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Enhancing rice yield in acidic soil through liming and fertilizer management

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Abstract

The effect of lime and fertilizer application, as the management of soil acidity, on the growth and yield of rice cv. BRRI dhan50 was investigated during *Aman* rice season at the Agronomy Field Laboratory of Sylhet Agricultural University, Bangladesh. The experiment was consisted of two factors namely lime and fertilizer. There were four levels of lime (0, 0.50, 1.00, and 1.50 t ha^{-1} of $CaCO_3.MgCO_3$) and three levels of fertilizers (control, FYM @ 10 t ha^{-1}, and chemical fertilizer @ 100-30-42-4-3-0.4 kg ha^{-1} of N-P-K-Ca-S-Zn). The experiment was laid out in a randomized complete block design with three replications where the unit plot size was 4.0 m x 2.5 m. Growth parameters, yield components and yield of BRRIdhan 50 rice increased with increasing lime rate in association of fertilizer in acidic soil. The highest grain yield (2.90 t ha^{-1}) was recorded from the application of 1.50 t ha^{-1} lime and the lowest (2.06 t ha^{-1}) was from control (0t ha^{-1}), irrespective of fertilizer. On the other hand, the best effect of fertilizers on grain yield (3.08 t ha^{-1}) was found with the application of FYM @ 10 t ha^{-1} and the lowest yield (1.59 t ha^{-1}) was in control. The treatment combination of lime 1.50 t ha^{-1} and FYM (@ 10 t ha^{-1} produced the highest grain yield (3.60 t ha^{-1}), which was followed by treatment combination of lime 1.50 t ha^{-1} and chemical fertilizer @ 100-30-42-4-3-0.4 kg ha^{-1} of N-P-K-Ca-S-Zn (3.28 t ha^{-1}). Additionally, application of lime and FYM improved the soil fertility and properties of acidic soil for crop production by increasing the pH, organic matter and availability of some essential nutrients. From the study, it was indicated that both FYM and lime could affect to enhance the grain yield of rice in acidic soil.

Introduction

Rice (*Oryza sativa* L.) is the staple food for nearly half of the population and second most widely cultivated crop plant in the world (FAO, 2008; Huang *et al*., 2010). Rice is the most extensively cultivated crop in Bangladesh, but yield is far below (4.5 t ha^{-1}) than that of many other countries like China 6.8 t ha^{-1}, in Japan 6.7 t ha^{-1}, in Korea 7.2 t ha^{-1}and USA 8.4 t ha^{-1} (FAO, 2017). Aromatic rice varieties constitute a small but elite group of rice and have gained greater importance with the worldwide increase in the demand of rice. Recently some modern aromatic rice varieties have been developed like, BRRI dhan34, BRRI dhan50 (*Banglamoti*), Binadhan-9 and Binadhan-13 etc. Cultivation of aromatic rice is becoming popular for its high price and export potential. Not only is aroma one of the most important characteristics for determining excellent quality rice but aromatic varieties have comparable or superior nutritional values and better amino acid profiles, for example, Basmati rice having a higher lysine, phenylalanine, leucine and methionine content than non-aromatic varieties (Sekhar and Reddy, 1982). Bangladesh Rice Research Institute has developed an aromatic fine rice variety BRRI dhan50 (*Banglamoti*) like the Basmati rice of Pakistan and India, but its yield was expected to be double. Thus, *Banglamoti* rice was trialed in different regions of Bangladesh and could be cultivated in both *Aman* and *Boro* seasons. Hoque *et al*. (2013) reported that BRRI dhan50 is a potential variety of aromatic fine rice for Sylhet region of Bangladesh.

Most of the agricultural soils of Sylhet region are acidic in nature with pH value of 4.9-6.1 (Hossain and Sattar, 2002). Liming of acid soils changes the pH, rectifies adverse effects and also improves the soil fertility (Reddy and Subramanian, 2016). A judicious application of lime and fertilizer may help overcome this problem of soil acidity although rice can be grown from pH level 5.5 to higher level. But soil with extreme low pH may need liming for having a good yield. Sub-optimal rate of lime cannot raise soil pH to a target one. On the other hand, too much addition of lime can decrease the availability of micronutrients, especially Fe, Mn, Zn and Cu sufficiently to cause deficiencies of those plant nutrients (Haynes, 1982). Also, over dose of lime application makes insoluble form of phosphate combined with Ca and Mg (Westermann, 1992; Murphy and Sims, 2012). So, determination of an accurate lime requirement for an acid soil is important to bring soil pH in suitable range for facilitating nutrient availability to plants and thereby encourage proper growth and yield of crops.

