flooding after seedling transplanting usually causes tiller damage. Varietal difference in tolerance to flood-damage has been widely reported (Srivastava, 2007; Colmer et al., 2013; Inandan et al., 2014). Variation in hill density observed in the present study might have been due to variable response of rice varieties to flooding tolerance. Presenting seasonal fluctuation in stand density of deep water rice, Catling et al. (1983) showed that flooding decreased plant stand and tiller density to the extent of 54% in Bangladesh. The number of hills per m² and the number of tillers per m² did not differ appreciably between the growing seasons (Table 1). Combined analysis was performed using data on hill and tiller densities (Table 2). It is apparent that tiller density differed significantly among the varieties. Averaged over fertilizer treatments, tiller density ranged between 162 and 217 per m² across varieties. The highest tiller density was recorded for Moulata followed by
Lalmota while Sadamota produced the least. Tillering is a varietal character (Yoshida, 198; Nuruzzaman et al., 2000) and environmental conditions and management factors having greater influence on tiller production. Significant influence of planting distance or population density on tiller production has been reported (Counce, 1987; Islam and Hossain, 2002). Sparsely planted rice hill produces relatively larger number of tillers compared with closed planted hills (Duy et al., 2004). Moulata displayed the greatest tiller density even though the variety had the lowest hill density per unit area. This was attributed to larger number of tillers per hill (Table 2).

One of the most important plant processes that greatly enhances rice yield is tillering (Hanada, 1993; Yan et al., 2010). Varieties differed significantly in the number of tillers produced per hill. Lalmota and Sadamota produced identical number of tillers per hill but was significantly lower than the number of tillers produced in Moulata. It is probable that relatively sparsely distributed Moulata plants might have compensated growing more tillers per hill (Huang et al., 2013).

**Fertilizer effect**

The effect of fertilizer application on the number of hills per unit area was rather inconsistent. No significant effect of fertilizer application on hill density was observed in 2011 to 2012 growing season. But in 2012 to 2013 growing season, application of 25 and 50% of recommended rate of fertilizers increased the number of hills retained per unit area at harvest in varieties Lalmota and Sadamota. Combined analysis of two years’ data, however, showed no significant effect of fertilizer application on hills or tillers per unit area. The results are contrary to the observations of Reddy et al. (1985) and Youseftabar et al. (2012) who had obtained positive response of tillering to fertilizer application. Our results are in agreement with Amarasinghe et al. (2014) who reported that application of fertilizer decreased tillering in certain indigenous cultivars while in other cultivars there was positive response.

**Grain yield and yield attributes**

**Variety effect**

Table 3 summarizes grain yield and yield attributes as influenced by variety and fertilizer application. Both variety and fertilizer application had significant influence on the number of panicles per m$^2$, but the interaction of variety and fertilizer application on panicle density was not statistically significant. There was no significant variation in panicle density between the two growing seasons. Number of panicles per m$^2$ ranged between 141

<table>
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<td>Lalmota</td>
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<td>176</td>
</tr>
<tr>
<td>Sadamota</td>
<td>143</td>
<td>165</td>
</tr>
<tr>
<td>LSD0.05</td>
<td>19</td>
<td>28</td>
</tr>
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Fertilizer rates: FP – farmers’ practice of usually no use of fertilizers, 25% RF – 20% of fertilizer rate recommended for irrigated HYVs, and 50% RF - 50% of fertilizer rate recommended for irrigated HYVs.
and 222 across varieties, fertilizer treatments and between two seasons. Averaged over two seasons, variety Moulata produced the largest number of panicles per m² (196) while the other two varieties, Lalmota (161) and Sadamota (160) produced identical but significantly lower number of panicles per unit area. The number of filled spikelets per panicle was more in Sadamota (96.0) than the other two varieties which produced identical but much lower number of spikelets per panicle. Varieties differed significantly in grain size or individual grain weight in both the growing seasons but inter-annual variation was not significant (Table 3). Single grain weight varied between 24.38 and 30.54 mg across varieties with highest being in Sadamota. Moulata recorded the lowest grain weight.

Grain yield was generally higher in 2012 to 2013 growing season than in the previous year. Averaged over varieties and fertilizer treatments, grain yield was 2.554 t per ha in 2011 to 2012 and 3.152 t per ha in 2011 to 2012. Grain yield was 23% higher in 2012 to 2013 growing season than in the previous year. Both variety and fertilizer application had significant influence on the variation in rice grain yield in both growing seasons. Trends of change in yield and yield attributes being similar due to treatments in both the years, a combined analysis was performed (Table 4). Averaged over seasons and fertilizer application treatments, grain yield ranged between 2.507 and 3.259 t per ha across varieties with highest being recorded for Sadamota. Lalmota and Molulata produced identical but significantly lower yield than Sadamota.

