EFFECT OF FERTILIZER, MANURE AND LIME ON GROWTH AND YIELD OF BORO RICE IN ACIDIC RED SOIL

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This is to certify that thesis entitled, **"EFFECT OF FERTILIZER MANURE AND LIME ON GROWTH AND YIELD OF BORO RICE IN ACIDIC RED SOIL"** submitted to the Faculty of Agriculture, Sher–e–Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in SOIL SCIENCE,** embodies the result of a piece of *bona fide* research work carried out by **ATIYA SHARMIN MITU, Registration No: 08- 02797** under my supervision and guidance. No of part of the thesis has been submitted for any other degree of diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED

TO MY

BELOVED PARENTS

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ABSTRACT

An experiment was conducted to evaluate the yield and yield potentialities of Boro rice along with change of nutrients in rice grain as influenced by acidic red soil and different types of fertilizers in net house of Soil Science Department, SAU, Dhaka during the *Boro* season of 2013–14. Two acidic red soils of Bhatgaon (S_1) and Goari (S_2) along with nine different fertilizer treatments *viz.* T_0: Control, T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (Recommended dose of chemical fertilizer), T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime kg^{-1} soil, T_3: 50% NPKS + 5 ton cowdung ha^{-1}, T_4: 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil, T_5: 50% NPKS + 5 ton compost ha^{-1}, T_6: 50% NPKS + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil, T_7: 50% NPKS + 3.5 ton poultry manure ha^{-1} and T_8: 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil were used for the present study. The pore–water samples were collected during rice growing period. The pore–water P concentration decreased with increasing days after transplantation of rice and higher levels of pore–water P concentrations were found in the inorganic plus manure and lime applied fertilizer treatments (0.400 ppm). The pore–water P concentrations and other yield attributes were positive and strongly correlated with the grain and straw yields of rice. The *Boro* rice yields were significantly affected by soil and fertilizer treatments. The soil of Bhatgaon had more efficient to produced more effective tillers (22.11) along with highest yield of grain (35.15 g pot^{-1}) and straw (54.37 g pot^{-1}) than the soil of Goari. N, P, K and S content in Boro rice grain had also higher in Bhatgoan (1.316, 0.079, 0.524 and 0.119%, respectively) than Goari. Similarly, 50% organic manure along with organic and lime application obtained the tallest plant (70.42 cm), longest panicle (22.31 cm), more filled grains panicle^{-1} (74.83 cm) and greater production of *Boro* rice (41.67 g pot^{-1}) compared to 100% recommended dose of NPKSZn. N, P, K and S content in rice grain were also statistically significant due to different fertilizer treatments while 50% NPKS + 3.5 ton poultry manure ha^{-1} + 1.0 g lime kg^{-1} soil showed significant and higher levels of NPKS (1.902, 0.070, 0.538 and 0.169%, respectively) than that of other treatments of the study. However, all the studied characters except productive tillers hill^{-1} were not statistically significant due to the effects of interaction but more tillers was obtained from the soil of Bhatgaon under 50% organic + poultry manure (10.67) while highest grain yield (49.00 g pot^{-1}) was produced from 50% inorganic + 5 ton organic cowdung. The soil of Bhatgoan treated by 50% NPKS along with organic and lime also more effective for getting the highest N, P and S content in Boro rice grain. Therefore, the farmer(s) of our country may apply organic manure and lime along with 50% NPKS for enhancing the production of boro rice in our country which may reduced 50% NPKS. Thus the farmers of our country can be economically benefited by the 50% reduced of chemical fertilizer.

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LIST OF ABBREVIATIONS

%	=	Percentage
µM	=	Micro mol
^{0}C	=	Degree Celcius
AEZ	=	Agro–Ecological Zone
ANOVA	=	Analysis of variance
BARC	=	Bangladesh Agricultural Researcher Council
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
BBS	=	Bangladesh Bureau of Statistics
BRRI	=	Bangladesh Rice Research Institute
CRD	=	Completely randomized design
cv.	=	Cultivar
DAT	=	Days after transplanting
Div.	=	Division
DMRT	=	Duncan's Multiple Range Test
e.g.	=	Exempli gratia (by way of example)
et al.	=	And others
FAO	=	Food and Agriculture Organization
Fig.	=	Figure
g	=	Gram
HI	=	Harvest index
i.e.	=	edest (means that is)
IRRI	=	International Rice Research Institute
LSD	=	Least significant difference
mgL^{-1}	=	Milligram per litre
NICS	=	National Institute of Crop Science
NPK	=	Nitrogen, Phosphorus, Potassium
NPKS	=	Nitrogen, Phosphorus, Potassium, Sulphur
pH	=	Negative logarithm of hydrogen ion
RCBD	=	Randomized Complete Block Design
RD	=	Recommended dose
RDF	=	Recommended dose of fertilizer
RDCF	=	Recommended dose of chemical fertilizer
SAU	=	Sher–e–Bangla Agricultural University
spp	=	Species (plural number)
var.	=	Variety
Viz.	=	Namely

CHAPTER 1
INTRODUCTION

Rice belongs to the Gramineae family with the genus *Oryza* which contains about 22 different species (Wopereis *et al*., 2009). It is the dominant staple food for many countries of the world (Mobasser *et al*., 2007). It is also the most important food crop and a major food grain for more than a third of the world population and 50% of the global population (Zhao *et al*., 2011). Among the most cultivated cereals in the world, rice ranks as second to wheat (Abodolereza and Racionzer, 2009). Rice is grown in more than 10 countries with a total harvested area of nearly 160 million hectares, producing more than 700 M tons every year (IRRI, 2010). According to the FAO of the UN, 80% of the world rice production comes from 7 countries (UAE/FAO, 2012).