In addition to soil acidity, the widespread problem of Bangladesh soil is the declination of soil fertility gradually. Low organic matter content of the soil, imbalanced use of chemical fertilizers, less use of

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organic manures and inadequate attention given for its improvement and maintenance have made the situation difficult (Karim *et al.*, 1994). Before 1980's, deficiency of NPK was a major problem of Bangladesh soil but thereafter along with NPK deficiencies of S and Zn are frequently reported (Islam and Hossain, 1993; Haque and Jahiniddin, 1994). Presently, there has been a great increase in fertilizer use, yet different nutrients used in the country are not balanced. In Bangladesh most of the cultivated soils have less than 1.5% organic matter (Rahman *et al.*, 2014), whereas good agricultural soil should contain of least 2% organic matter. Moreover, this important component of soil is declining with time due to intensive cropping and use of higher doses of fertilizers with little or no addition of' organic matter. In general, organic manures improve soil physical, chemical and biological properties in addition to supplying substantial quantities of plant nutrients and chemical NPK fertilizers would be quite promising in providing greater stability in production (Karažija *et al.*, 2015).

The problem of nutrient deficiencies as well as nutrient mining caused by intensive cropping with HYV of rice and nutrient imbalance can be minimized by judicious application of nutrients through organic manures. Losses of soil organic matter can only be replenished in the short term by application of organic matter such as manures like FYM (Farmyard manure), compost, and decomposed cow dung. FYM is the well decomposed mixture of cow dung, urine and straw materials used as bedding and feed residual of farm animal; which is rich in organic matter and plant nutrient element (Gowarikere*t al.*, 2009). Application of organic manure alone or in combination with recommended fertilizer dose can play important role in rice cultivation. Hoque *et al.* (2016) reported that, application of well decomposed cow dung in BRRI dhan50 produced the maximum grain yield in comparison to chemical fertilizers.

Fertilizers both chemical and organic may eventually make the soil more acidic. Hydrogen is added in the form of ammonia-based fertilizers (NH_4^+), Urea-based fertilizers [$CO(NH_2)_2$] and as proteins (amino acids) in organic fertilizers. Transformation of these sources of N into nitrate (NO_3^-) releases H^+ to create soil acidity (Caires *et al.*, 2005). Therefore, fertilization with ammonium or even adding large quantities of organic matter to a soil will ultimately increase the soil acidity and lower the pH. Therefore, the present research work was undertaken to observe the effects of different level of lime application to acid soils along with 3 levels of fertilizer to ameliorate soil acidity and its impact on productivity of rice variety BRRI dhan50 (*Banglamoti*).

Materials and Methods

Experimental site and soil properties

The experiment was conducted at the experimental field of Sylhet Agricultural University (SAU), Sylhet, during the period of July to December 2012. The experimental area belongs to the highly acidic and silty clay loam soil under Agro-ecological Zone Northern and Eastern Piedmont Plain (AEZ 22). Before starting the experiment, initial composite soil samples (0 – 15 cm depth) were collected from the experimental plots and analyzed using available laboratory techniques. The soil was silty loam with low organic matter (1.38%) and acidic in nature (pH 5.2). The N (0.11 %) and S (22 ppm) content werelow and P (47.0 ppm) content was very low. The K (0.18 meq/100 g), Zn (0.98 ppm) and B (0.40 ppm) content weremedium (Table 1).

Plant materials and Treatments

The rice variety used in the experiment is BRRI dhan50 (*Banglamot*i) which was collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur, Bangladesh. BRRI dhan50 is long-grain aromatic fine rice, almost similar to cv. Bashmati. Lime dolomite dust [$CaCO_3.MgCO_3$] of agricultural field grade and chemical fertilizers were collected from local market of Sylhet, Bangladesh. FYM was collected from government dairy farm, Sylhet, Bangladesh. The experiment comprised of two factors: (a). lime (four levels): i) Control (t ha^{-1}), ii) 0.5 (t ha^{-1}), iii) 1.0 (t ha^{-1}) and iv) 1.5 (t ha^{-1}). (b) fertilizer (three levels): i) control ii) FYM @ 10 t ha^{-1} and iii) chemical fertilizer @ 100-30-42-3-0.4 kg ha^{-1} of N-P-K-S-Zn (farmers practice).

Preparation of experimental plots and growing crop

The selected experimental field was first opened by a power tiller in dry condition and then ploughed again and cross ploughed under wet condition followed by laddering to get a good puddle. Weeds and stubbles were removed from the field the land was mudded and leveled well before laying out. The layout of the experiment was done in accordance with the design adopted with a unit plot size of 10 m^2 (4.0 m × 2.5 m) and the total number of plots were 36. Each treatment was replicated thrice. Lime was applied as dolomite dust [$CaCo_3.MgCO_3$] before 10 days of transplanting of rice as per treatments. At the final land preparation, FYM, triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc fertilizers were applied according to treatments. Lime and fertilizers were thoroughly mixed with soil by spading. Urea was top dressed in three equal splits at 15, 35 and 50 days after transplanting. Seedlings were grown in nursery bed with proper care and management, 32 days-old seedlings were transplanted at 20 cm× 15 cm spacing as single seedling per hill. Irrigation, weeding and plant protection measures were taken as per necessity.