### Fertilizer effect

Fertilizer application significantly increased panicle density (Table 3). Application of a moderate dose of fertilizers increased the number of panicles per unit area by 14 to 17% over farmers’ practice. Fertilizer application tended to increase the number of filled spikelets per panicle; but the difference was not statistically significant. Grain size or single grain weight differed a little due to fertilizer application (Table 4).

Grain yield increased steadily with increasing rate of fertilizers. Incremental rate with 50% of recommended dose over FP was 21% in 2011 to 2012 and 26% in the subsequent year. The overall increase in grain yield due to fertilizer application was 23.9%. Yield response to fertilizer application across varieties varied between 21% (Sadamota) and 26% (Moulata). Magnitude of yield difference due to lower dose of fertilizer application appears to be small but substantial in indigenous rice varieties (Saito et al., 2006).

Variety and fertilizer application interaction on grain yield was also statistically significant. Application of moderate dose of fertilizers that is, 50% RF (40 kg N, 15 kg P and 24 kg K per ha) gave higher yields in all the varieties in both years. Farmers’ adopted practice of growing indigenous varieties of rice without fertilizer application gave markedly lower yield than fertilizer applied crop. Although, the magnitude of difference was not high, application of fertilizer increased grain yield significantly. Our results are in agreement with the report of Saito et al.
(2006) who obtained marginal increase in grain yield of indigenous rice due to fertilizer application. Variety, Moulata appeared to have responded more to fertilizer application than the other varieties producing over 26% higher yield. Sadamota when grown with higher rate of fertilizer gave nearly 4 tons ha\(^{-1}\) of grain yield which was 24% higher than the yield obtained from the crop grown without applied fertilizers. Sinha and Mishra (2015) also reported that some of the indigenous rice varieties in West Bengal (India) showed yield performance of over 5 t ha\(^{-1}\).

Three component traits - grain number per panicle, grain weight, and number of panicles per plant are the determinants of rice grain yield (Xing and Zhang, 2010). Yield traits are again genetically regulated (Futsuhara and Kikuchi, 1984). Number of panicles per plant depends on the tillering ability of the plant. Varieties differ widely in tillering ability (Nuruzzaman, 2000; Hamid et al., 2015). Rice plants do not produce panicles in all the tillers.

Lafarge (2011) demonstrated the positive contribution of unproductive tillers to yield formation. Varieties with greater number of tillers per unit area generally produce larger number of panicles. Fertilizer application increased the number of panicles in varieties Lalmota and Sadamota; but not in Moulata. Differential response of varieties to fertilizer application in respect of panicle formation has been reported earlier (Mae, 2011; Ding et al., 2014). Varieties differ widely in number of grains per panicle (Amin et al., 2006). Grain weight is fairly a varietal character and more or less genetically fixed (Yoshida, 1981). Enormous variation in rice grain weight has been reported (Fukushima et al., 2011).

In the present study, fertilizer induced higher yield in variety Sadamota can be attributed to increased number of spikelets per panicle and higher grain weight. Both variety and fertilizer application influenced panicle density and the number of spikelets per panicle, and although the difference was not spectacular. Fertilizer application increased tiller density, number of panicles per m\(^2\), and spikelets per panicle that ultimately contributed to increased grain yield. In contrast, variety Moulata had more panicles per unit area than the other varieties but fewer spikelets and lesser grain weight that resulted in lowest yield.

Conclusions

The common perception about the natural enrichment of soil fertility through seasonal flooding led the farmers to growing indigenous rice varieties extensively in tidal floodplain in southern Bangladesh without applying chemical fertilizers resulting in poor yield. Positive response of rice grain yield to fertilizer application dispels the farmers’ misperception suggesting that a substantial yield increase of indigenous rice varieties is possible by applying a moderate dose of fertilizers. Fertilizer recommendation for growing indigenous rice varieties in tidal floodplain is currently not available. Results of this study clearly indicate that application of fertilizers at 40 kg N, 15 kg P and 24 kg K per ha substantially increases rice grain yield. Tidal submergence during the growing season presents problem in fertilizer application. For effective use of applied fertilizers it would be necessary to develop methods of fertilizer application suitable for rice growing in the tidal floodplain.

ACKNOWLEDGEMENTS

One of us(MAH) actively participated in conducting the trials and collected data but suddenly died at the time the manuscript was at preparation stage. We pray for his departed soul. We are grateful to the participating farmers of Rajapur and Jhalakatisadarupazilla for running the trials. This research was funded by Krishi Gobeshona Foundation (KGF) through the CGP project 2.20. AH assisted designing the study, performed statistical analysis of experimental data, writing and editing of the manuscript; MAH and MAJ had carried out the field experiments and taken measurements; SA assisted in data analysis and MJU was responsible for overall management of the study. All authors read and approved the final manuscript.

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