In Bangladesh, rice covered an area of 28.49 million acres with a production of 33.54 million M tons while the average yield of rice in Bangladesh is around 1.18 T tons acres^{-1} (BBS, 2012). In case of *Boro* rice, it covers the largest area of 11788 Ha (41.38% of total rice cultivation area) T acre (local 195 + HYV 9968 + HYB 1625 T acre) with a production of 1.86 million tons (55.50%) and the average yield is about 1177 kg acre^{-1} during 2010–11 (BBS, 2012). Besides, based on the rice cultivation, Bangladesh is the 5th largest country of the world (BBS, 2012). Alam (2012) also reported that rice covers about 82% of the total cropped land of Bangladesh. It accounts for 92% of the total food grain production in the country and provides more than 50% of the agricultural value addition employing about 44% of total labour forces. According to the latest estimation made by BBS, per capita rice consumption is about 166 kg year^{-1}. Rice alone provides 76% of the calorie intake and 66% of total protein requirement and shares about 95% of the total cereal food supply (Alam, 2012).

The population of Bangladesh is growing by two million every year and may increase by another 30 million over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020 (BRRI, 2011). During this time total rice area will also shrink to 10.28 million hectares. Rice yield therefore, needs to be increased by 53.3% (Mahamud *et al*., 2013). However, Bangladesh has made commendable progress in reducing extreme poverty and food insecurity through productivity increase in agriculture. Bangladesh has also become self–sufficient in rice through intensification of crop culture with the use of seed–fertilizer–water–pesticide–mechanization of tillage technology. But, intensification of crop caused degradation of soil, soil acidity, depletion of surface and underground water, pollution of farm and non–farm environment, nutrient mining, arsenic and other heavy metal pollution. On the other hand, agricultural land is decreasing day by day. About 220 hectares agricultural lands are decreased per year due to urbanization, industrialization, housing and road construction purposes.

Toxicity of aluminum and manganese is the most important growth limiting factor in many acid soils and this toxicity effect can be reduced by the application of liming materials. Besides this, the reduced uptake of calcium and magnesium in the soil solution can also be alleviated with the application of lime. The application of liming materials to such soils will inactivate the iron and aluminum, thus increasing the level of plant available phosphorus and other macronutrients. Most of the organisms responsible for the conversion of ammonia to nitrates require large amounts of active calcium. As a result nitrification is enhanced by liming to a pH of 5.5 to 6.5. Decomposition of organic matter and other plant residues can also be improved with the application of lime by increasing the activity of micro–organisms.

The depleted soil fertility is a major constraint to higher crop production in Bangladesh. The increasing land use intensity has resulted in a great exhaustion of nutrients in soils. Rice–rice cropping system is the most important cropping system in Bangladesh. Continuous cultivation of this highly exhaustive cropping sequence in most of the irrigated fertile lands has resulted in the decline of soil physico–chemical condition in general and particularly soil organic matter (SOM) content.

Plant residues increase soil pH, and temporal changes in alkalinity depended on the residue and soil type (Butterly *et al*., 2013). Dong *et al*. (2012) reported that organic manure should be recommended to improve soil fertility in red soil of China. A number of studies have shown that plant material increases pH (Pocknee and Sumner 1997; Tang *et al*. 1999). Manure amendments markedly increased the contents of SOC, TN, and other available nutrients, and reduced soil acidification (Liu *et al*. 2011). The effect of residues on pH change varies widely between studies due to differences in residue composition and soils used. The initial pH of the soil is important for the pH change (Tang and Yu 1999). A number of long–term field trials have observed soil acidification where residues have been retained (Paul *et al*. 2001; Xu *et al*. 2002), which was largely due to high soil N status. Increasing Ca concentration in the nutrient solution and liming had a beneficial effect on plant growth under Al stress and alleviated Al toxicity of plants (Shen *et al*., 1993). Thus, liming is the usual method for ameliorating the acid soil.

Nayak *et al*., (2007) reported that application of compost and inorganic fertilizer increased microbial growth in soil, vegetative growth and maximum tillering of rice. Xu *et al.,* (2008) observed that application of half inorganic fertilizer and half organic manure increase nutrient absorption, panicle number, and yield of rice & also increased soil organic matter. Nambiar (1991) observed that integrated use of organic manure and chemical fertilizers would be quite promising not only in providing greater yield but also to maintain better soil fertility. Addition of organic manure tends to increase aggregate stability which improves porosity, aeration and water retention of soil (Lal, 2008). Balanced fertilization and complementary use of inorganic fertilizers with FYM, cow dung, poultry litter, sugar mill waste (press mud) and other wastes will go a long way in both improving the yield as well as improving the soil quality (Aulakh *et al*., 2001).

The amelioration of degraded acidic paddy soils in the red soil region and maintenance of the region's sustainable development of agricultural production has become an urgent need in Bangladesh. To increase the efficiency of manure and fertilizer in acidic soil rice cultivation, it is necessary to identify the suitable combination of manure and fertilizer with or without lime. Poultry manure, cowdung, compost and lime may be used for increasing crop yield, maintaining fertility of the soils and ameliorating the acidity of soils. It is necessary to identify the suitable manure for increasing the soil pH, fertility and productivity of acidic soils. It will, therefore, be necessary to place greater emphasis on strategic research to increase the efficiency of applied and soil native nutrients through integration with organic manures and lime, which will help in accomplishing the objectives of sustaining soil health, increasing soil pH and nutrient availability of acidic red soils. From the above aspect, the present study was conducted to investigate the effects of manure (organic) and fertilizer (inorganic) with or without lime on the growth, yield of rice and nutrient availability in postharvest soil. Considering the above facts, the present research study was therefore undertaken to find out following objectives:

i. To investigate the effects of acidic red soil on the yield of *Boro* rice
ii. To identify the suitable combination(s) of fertilizer and manure with or without lime on the aspect of *Boro* rice productivity, availability of P in pore–water of acidic paddy soils.
iii. To select the most advantageous interaction, if any, between acidic paddy soil and fertilizer–manure with or without lime in respect of the above observation.