Data collection and analysis

Five hills from each plot were randomly selected for collecting data on growth and yield parameters. The crops were harvested at full maturity. Five randomly selected plants were uprooted for data recording on plant and yield parameters like plant height, total tillers $hill^{-1}$, effective tillers $hill^{-1}$, panicle length, spikelets $panicle^{-1}$, grains panicle-^{1}, sterile grains $panicle^{-1}$, disease spotted seed, 1000-spikelets weight, grain yield, straw yield and harvest index (ratio of grain yield and biological yield). Grain and straw yields were recorded after sun drying. Moisture in grain was determined using moisture meter (GMK-303RS) and adjusted at 14% by sun drying. Data were statistically analyzed using the Analysis of variance (ANOVA) technique with the help of computer package program (MSTAT). The mean differences were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results and Discussion

Effect of lime and fertilizer on plant characters and yield of BRRI Dhan50

Results and discussion on effect of individual effect of lime and fertilizers and their interactions were discussed below. All the plant and yield characters studied in this experiment showed significant variation due to liming, fertlizer application or due to their interaction (Table 2, 3 and 4).

Plant height

Application of lime @ 0.50 t ha^{-1} produced the maximum plant height (75.90 cm) while the control treatment had the shortest plants (71.68 cm). The positive effects of liming on crops have been reported to increase plant height in acidic soil (Alfaons *et al*., 2008). The effect of fertilizer from various sources had significant influence on plant height of BRRI dhan50 rice (Table 3). The highest plant height (78.71 cm) was observed in case of chemical fertilizer dose 100-30-42-4-3-0.4 kg ha^{-1} of N-P-K-Ca-S-Zn (F_3) which was followed by organic fertilizer (F_3) i.e., FYM @ 10 t ha^{-1} (75.9 cm) and the lowest (69.1 cm) was observed in F_1 (control). One of the major reasons of this effect might be due to high dose of fertilizer specially nitrogen which increased the plant height. Plant height is mostly governed by the genetic makeup of the cultivar, but the environmental factors also influence it. Mohammad *et al*. (2002) also reported that application N increase the plant height of rice. Muhammad *et al*. (2005) conducted an experiment with fine grain rice cv. Basmati 2000 involving seven nitrogen rates, i.e. 0, 25, 50, 75, 100, 125 and 150 kg ha^{-1} and found that 150 kg N ha^{-1} produced the tallest plant that was statistically similar to 125 kg N ha^{-1}. Similar result was also reported by Chopra and Chopra (2004) in rice.

The data presented in Table 4 indicated that with the increased fertilizer level and lime, plant height increased progressively. The interaction of L_4F_1 produced the least plant height (66.4 cm) and the maximum plant height was observed in L_4F_3 (81.6 cm). It could be observed from the data presented in Table 4 that there was an increasing trend of plant height with increasing rate of lime and fertilizer treatment levels F_1 to F_3.

Number of tillershill^{-1}

The maximum number of tillers (21.33) and number of effective tillers (16.15) hill^{-1} was recorded at L_4 (lime @1.50 t ha^{-1}), and minimum total (17.07) and effective tillers (13.97) was found in L_1 (Control). Patiram and Prasad (1990) conducted an experiment on an acid soil to evaluate the effect of dolomite limestone on rice yield and they observed that dolomite limestone increased soil pH and number of tiller significantly. These results supported the previous findings that lime is effective in alleviating soil acidity (Venkatesh *et al*., 2002; Chang and Sung, 2004; Cifu *et al*., 2004; Caires *et al*., 2008).

Number of panicles was the result of the number of tillers produced and the proportion of effective tillers which survived to produce panicle. In this study, number of total tillers hill^{-1}of BRRI dhan50 was also influenced by fertilizer treatment (Table 3). The highest number of total tillers hill^{-1}(23.4 cm) was recorded in (F_3) and the lowest number of tillers hill^{-1}(14.4) was found in F_1 (control). Wagh and Thorat (1988) reported that increased rate of NPK and other fertilizer significantly increased the total tillers hill^{-1}in rice. Maske *et al*. (1997) reported that number of tillers hill^{-1}increased significantly with increased N level in rice. The reclamation of soil acidity through lime and fertilizer management in *Banglamoti* rice had significant effect on the number of effective tillers hill^{-1}irrespective of lime rate (Table 2 and 4). The results indicated that the maximum number of effective tillers hill^{-1}(17.8) was produced by the treatment of organic fertilizer FYM (F_2) and lowest number of effective tiller hill^{-1}(11.8) was recorded from L_1 (Control) presented in Table 3. Herve *et al*. (2017) reported that effective tillers increased with increasing application of N fertilizer levels in rice.

The number of total tiller production in different in treatments showed that it fluctuated from one treatment combination to another and also from treatment to treatment. The data presented in Table 4 indicated that with the increased of lime, fertilizer treatment from F_1 to F_3, the number of tillers increased significantly. The treatment combination L_3F_3 produced the maximum number of total tillershill^{-1}(27.1) and it was followed by L_4F_3 and the minimum number of tiller production was observed in L_1F_1 (Table 4). It was observed that interaction effect of lime and fertilizer on number of effective tiller hill^{-1}was significant at 1% level of probability (Table 4). The highest number of effective tillers hill^{-1}(21.5) was observed from the treatment combination of L_4F_2 in BRRI dhan50 and the lowest number of effective tiller hill^{-1}(9.6) was recorded in the combination L_1F_1 (Table 4). It could be seen from the data presented in Table 4 that with increased rate of lime and fertilizer treatments of F_1 to F_3, the number of effective tillers hill^{-1}showed an increased trend except L_4F_3.

Panicle length

The results revealed that different liming rates had significant effect on panicle length. The longest panicle (21.49 cm) was recorded with lime rate 1.50 t ha^{-1} (L_4) and shortest panicle (19.48 cm) was recorded in control (0 t ha^{-1} lime). Panicle length without lime was the least which indicated that high acidity restricted its length. Similar results of the lowest panicle were reported by with Banerjee and Das (2001).

The differences among the fertilizer doses irrespective of lime rate of panicle length were found to be statistically significant (Table 3). The longest panicle (21.7 cm) was found in organic manure cow dung (F_2). The smallest panicle (18.6 cm) was observed in control treatment (F_1, no fertilizer). Azad *et al*. (1995) noted significant increased panicle length with the increased levels of fertilizer nitrogen. Hasanuzzaman *et al*. (2010) observed that application of cow dung and urea-N alone or in combination exerted positive effect on panicle length of BRRI Dhan50. A significant increase in panicle length was due to application of organic manures and fertilizer nitrogen, sulphur, zinc and boron. However, the longest panicle (25.0 cm) was recorded in the interaction L_4F_2 and the minimum panicle length was recorded (17.7 cm) in the combination L_1F_1.

Number of spikeletspanicle^{-1}

The mean data of number of spikelets panicle^{-1}irrespective of fertilizer treatment showed a significantly variation due to application of lime in the acid soil. The number of spikelets panicle^{-1}ranged from 113.5 to 122.0. The highest was recorded in L_4 where total number of spikeletspanicle^{-1} was 122.0. It is evident from the Table 1 that maximum number of spikelets panicle^{-1}was recorded from those plots where lime applied was applied 1.50 t ha^{-1}. Liming of acid soil has been suggested as the most efficient practice to attain and maintain a suitable pH for the growth of panicle of crops (Slattery and Conventry, 1993; Moody *et al*., 1995). Improvement of soil productivity by liming can increase crop yields, as observed in wheat (Coventry *et al*., 1997; Scott *et al*., 2001) and rice crops.

A significantly variation in total spikelets panicle^{-1}was observed due to fertilizer treatment of manures, fertilizers and control (Table 3). The number spikelets panicle^{-1}ranged from 101.9 to 125.9. The highest and lowest numbers of spikelets panicle^{-1}were recorded from the treatments F_2 and F_1, respectively. Application of organic manure cow dung 10 t ha^{-1} and chemical fertilizer at recommended dose (F_2) produced spikelets panicle^{-1}125.9 and 122.4, respectively which was statistically similar. Table 2 also showed that BRRI Dhan50 responded better to the nutrients supplied from the organic manure as compared to those from the chemical fertilizer. Mondal *et al*. (1990) reported that spikelets panicle^{-1}with increasing NPK rates and FYM application. Hasanuzzaman *et al*. (2010) observed significantly increased number of grainspanicle^{-1} from manure treated plots. They reported that increasing rates fertilizer application increased grainspanicle^{-1}significantly over control in rice. Similar result was reported in fine grain rice (BINA, 2009).

The interaction between lime and fertilizer treatment had significant effect on the number of spikelets panicle^{-1}(Table 4). The highest number of spikelets panicle^{-1}(136.1) observed from the combination L_4F_2 and the lowest number of spikelets panicle^{-1}(99.6) was observed in the combination of L_2F_1 which was statistically similar in treatment combination L_1F_1 (Table 4). Positive responses of lime on different crop yield in acid soil were reported Caires *et al*. 2005; Reddy and Subramanian, 2016; Westermann, 1992; Venkatesh *et al*. 2002). They reported that, management of soil performed better in producing more grains either alone or in combination with lime and fertilizer in acid soil and increase number of grainspanicle^{-1}.

Number of unfilled spikelets panicle^{-1}

Data presented in Table 2 showed that lime rate @ 0 t ha^{-1} (L_1) *i.e*. control produced the maximum number of unfilled spikelets (27.01 %) followed by L_2 (22.9 %), L_3 (20.9 %) whereas the lowest number of unfilled spikelets (21.0 %) was recorded in L_4 (1.50 t ha^{-1} of lime). These results indicated that lime application had positive effect on filled grain which ultimately produced higher yield.