CHAPTER 2
REVIEW OF LITERATURE

The present study deals with effect of organic (cowdung, compost and poultry manure) and inorganic (NPKSZn) fertilizer along with or without lime on productivity of rice in acidic red soil collected from Bhatgaon and Goari of Bhaluka. For aiming this point, nine different fertilizer and manure treatments along with or without lime were used for evaluating the different characters of morpho–physiology, yield and yield attributing, soil pore–water P concentration and nutrient status in Boro rice grain under net house of SAU. Literatures available on these aspects are reviewed in this chapter.

2.1 Effect of acidic soil and organic–inorganic based fertilizers and lime on morpho–physiologycal, yield and yield attributes of *Boro* rice

2.1.1 Effect of acidic soil

Two acidic soils at South–Surma, Sylhet in 2009–10 and at FSRD site Jalalpur, Sylhet in 2010–11 were evaluated by Rahman *et al*. (2013) to determine relative adaptability of wheat variety. All the yield components of wheat viz., number of spikes m^{-2}, grains $spike^{-1}$, 1000–grain weight and grain yield significantly responded to both the years and locations.

The soil of South–Surma and FSRD site Jalalpur were strongly acidic and lime application in such a soil increased soil pH resulting increase in nutrient availability and thereby favoured plant growth and tillering of wheat (Rahman *et al*., 2002).

2.1.2 Effect of different types of fertilizers

2.1.2.1 Effect of inorganic/chemical fertilizer

A long–term (33 years) experiments were conducted by China *et al*. (2014) who found that the impact of fertilizers on grain yields was 2NPK > NPK > NP > NK > N, and application of P fertilizer not only increased the rice yield, but improved yield stability. The experimental site locates at the experimental farm of the Research Institute of Red Soil of Jiangxi province, Jinxian county, China (28°21'N, 116°10'E).

An experiment was conducted by Rattanapichai *et al*. (2013) to study the effects of various soil conditioners, MK doses (0, 1.56, 3.12 and 6.25 tons ha^{-1}) and NPK fertilizers (16–8–8 and 16–16–8) on growth and yield of rice grown in acid sulfate soil in Thailand, a Rangsit (Rs) soil series. The result showed that application of MK caused an increase in tillers per plants, biomass and grain yield as well as silicon uptake. However, there was no effect on native phosphorus in soil and phosphorus uptake. The 16–16–8 fertilizer application increased the number of tillers per plants; shoots dry matter and grain yield were higher than in 16–8–8 fertilizer model. Grain yields showed highest response when 1.56 $kgha^{-1}$ of MK (0.63 kg grain kg^{-1} MK) was applied, and the harvest index was highest as well.

Vetayasuporn (2012) conducted an experiment to determine the effects of organic–chemical fertilizer and chemical fertilizer (NPK 16:16:8) on the growth and yield of rice in acidic soil of Roi–Et province, Northeast Thailand. Five treatments were compared consisting of: T_1 (control without fertilizer); T_2 (312.5 kg ha^{-1} organic–chemical fertilizer); T_3 (625 kg ha^{-1} organic–chemical fertilizer); T_4 (937.5 kg ha^{-1} organic–chemical fertilizer) and T_5 (chemical fertilizer; 312.5 kg ha^{-1} NPK 16:16:8). Yield of rice grains under all treatments increased between 2–4 times when compared to the control (1.37 t ha^{-1}). Application of organic–chemical fertilizer alone showed 2–2.5 times (2.66–3.43 t ha^{-1}) increased yield of grains over the control. However, maximum grain yield (5.57 t ha^{-1}) was obtained from T_5 (chemical fertilizer) which also gave the highest all yield parameters such as number of grain per panicle (108.20), total number panicle per hill (14.82), plant height (62.48 cm) and percentage of filled grain (82.17%).

A pot and a field experiment were conducted to observe the growth and yield characteristics of super high yielding rice varieties by Zhang *et al*. (2009). Zhongzheyou 1 and Yongyou 9 in red paddy soils (K levels: 50 and 90 mg kg^{-1}) with various potassium fertilizer rates (KCl: 0, 75, 150 and 225 kg m^{-2}). The soil K content had significant effect on the panicle number, percentage of productive culms, grain number per panicle, grain density, plant height, and grain yield. The plant height significantly increased with increasing potassium application rate, especially for Zhongzheyou 1. The grain yield of the two varieties increased by 5.6% and 8.8% with potassium application, and no significant difference was found among different potassium application levels.

Rahman *et al*. (2002) reported that the micronutrients had no effect on yield of rice and wheat as well as not changing postharvest soil nutrient content of acidic soil. Additive fertilizer nutrients increased the number of grains panicle^{-1} of rice and grains spike^{-1} of wheat. Phosphorus fertilizer significantly increased the grain yields of both rice and wheat, but magnesium application resulted in increasing wheat yields but not that of rice

2.1.2.2 Effect of cowdung alone or in combinations with chemical fertilizer

Malika *et al*. (2015) reported that the integration of chemical fertilizers with manures improved crop yield of BINA dhan 7 and minimizes the detrimental effects of fertilizers. Application of organic and inorganic fertilizers significantly increased the yield attributes as well as grain and straw yields of rice. The treatment T_5 (75%RFD + CD 2.5 t ha^{-1} + PM 1.5 t ha^{-1} + Com 2.5 t ha^{-1}) produced the highest grain yield (5670 kg ha^{-1}) and straw yield (6768 kg ha^{-1}) of rice. The lowest grain yield (3692 kg ha^{-1}) and straw yield (3751 kgha^{-1}) were found in T_0. Further, it was observed that application of same doses of fertilizers with poultry manure performed better than that of cowdung and compost.