Chemical fertilizer (F_3) irrespective of lime rate produced the maximum number of unfilled spikelets (24.9 %) although it was statistically similar to F_1. Similarly, disease spotted seed was also the highest in F_3 (18.23) and the lowest in F_2 (12.54).

Interaction effect between lime and fertilizer management in BRRI dhan50 did not follow any trend in respected of unfilled spikelets (Table 4). However, the highest unfilled spikelets (31.2 %) was recorded from the combination of L_1F_3 and the lowest (17.0 %) was observed from combination of L_4F_2 (Table 4).

Number of diseased spotted spikelets panicle^{-1}

BRRI dhan50 was susceptible to insects and diseases and soil management influence the susceptibility. Application of lime at 1.50 t ha^{-1}produced lowest percentage of diseases spotted spikelets (13.39 %). Chemical fertilizer (F_3) irrespective of lime rate caused disease spotted seed which was also the highest in F_3 (18.23) and the lowest in F_2 (12.54). Interaction effect between lime and fertilizer management in BRRI dhan50 revealed the lowest percentage of diseases spotted seed in L_4F_2 (10.50) and the highest in L_1F_3 (23.80 followed by L_1F_1 (20.13).

Thousand-grain weight

The 1000-grain weight was affected by different levels of lime (Table 2). The highest 1000-grain weight (18.53 g) was produced by treatment L_4 (lime rate 1.50 t ha^{-1}). On the other hand, treatment L_2 (lime rate 0.50 t ha^{-1}) produced the lowest 1000-grain weight (17.78 g) which was similar to L_1 and L_3. The 1000-grain weight was significantly affected by different levels of lime. Application of lime increased 1000-grain weight over less liming. The reduced soil acidity and higher nutrient availability because of liming enhanced crop growth and increase yield contributing character 1000-grain weight which resulted in higher yields (Scott *et al*., 1999; The *et al*., 2006).

Table 1. Characteristics of the soil before treatment application and after harvesting of the crops

Chemical analysis	Treatments	pH	OM (%)	N (%)	K (meq/100g)	P (ppm)	S (ppm)	Zn (ppm)
Initial soil		5.2	1.38	0.11	0.18	47	22	0.98
Post-harvest soil	Control	5.2	1.38	0.11	0.18	42	23	0.98
	FYM	5.2	1.42	0.13	0.19	45	29	3.02
	Fertilizer	5.2	1.39	0.14	0.18	48	39	3.11
	Lime@50kg ha^{-1}	5.4	1.38	0.12	0.17	43	29	3.0
	Lime@100kg ha^{-1}	5.7	1.39	0.13	0.17	46	33	3.0
	Lime@150kg ha^{-1}	6.0	1.39	0.14	0.16	46	37	3.02

Table 2. Effect of lime on plant characters and yield of rice cv. BRRI dhan50

Lime	Plant height (cm)	Tillers hill^{-1} (No.)	Effective tillers hill^{-1} (No.)	Panicle length (cm)	Spikelets panicle^{-1} (No.)	Unfilled spikelets (%)	Disease spotted spikelets (%)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
L1	71.68b	16.15b	13.97b	19.48b	113.5b	27.01a	18.17a	17.91b	2.06d	2.58c	43.82a
L2	75.90a	19.30a	15.96a	20.13ab	112.5b	22.86b	16.91a	17.87b	2.41c	3.04b	43.97a
L3	75.21a	21.11a	15.49ab	21.06ab	119.0a	20.88b	13.50b	18.03b	2.71b	3.46a	43.63a
L4	75.50a	21.33a	17.07a	21.49a	122.0a	20.98b	13.39b	18.53a	2.90a	3.54a	43.61a
CV (%)	3.89	6.53	7.50	5.46	2.65	6.84	9.90	1.37	3.72	3.89	3.79
LSD	4.98	2.16	1.98	1.89	5.24	2.65	2.59	0.42	0.16	0.2074	2.81
Sig. level	*	**	**	**	**	**	**	**	**	*	*

In a column, means followed by common letters are not significantly different from each other at 5% or 1% level of probability according to DMRT. * = Significant at 5% level, ** = Significant at 1% level. L1 = lime 0 t ha^{-1}, L2 = lime 0.5 t ha^{-1}, L3 = lime 1.0 t ha^{-1} L4 = lime 1.5 t ha^{-1}.