A greenhouse pot experiment was conducted by Gitari *et al*. (2015) to determine the effect of agricultural lime and goat manure on soil acidity and maize growth parameters. Nitrogen and phosphorus fertilizers at the rates of 50 and 70 kg ha^{-1}, respectively, and goat manure at three rates (0, 5 and 10 mg ha^{-1}) and agricultural lime ($CaCO_3$) at six rates (0, 2.5, 5, 7.5, 10, and 12.5 Mg ha^{-1}) were used for the study. Maize, variety H513 as test crop, was grown for a period of 8 weeks. The results were measured on plant heights, root lengths and dry matter biomass. Linear correlation analyses were done using the Microsoft Excel 2010. Results generally showed that the treatment with 12.5 Mg ha^{-1} of lime and 10 Mg ha^{-1} of manure had the best for maize yield along with highest root length (41.3 cm), plant height (150.3 cm) and dry biomass weight (755.4 kg ha^{-1}) obtained.

The experiment was carried out by Pandey *et al*. (2014) during kharif 2002 and 2003 in Vertisoils (acidic) at research farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh India. Experiment was comprised of different levels of inorganic fertilizer (NPK) and its conjunction with different organic fertilizers. Yield and yield attributing characters was significantly increased with increasing fertilizer levels from 50:30:20 kg, NPK ha^{-1} to 150:80:60 kg, NPK ha^{-1} during both the year of experiment. Grain yield and yield attributes were significant among different treatments. Application of 100:60:40 kg NPK ha^{-1} + blending of N with cow–dung urine (T_9) or poultry manure (T_{10}) resulted higher effective tillers, panicle length, and test weight which is statistically at par to that of inorganic level 150:80:60 kg NPK ha^{-1} (T_1). Almost similar trend was noticed when said organic fertilizer was combined with lower level of inorganic fertilizer (50:30:20 kg NPK ha^{-1}), which tended to produced above yield components comparable to that of inorganic fertilizer level of 100:60:40 kg NPK ha^{-1}. Thus it was concluded that use of inorganic fertilizer with different organic fertilizers sources are better for sustaining growth, yield and nutrient uptake by hybrid rice.

Naing *et al*. (2010) investigated the effect of organic and inorganic fertilizers on growth and yield of five upland black glutinous rice varieties and soil property. Experiments were laid out in a split–plot design with four replications. Four fertilizer treatments (control, FYM or cattle manure @ 10 t ha^{-1}, NPK at the rate of 50–22–42 kg N–P–K ha^{-1}, the combination of the FYM and NPK were randomized in the main plots and five black glutinous rice varieties were randomized in the sub plots. Number of tillers and panicles per hill and grains per panicle, thousand grain weight, number of filled and unfilled grains and grain yield were recorded at harvest time. The results from both years indicated that using the combination of FYM cattle^{-1} manure and inorganic fertilizers increased tiller and panicle number per hill, grain number per panicle and grain yield.

Whalen *et al*. (2002) reported that the crop production in acid soils can be improved greatly by adjusting the pH to near neutrality. Although soil acidity is commonly corrected by liming, there is evidence that animal manure amendments can increase the pH of acid soils. Fresh cattle manure and agricultural lime were compared for their effects on soil acidity and the production of wheat in a greenhouse study. Wheat yield, the nutrient content of grain and straw, and selected soil properties were determined on a Gray Luvisol (pH 4.8) from the Peace Region of Alberta. Soil pH increased with lime and manure applications, and wheat yields were higher in limed and manure– amended soils than unfertilized, unlimed soils. Wheat grain plus straw production were lower in unfertilized soils than in soils that received lime and manure applications, but only the highest lime and manure application rates (4 g $CaCO_3$ kg^{-1} and 40 g manure kg^{-1}) produced more wheat than fertilized soils.

The pH of acidic soils increases following beef cattle manure applications, which may be due to calcium carbonates and organic acids in the manure that buffer soil acidity (Whalen *et al*. 2000). Therefore, animal manure could be substituted for agricultural lime to improve production in acidic soils.

2.1.2.3 Effect of compost alone or in combinations with chemical fertilizer

Sardar *et al*. (2015) conducted an experiment to investigate the effect of different sources of organic matter on the yield of rice and soil at red and lateritic zone of Rice Research Station, Bankura, West Bengal, India. Average of three years data revealed that inclusion of vermi–compost in the fertilizers schedule of rice cultivation increased the grain yield (30.26%) as well as straw yield (32.70%).

In a study of Annonymous (2015) on fertilizer economy through organic manures in rice–rice cropping system, it was found that total produce with application of 90 kg N + 12 t FYM ha^{-1} to Kharif rice and 60 kg N ha^{-1} to Rabi rice was close to 120 kg N ha^{-1} + 60 kg P_2O_5 ha^{-1} to Kharif rice and 60 kg N ha^{-1} to Rabi rice. Annual dressing of 10–15 t FYM ha^{-1} along with optimal NPK fertilisers enhanced rice yield over the optimal NPK dose by 25 and 20 percent in Kharif and Rabi season respectively under the lateritic soils of Bhubaneshwar. Similarly, in the red soils of Hyderabad, the average increase in rice yield due to NPK + FYM was 17–21% in both Kharif and Rabi seasons. These and other results suggest that substitution of 25–50% of the N through FYM in Kharif and application of 75–100% optimum level of NPK in the Rabi produced the highest yields of rice.