Table 3. Effect of fertilizer on the plant characters and yield of rice cv. BRRI dhan50

Fertilizers	Plant height (cm)	Tillers hill^{-1} (No.)	Effective tillers hill^{-1} (No.)	Panicle length (cm)	Spikelets panicle^{-1} (No.)	Unfilled spikelets (%)	Disease spotted spikelets (%)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
F1	69.09b	14.37c	11.83b	18.59b	101.9b	23.15ab	16.70a	17.01c	1.585c	2.40b	40.01b
F2	75.92a	20.70b	17.84a	21.69a	125.9a	20.73b	12.54b	18.92a	3.084a	3.51a	46.45a
F3	78.71a	23.35a	17.18a	21.33a	122.4a	24.91a	18.23a	18.33b	2.892b	3.56a	44.81a
CV (%)	3.89	6.53	7.50	5.46	2.65	6.84	9.90	1.37	3.72	3.89	3.79
LSD	4.91	2.16	1.99	1.89	5.24	2.65	2.59	0.42	0.16	0.20	2.81
Sig. level.	**	**	**	**	**	**		**	**	**	**

In a column, means followed by common letters are not significantly different from each other at 5% or 1% level of probability according to DMRT.* = Significant at % level, **= significant at 1% level. F1 = fertilizer 0 t ha^{-1}, F2 = fertilizer (FYM) 10 t ha^{-1}, F3 = fertilizer (chemical) 100-30-42-4-3-0.4 kg ha^{-1} of N-P-K-Ca-S-Zn.

Table 4. Interaction effect of lime and fertilizer on the plant characters and yield of rice cv. BRRI dhan50

Interactions (lime × fertilizer)	Plant height (cm)	Tillers hill^{-1} (No.)	Effective tillers hill^{-1} (No.)	Panicle length (cm)	Spikelets panicle^{-1} (No.)	Unfilled spikelets (%)	Disease spotted spikelets (%)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
L1F1	70.01ef	12.60h	9.60f	17.73f	99.80e	23.70bcde	20.13b	16.90d	1.27h	1.913d	40.03ef
L1F2	71.74de	17.54f	14.80cd	19.97cde	121.2cd	26.13b	13.93ef	18.53bc	2.55d	2.880c	46.98ab
L1F3	73.28cde	18.31ef	17.50b	20.73bc	119.3d	31.20a	23.80a	18.30c	2.35e	2.940c	44.44bcd
L2F1	71.61de	14.92g	11.27ef	18.13ef	99.63e	21.77de	17.00c	16.97d	1.49g	2.010d	42.71de
L2F2	77.05abc	20.21de	18.30b	20.77bc	120.0d	21.53de	13.70ef	18.43bc	2.91c	3.543b	45.09abcd
L2F3	79.05ab	22.77c	18.30b	21.50bc	117.8d	25.27bc	16.67cd	18.20c	2.81c	3.570b	44.10cd
L3F1	68.38ef	14.80g	11.83e	19.67cde	103.9e	23.10cde	15.20cde	17.10d	1.72f	2.743c	38.58f
L3F2	76.32bcd	21.51cd	16.70bc	21.03bc	126.5b	18.23f	12.03fg	18.80b	3.27b	3.783a	47.42a
L3F3	80.94ab	27.02a	17.93b	22.47b	126.7b	21.30e	14.80cde	18.20c	3.13b	3.850a	44.90abcd
L4F1	66.35f	15.15g	14.63d	18.83def	104.2e	24.03bcd	13.93ef	17.07d	1.847f	2.923c	38.72f
L4F2	78.57ab	23.55bc	21.5a	25.00a	136.1a	17.03f	10.50g	19.93a	3.59a	3.830a	46.31abc
L4F3	81.59a	25.29ab	15.00cd	20.63bcd	125.8bc	21.87de	14.20def	18.60bc	3.26b	3.867a	45.79abc
CV (%)	3.89	6.53	7.50	5.46	2.65	6.84	9.90	1.37	3.72	3.89	3.79
LSD	4.98	2.16		1.899	5.24	2.65	2.60	0.42	0.16	0.21	2.81
Sig. level	**	**	**	**	**	**	**	**	**	**	

In a column, means followed by common letters are not significantly different from each other at 5% & 1%level of probability according to DMRT. *=significant at 5% level, **=significant at 1% level. L1 = lime 0 t ha^{-1}, L2 = lime 0.5 t ha^{-1}, L3 = lime 1.0 t ha^{-1} L4 = lime 1.5 t ha^{-1}. F1 = fertilizer 0 t ha^{-1}, F2 = fertilizer (FYM) 10 t ha^{-1}, F3 = fertilizer (chemical) 100-30-42-4-3-0.4 kg ha^{-1} of N-P-K-Ca-S-Zn.

The 1000-grain weight of varied significantly due to application of manures and fertilizers. The 1000-grain weight ranged from 17.01 g to 18.33 g. The highest value was noted in F_2 treatment and the lowest 1000-grain weight was noticed in the treatments F_1. Fertilizer application exerted increasing effect on grain weight as compared to the manures. Ganajzni *et al*. (2001) recorded greater 1000-grain weight in the fertilizer applied plot than the control plot. Lawal and Lawal, (2002) observed that increasing levels of nitrogen significantly increased 1000-grain weight up to 80 kg N ha^{-1}.