Hossain (2013) conducted an experiment to investigate the effects of inorganic fertilizers alone and in combination with different organic fertilizers in order to achieve high yield and sustainable soil chemical and organic matter balance. The experiment was conducted at the field laboratory of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during 2012–13. The treatment combinations were T_1 (NPK), T_2 (NPK+ FYM), T_3 (NPK+ Vermi–compost), T_4 (NPK+ Rotten Rice Straw) and T_5 (NPK+ Poultry Manure). The results showed that grain and straw yields of wheat were significantly influenced by the treatments. The highest grain yield was obtained in T_2 followed by T_3 and T_5. The grain yield of wheat due to different treatment followed the order of: $T_2>T_3>T_5>T_4>T_1$ with the record of 2.48, 2.28, 1.83, 1.82 and 1.59 t ha^{-1}, respectively.

Sukristiyonubowo *et al*. (2013) reported that the application of 2 ton ha^{-1} $year^{-1}$ dolomite, 2 ton ha^{-1} $season^{-1}$ rice straw compost and mineral fertilizers (200 kg urea, 100 kg SP–36 and 100 kg KCl ha^{-1} $season^{-1}$) improve the rice yield by combined addition of organic matter (straw compost), lime and mineral fertilizer. With these applications the rice yield of 3,5 – 4,2 tons ha^{-1} $season^{-1}$ can be reached under weathered soils, especially ultisols and oxisols.

Sukristiyonubowo *et al*. (2011) conducted an experiment to know the soil fertility status and properly manage its fertility status to improve rice yield and sustain rice farming. Application of 250 kg urea, 100 kg super phosphate–36 and 100 kg potassium chloride ha^{-1}, in which N and K fertilizers were split three times plus 2 tons dolomite and 2 tons compost ha^{-1} also the residual effect of dolomite and compost improved rice growth and biomass production.
A field experiment was conducted by Singh *et al*. (2011) with rice (*Oryza sativa* L.) and pea (*Pisum sativum*), grown in a sequence at Zonal Research Station, Darsai on an acid upland soil (Alfisol) of East Singhbhum to study the effect of N, P and K fertilizers with or without FYM, lime, sulphur and boron yield, nutrient uptake and fertility status of soil available N, P, K and S. The highest grain yield of rice and pea was recorded in the treatment receiving 50% of recommended dose NPK fertilizers along with application of 5 t FYM + 250 kg lime + 20 kg S + 1 kg B ha^{-1}.

Oluwatoyinbo *et al*. (2009) reported that the acid sands occur commonly in the high–rainfall areas along the coastal plains of Nigeria. Pot and field experiments were conducted to determine the effects of lime ($CaCO_3$) and compost application the growth and yield of okra [*Abelmoschus esculentus* (L) Moench] on an acid soil. Treatments comprised three levels of compost 3 (0, 2.5 and 5.0 t ha^{-1}) and two levels of lime (0, 250 kg ha^{-1} $CaCO_3$) applied solely and in combination with compost. Okra growth was most favored with application of 5 t h^{-1} compost. Lime application also gave comparable growth and the highest yield of 4.4 t ha^{-1}. A yield of 4.1 t ha^{-1} from application of 5 t ha^{-1} compost was also comparable. Addition of compost to lime gave lower but comparable growth and seed yield and reduced the soil acidity more than either sole lime or sole compost applications.

Yung–Yu (2005) conducted a pot experiments to evaluate the effects of the application of two Merent kinds of composts: pea–rice hull compost (PRC) and cattle dung–tea compost (CTC) on rice growth. The soil used for the study was an Oxisol. These composts Mered in their nitrogen composition, as well as in their effect on plant height, number of tillers, dry matter yield of rice plants. Plants were cultivated in l/6,000 Wagner pots, which contained 3 kg of soil, completely mixed with the composts (PRC 404g; CTC 380g) and chemical fertilizer (CHEM), respectively in the Arst crop. At the most active tillering and heading stages of the plants of the first crop, the number of tillers, dry matter yield were found to be higher in CHEM treatment than those in the other treatments. The values of the plant height and straw growth of the rice plants with the PRC treatment were the highest among all the treatments at the maturity stage.

2.1.2.4 Effect of poultry manure alone or in combinations with chemical fertilizer

The integrated use of organic and inorganic manures on the yield of rice was evaluated by Arif *et al*. (2014) in acid soil of Chakkanwali Reclamation Research Station, District Gujranwala, Pakistan. The organic sources used were farmyard manure, poultry manure, rice straw, sesbania, compost and mung bean residues alone and in combinations with 50% of recommended dose of fertilizer (RDF). Recommended dose of fertilizer (150–90–60 kg NPK ha^{-1}) and control treatments were also included in the experiment. The results showed that organic and inorganic manures in combination increased the plant height, fertile tillers $hill^{-1}$, number of grains $panicle^{-1}$, panicle length, number of panicles $hill^{-1}$, 1000–grain weight, biological yield, grain yield and harvest index. Maximum number of fertile tillers $plant^{-1}$ (16.79), number of panicles $hill^{-1}$ (8.41), 1000–grain weight (21.12 g), biological yield (10.19 t ha^{-1}), grain yield (4.47 t ha^{-1}) and harvest index (43.76%) were recorded from the plots receiving poultry manure @ 10 t ha^{-1} in combination with 50% of RDF. This was followed by 100% RDF. It is evident that yield of rice can be increase significantly with the combined use of organic manure with chemical fertilizers.

Meena and Singh (2012) studied on the effect of various sources (farm yard manure, vermicompost and poultry manure) and rates of organic manures (100%, 125% and 150% RND) on yield, quality of produce and soil quality in rice–table pea–onion cropping sequence. Poultry manure @ 150% RND gave higher grain (57.96 q ha^{-1}) and straw yield (91.27 q ha^{-1}) in rice, green pod yield (70.72 q ha^{-1}) and straw yield (70.03 q ha^{-1}) of table pea and bulb (270.84 q ha^{-1}) and haulm yield (35.13 q ha^{-1}) of onion.

A field experiment was conducted by Meena *et al*. (2010) to study the effect of various sources (farmyard manure, vermicompost and poultry manure) and rates of organic manures (100, 125 and 150% recommended nitrogen dose) on yield, quality of Rice, Table pea, Onion. Poultry manure at 150% recommended nitrogen dose gave higher grain yield (5.79 ton ha^{-1}) of rice, green pod yield (7.07 ton ha^{-1}) of table pea and bulb yield (27.08 ton ha^{-1}) of onion.

Ireri (2009) observed that the maize growth parameters (root length, height and biomass dry weight) were found to increase significantly as levels of manure and lime increased. Treatment $M_{10}L_{12.5}$ from greenhouse trial recorded the highest values for root length (41.3 cm), height (150.3 cm) and dry biomass weight of 755.4 Kg ha^{-1}.

Ju–mei *et al*. (2005) conducted a field experiment in Qiyang, Hunan province, a typical red soil region of southern China, to study the effects of organic and inorganic N fertilizers on ammonia volatilization and rice yield in paddy soil. Four treatments were PK treatment as control, NPK treatment (urea as N), NPKM treatment (half chemical fertilizers + half manure), M treatment (pig manure as N), same amount of N, P, K either organic or inorganic forms (N 150 kg m^{-2}, P_2O_5 100.5 kg m^{-2} and K_2O 109.5 kg m^{-2}) were applied in each plot. All fertilizers were applied once as base fertilizers before one day of rice transplanted. The rice yields of NPKM, NPK, M treatments were increased by 68.6%, 68.1% and 60.0% respectively for early rice, and increased by 72.0%, 69.6% and 34.2% for late rice compared with control treatment. Not only the yield of rice with NPKM treatment increased by 70 % averagely compared with PK treatment, but also the nitrogen loss was less compared with NPK treatment. N use efficiency of NPKM treatment was 34.9% , higher than that of NPK treatment (33.2%) and M treatment (28.0%).

2.1.5 Effect of lime alone or in combinations with chemical fertilizer

Two greenhouse experiments were conducted by Fageria and Knuppto (2014) to determine the influence of lime and gypsum on yield and yield components of upland rice and changes in the chemical properties of an Oxisol. The lime rates used were 0, 0.71, 1.42, 2.14, 2.85, and 4.28 g kg^{-1} soil. The gypsum rates were 0, 0.28, 0.57, 1.14, 1.71, and 2.28 g kg^{-1}. Lime as well as gypsum significantly increased plant height, straw and grain yield, and panicle density in a quadratic fashion. Adequate lime and gypsum rates for maximum grain yield were 1.11 g kg^{-1} and 1.13 g kg^{-1}, respectively. Plant height, straw yield, and panicle density were positively related to grain yield. Azman *et al.* (2014) reported that the low pH had adverse affect on plant growth. In spite of that, however, the rice yield was 3.5 t ha^{-1} based on the application of 4 t GML ha^{-1}, which was almost equivalent to the average national yield of 3.8 t ha^{-1}.

Asrat *et al*. (2014) examined the effects of integrated use of lime, manure and mineral P fertilizer on acid soils of Ethiopia for wheat production and status of residual soil P. The treatments were laid down in a randomized complete block design with three replications. The field study was conducted on Dystric Nitisols in the 2011 and 2012 main cropping seasons at Enerata Kebele, Gozamin District. Lime application hastened early germination while plant height was enhanced by interaction of lime and P. Most parameters were significantly ($p < 0.01$) affected by two–way interactions while three–way interactions effect increased grain and straw yields at non–significant ($p > 0.05$) level. The combined application of 5 t manure and 2.2 t ha^{-1} lime increased grain and straw yield by 279% and 187%, respectively. Although all treatments residual soil P were categorized under very low status, it has strong positive correlation ($r^2 = 0.79$) with lime application. The study showed the combined application of 5 t manure and 2.2 t ha^{-1} lime was found to be economical feasible to improve wheat yield and yield components and residual soil P of acidic soils of the study area

There were six lime treatments viz. Control, 0.5 t lime ha^{-1}, 1.0 t lime ha^{-1}, 1.5 t lime ha^{-1}, 2.0 t lime ha^{-1} and 2.5 t lime ha^{-1}. Dolochun ($CaCO_3$) was used as the liming material. The highest grain yield was found in T_4 (4.73 t ha^{-1}), which was statistically identical with the grain yields obtained in T_5 and T_6 treatments but superior to those found in T_1, T_2, T_3 treatments. Thus, the application of 1.50 t lime ha^{-1} is enough for satisfactory yield wheat (Kamruzzaman *et al.* 2013).

A field trial was carried out by Rahman *et al*. (2013) at South–Surma, Sylhet, in 2009–10 and at FSRD site Jalalpur, Sylhet in 2010–11 in collaboration with WRC and OFRD, BARI to examine the response of 7 wheat varieties at two levels of lime in split–plot design where lime was applied in main plots and different wheat varieties were grown in sub–plots. The result indicated that most of the yield components viz., spikes m^{-2}, 100–grain weight, and grain yield of wheat were significantly improved by liming for both the years and locations. There were variations in lime response among the wheat varieties. The index of relative adaptability (IRA %) for yield of BARI Gom–26 and Bijoy was more than 100% for both the years. The results indicated that these two wheat varieties are relatively tolerant to low pH and could be adapted in acidic soil of Sylhet.