Interaction effect between lime and fertilizer management in BRRI dhan50 on 1000-grain weight was found significant at 1% level of probability (Table 4). The maximum 1000-grain weight (19.93 g) was recorded from the combination of L_4F_2 and minimum 1000-grain weight was found (16.90 g) from combination of L_1F_1 (Table 4). Hoque *et al*. (2016) and Mondal *et al*. (1990) recorded an increase of 1000-grain weight of rice from the application of organic manures.

Grain yield

The mean effect of lime irrespective of fertilizer management on grain yield is presented in Table 1. It was observed that levels of lime significantly affected grain yield (Table 2). The highest grain yield (2.90 t ha^{-1}) was recorded in the treatment L_4 where lime was applied @1.50 t ha^{-1}. On the other hand, the lowest grain yield (2.06 t ha^{-1}) was recorded in treatment L_1 (control). Dixit *et al*. (1995) found significantly higher grain yield in rice due to lime application over control. In this study, the maximum grain yield in L_4 was contributed by higher number of effective tiller, spikelets panicle^{-1}and 1000-grain weight. Application of lime increased crop yields and addition of lime provide yield increases of rice by 35 % as direct and 31 % as residual effect over no lime application (control) has been reported elsewhere. Such yield increase due to liming has also been reported on rice (Caires *et al*., 2008; Ernani *et al*., 2002). Liming increases soil pH and reduces soil acidity (Murphy and Sims, 2012). Such reasons for increasing crop yields by liming have also been suggested by many researchers (Venkatesh *et al*., 2002; Cifu *et al*., 2004; Costa and Rosolem, 2007).

It was observed that there were significant differences in grain yields among the fertilizer management treatment (Table 3). The highest grain yield (3.55 t ha^{-1}) was recorded in treatment (F_3). On the other hand, the lowest grain yield (2.40 t ha^{-1}) was recorded in treatment F_1 (control). Singh and Jain (2000) stated that high rate of NPK significantly increased grain yield. Thakur *et al*. (1997) observed that application of fertilizer at optimum rate increased the number of effective tillershill^{-1} and filled grains panicle^{-1} that resulted in higher grain yield of rice than control.

The effect of interaction of lime and fertilizer treatments on the grain yield was significant at 1% level of probability (Table 4). The highest grain yield was recorded (3.59 t ha^{-1}) from the combination of L_4F_2. The lowest grain yield (1.27 t ha^{-1}) was observed from the combination of L_1F_1. It was observed from the results presented in Table 3 that the yields of 0 t limeha^{-1} with 0 kg fertilizer was the least yield and with increased level of lime along with fertilizer either chemical or manures increased yields.

Straw yield

There was significant difference in straw yields among the doses of liming (Table 2). The highest straw yield (3.54 t ha^{-1}) was recorded in treatment L4 where lime was applied @ 1.50 t ha^{-1}. On the other hand, the lowest straw yield (2.578 t ha^{-1}) was recorded in treatment L_1 (control). The straw yields of rice increased with the application of lime. Such yield increase due to liming has also been reported on rice (Caires *et al*., 2008; Ernani *et al*., 2002). Liming increases soil pH and reduces soil acidity ultimately increasing straw yields (Murphy and Sims, 2012). Such reasons for increasing straw yields by liming have also been suggested by many researchers (Warman *et al*., 1996; Tsakelidou, 2000; Tang *et al*., 2003).

Fertilizer treatments irrespective of lime rate affected straw yield significantly (Table 3). The highest straw yield (3.56 t ha^{-1}) was found in fertilizer treatment (F_3). The lowest straw yield (2.40 t ha^{-1}) was recorded in control (F_1). Hasanuzzaman *et al*. (2010) reported that straw yield increased with increasing fertilizer levels in rice. Kumar *et al*. (1996) observed that increasing levels of N significantly increased the dry matter and straw yields increased with increasing levels of NPK fertilizer and other micro nutrients.

The effect of interaction of lime and fertilizer on the straw yield was significant at 1% level of probability (Table 4). The highest straw yield was recorded (3.87 t ha^{-1}) from combination L_4F_3 (Table 3). The lowest straw yield (1.91 t ha^{-1}) was observed from the combination L_1F_1 (Table 4).

Harvest index

The mean data revealed that no significant difference between the harvest indices of the doses of lime rate was occurred. However, application of lime at the rate of 0.50 t ha^{-1} (L_2) produced the highest harvest index (43.97 %) which was similar to treatment L_3 (43.63 %). The lowest harvest index (43.61 %) was found in the highest application of dolochun at the rate of 1.50 t ha^{-1} (L_4).

Data revealed that a significant difference between the harvest indexes of the doses of fertilizer was occurred. Application of cow dung at the rate of 10 t ha^{-1} (F_2) produced the highest harvest index (46.45 %) which was similar to treatments F_3 (44.81 %). The lowest harvest index (40.01 %) was found in the control (F_1).

The interaction effect of lime and fertilizer treatment on *Banglamoti* rice showed that the harvest index was greatly influenced at 5 % level of probability. The highest harvest index (47.42 %) was recorded from combination L_3F_2. The lowest harvest index (38.58 %)) was observed from the combination L_3F_1 (Table 3).

Effect of lime, manures and fertilizer on soil characteristics

Application of lime, manures and fertilizers caused an increasing effect on the pH of the post-harvest soils (Table 1). The pH value of the post-harvest soils ranged from 5.2 to 6.0 as compared to the initial pH value of 5.2 (Table 1). All the treatments recorded higher soil pH value as compared to initial soil. The lowest value of pH was observed in L_2 and the highest value was recorded in L_4. Lime reduced soil acidity by changing some of the H^+ ions into water and carbon dioxide (CO_2). The results support previous findings showing that lime was effective in alleviating soil acidity (Caires*et al*. 2005; Venkatesh *et al*. 2002; Chang and Sung 2004; Cifu*et al*. 2004).

The organic matter content of the post-harvest soils slightly increases due to application of fertilizers while results were reverse in most cases when manures were applied (Table 1). Organic matter content of the post-harvest soils varied from 1.85 to 2 % and the value for the initial soil was 1.85 % (Table 1). It was observed that organic matter content tended to increase in soils treated with organic manures. The highest value of organic matter content was observed in the treatment F_2 and (control) recorded the lowest value. Zhang *et al*. (1996) showed that the combined application of organic manures and chemical fertilizers increased organic matter content in soil.

The total N content in the post-harvest soils varied from 0.11 % to 0.13% (Table 1). A slight increase in total N content was noted in all the soils treated with lime and cow dung while the treatments control showed a slight decrease in N value as compared to the initial soil. The results indicated that application of manures exerted an increasing effect on the total N content of the post-harvest soils. Gao and Chang (1996) reported that the application of organic manures increased the total N concentration in soil.

The results in Table 1indicated that the use of lime, manures and fertilizer had a considerable change in available P content of the post-harvest soils due to different treatment. Available P content in the postharvest soils ranged from 26 to 81 ppm. The highest value was recorded in the treatment L_4 and lowest available P content in the post-harvest soil was 26 ppm in treatment L_2.The P availability increased with increasing rats of lime (CaCO3) application up to @ 1.50 t ha^{-1} for the experimental field. With the lower rate of lime (@ 0.50 t ha^{-1}), the P availability increased substantially. On the other hand, with the higher rate of lime (@ 1.50 t ha^{-1}), the P availability decreased considerably. The P availability in soil was highly pH-dependent. In acid soil, the p availability decreased due to precipitation of P with insoluble Fe- and Al-Phosphates. This result agrees well with other findings, indicating that liming improves soil extracted P availability (Caires *et al.*,, 2005; Haynes, 1982; The *et al*. 2006).

Exchangeable K content in the post-harvest soils ranged from 0.16 to 0.19 me/100g soil (Table 1). Exchangeable K contents in the post- harvest soils were influenced due to the application of lime, manures and fertilizers. The highest value of exchangeable K 0.19 was found in the F_2 (cow dung) treatment while the treatment L_4 (lime) recorded the lowest value. Results also indicated that exchangeable K content was higher in soils treated with manures compared to those treated with lime (Table 1). Singh and Jain (2000) observed that K availability as increased with the increasing application of organic matter.

Available sulphur contents in the post-harvest soils were influenced due to use of different treatments (Table 1). Sulphur contents in the post-harvest soils ranged from 29 to 39 ppm, whereas it was 22 ppm in the initial. The highest available S content was recorded 39 ppm in chemical fertilizer treatment and the lowest value was recorded in (cow dung) F_2 treatment (Table 1). Ganeshamurthy and Reddy (2000) also reported that application of cow dung increased the available S in the post-harvest soils.

Available zinc contents in the post-harvest soils are presented in the Table 1. Available zinc contents in the post-harvest soils were influenced due to use of different treatments. Available zinc contents in the post-harvest soils ranged from 0.98 to 3.11 ppm. The zinc content in the initial soil was 0.98 ppm. The highest available Zn content was recorded in the 3.11 ppm (chemical fertilizer) treatment and the lowest value was recorded in control.

Conclusion

From the study, it can be concluded that yield performance of BRRI dhan50 rice was maximum when it was cultivated by applying lime @ 1.50 t ha^{-1} in combination with organic fertilizer FYM @ 10 t ha^{-1} in acid soils. Dolochun ($CaCO_3$, $MgCO_3$) as source of lime can be used to reduce the acidity level and raising pH level of soils. Side by side, organic fertilizers (FYM @ 10 t ha^{-1}) is also needed to apply for optimum supply of plant nutrients.

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