The importance of lime application to ameliorate acidity on paddy field has been conducted by Sadiq and Babagana (2012). They found that the application of lime precipitates Al and Fe in the soil and result in higher rice yield.

NCDACS (2011) reported that the application of lime to the soil, make it less sour (acid) and also supplies Ca and Mg for plants to use and increase the crop yield. Okalebo *et al.* (2009) found that the lime at 2 t ha^{-1} combined with 26 kg P ha^{-1} and nitrogen at 75 kg N ha^{-1} increased the soil fertilizer resulted in significant maize yield increases to 6 t ha^{-1}, compared to the small scale farmers' yield of 0.5 t ha^{-1}. In addition to N and P inputs, liming is a practice with potential to improve crop yields on acid soils that are predominant in western Kenya.

Ping *et al*. (2008) conducted a pot experiment to investigate the effects of seven amendments on the growth of rice and uptake of heavy metals from a paddy soil that was contaminated by copper and cadmium. The best results were from the application of limestone that increased grain yield by 12.5–16.5 fold, and decreased Cu and Cd concentrations in grain by 23.0%–50.4%. Application of calcium magnesium phosphate, calcium silicate, pig manure, and peat also increased the grain yield by 0.3–15.3 fold.

Suswanto *et al.* (2007) studied the effects of lime and fertilizer application in combination with water management on rice cultivation. The best yield of 14.15 t ha^{-1} was obtained for treatment with 4 t ha^{-1} lime together with 120 kg N ha^{-1} + 16 kg P ha^{-1} + 120 kg K ha^{-1}. This shows that liming together with prudent fertilizer management improves rice production an acid sulfate soil. They also reported that the application of GML + organic fertilizer can produce rice yield up to 7.5 t ha^{-1}.

The study revealed a concomitant increase in pH and Ca+Mg contents and a decrease in Al concentration of the soil. This altogether resulted in a mammoth increase in crop yield. In a similar experiment conducted elsewhere in the country where 1.0 t ha^{-1} and 2 t ha^{-1} lime were applied, the authors recorded 72% and 48% increases in yield, respectively, over no lime treatment (Buri *et al*., 2005). Other experiments conducted by the same author found that the combined application of lime and phosphorus on an Oxisol and Ultisol soil of low pH (ranging from 4.1–4.5 and 4.7–5.0) showed a considerable increase in maize grain yield by both lime and phosphorus.

Rahman *et al*. (2005) reported that the application of lime improved the crop yield by eliminating the production constraints and favouring production factors related to nutrient availability.

Rahman *et al*. (2002) reported that the application of lime to an acidic soil is a common practice in many countries, but it is not practiced in Bangladesh. Lime application may improve yields and may influence nutrient levels in the an aerobic rice and aerobic wheat cropping system in the acidic alluvial soils of Bangladesh. To quantify those affects, an experiment was initiated in an acidic soil in Dinajpur 1999 under rice–wheat cropping system starting from the Transplanted monsoon rice. The experimental design was a split–split plot with 3 replications, taking 2 micronutrient treatments (foliar spray of water and foliar application of Zn, Mn, Cu, B & Mo) in the main plots, 3 levels of lime (0, 1 and 2 t ha^{-1}) in sub plots and 4 fertilizer treatments (control, recommended NKS, NPKS and NPKSMg) in sub–sub plots. Results showed liming significantly increased yield and yield components of both rice and wheat. The highest rice (4.69 t ha^{-1}) and wheat (4.13 t ha^{-1}) yields were recorded with the application of lime at the rate of 2 t ha^{-1}.

Rahman *et al*. (2002) reported that application of lime influenced the nutrient availability of soil, resulting increased the yield and yield components of both anaerobic rice and aerobic wheat cropping system

The highest pH value of soil was found in the soil receiving 1.5 g kg^{-1} lime ($CaCO_3$). Compared to application of lime alone, combined application of lime and pig manure had no significant effect on soil pH (Shen and Shen, 2001). They also reported that the liming markedly decreased total and monomeric inorganic Al concentrations in the soil solution. The concentrations of total and monomeric inorganic Al in soil which received 1.5 g kg^{-1} lime were about 54% and 50% of those in the control soil without lime or organic materials added. With regular fertilizer and lime applications, crop production can be considerably extended beyond typical cropping cycles for shifting cultivation (Smyth and Cassel 1995)

Khan *et al.* (1994) conducted a pot experiment to the growth, yield, and nutrition of rice plants cultivated in an acid sulfate soil treated with chemical fertilizers, basic slag, lime ($CaCO_3$), MnO_2, and leaching. The soil showed a low pH (4.0–4.5: field), high ECe (0.7–1.6 S m^{-1}) and consisted of a sulfuric horizon within the 1.2 m depth of the soil surface. Maximum growth and yield of rice cultivated in the soil were attained by the application of leaching plus basic slag treatment at the rate of 12.5 g kg^{-1}. The other treatments also resulted in a significantly ($p \leq 0.05$) improved performance compared with the control treatment (where no amendment was applied). Leaching, basic slag, MnO_2, and lime as single amendment brought about a grain yield increase of 500–900%, while leaching plus various doses of basic slag and lime resulted in an increase of grain yield of more than 1,500% over the control treatment.

Increasing Ca concentration in the nutrient solution (Shen *et al.*, 1993) and liming (Yu and Qin, 1998) had a beneficial effect on plant growth under Al stress and alleviated Al toxicity of plants. Thus, liming is the usual method for ameliorating Al toxicity in the acid soil. However, it has been discovered that liming may also cause negative effects on plant growth and soil properties (Ahmad and Tan, 1986).

2.2 Effect of acidic soil on nutrient concentration in grain and straw

2.2.1 Effect of acidic soil

Zhu *et al.* (2014) found investigated acidic soils with a wide range of soil fertility. Soil S_2 had the highest pH (5.31), the greatest SOC (15.2 g kg^{-1}), and null exchangeable Al^{3+}, while Soil S_3 contained the highest available N and P among the investigated soils because it received organic manure in vegetable garden. Of the two red soils derived from Quaternary red clay, Soil S_3 had greater soil fertility than Soil S_4, with greater SOC, TN, TP, available N and available P, but much less exchangeable Al^{3+}. Of the two red soils derived from sandstone, Soil S_5 had greater soil fertility than Soil S_6. Among the investigated soils, Soils S_1, S_4, and S_6 had lower pH (3.77–3.78), less SOC (3.3–6.2 g kg^{-1}), less nutrients (0.54–0.75 g kg^{-1} total N, 28.4–40.9 mg kg^{-1} available N, 3.8–25.6 mg kg^{-1} available P), but more exchangeable Al^{3+} (2.70–4.54 cmol kg^{-1}) than Soils S_2, S_3, S_5, and S_7. The exchangeable Al^{3+} was negatively related to pH (r = 0.80, P<0.05). Soil textures of Soils S_1 and S_4 were higher than Soils S_2 and S_3. The textures of Soils S_5–S_7 were sandy loam.

Chimdi (2014) conducted an experiment on acidic soils collected from agricultural lands of selected Districts of East Wollega Zone and its aim was to determine the status, extents and rating of the level acid saturation percentages of the soils of agricultural lands of the study area. The results of the study revealed that the soils of East Wollega Zone are ranged the soil pH (H_2O) from 4.63 to 6.01 which rated as very strongly acidic at Wayu Tuka to moderately acidic at Gida Ayana District. Highest (71.85%) and lowest (17.45%) PAS were recorded in the soils collected from Wayu Tuka and Diga Districts, respectively. The inverse relationship of exchangeable acidity and PAS with PBS may be attributed to intensive cultivation which leads to the higher exchangeable acidity content in soils collected from Wayu Tuka District than the remaining agricultural fields. The status of soil acidity in almost all the agricultural field of present study are beyond acidity tolerance limit of acid sensitive crops in the area. Therefore, due attention must be given to minimize the severity of Al toxicity of the soils with high PAS in the area, to reinstate intensively cultivated agricultural fields by improving the soil properties through crop rotation, returning crop residues to the fields and by using different amendment options such as agricultural liming materials.

2.2.2 Effect of organic/chemical fertilizer

Zhu *et al*. (2014) also reported that the 7 acidic red soils varying in texture, pH, and soil nutrient were taken from southern China concerning 4 treatments: zero biochar and fertilizer as a control (CK), 10 g kg^{-1} biochar (BC), NPK fertilizers (NPK), and 10 g kg^{-1} biochar + NPK fertilizers (BC+NPK). 15N–labeled fertilizer was used as a tracer to assess N use efficiency. After a 46–d pot experiment, biochar addition increased soil pH and available P, and decreased soil exchangeable Al^{3+}, but did not impact soil available N and cation exchange capacity. The N use efficiency and N retained in the soil were not significantly affected by biochar application except for the soil with the lowest available P (3.81 mg kg^{-1}) and highest exchangeable Al^{3+} (4.54 cmol kg^{-1}). Greater maize biomass was observed in all soils amended with biochar compared to soils without biochar (BC vs. CK, BC+NPK vs. NPK). This agronomic effect was negatively related to the concentration of soil exchangeable Al^{3+} ($P < 0.1$). The results of this study implied that the liming effect of biochar improved plant growth through alleviating Al toxicity and P deficiency, especially in poor acidic red soils.

A long–term (33 years) experiments were conducted by China *et al*. (2014) to investigate the effect of chemical fertilization rice yield, yield trends, soil properties, agronomic efficiency of applied nutrients and nutrient balance for the double rice cropping systems in subtropical China. The experimental site locates at the experimental farm of the Research Institute of Red Soil of Jiangxi province, Jinxian county, China (28°21'N, 116°10'E). The treatments were different combinations of N, P and K fertilizers (N, NP, NK and NPK), double dose of recommended NPK (2NPK) and no fertilizer control (control). Compared with no fertilizer control, all fertilization treatments had no significant effects on soil pH and SOC contents ($P > 0.05$), but generally increased nutrients content when corresponding elements were applied.
From the research findings of Rattanapichai *et al*. (2013) it was founnd that the different doses of MK (0, 1.56, 3.12 and 6.25 tons ha^{-1}) and NPK (16–8–8 and 16–16–8) caused an increase in silicon uptake of grain and straw. However, there was no effect on native phosphorus in soil and phosphorus uptake.

Cui *et al*. (2012) also found that the addition of boron–containing goethite to the soils resulted in increased rape growth, elevated soil pH and decreased exchangeable acidity. The addition of boron–containing goethite improved the uptake of iron , calcium , magnesium , and copper element and decreased the uptake of Mn and zinc element in rape seedling. The results suggested that boron–containing goethite could provide a better soil acidity environment for plant growth; it was also an important agent increasing a part of manganese difficult to use for plant and reducing the activity of soil manganese, which was beneficial to altering rape seedling growth

2.2.2.1 Effect of cowdung alone or in combinations with chemical fertilizer

Malika *et al*. (2015) reported that the NPKS uptake and use efficiency of BINA dhan7 were markedly influenced by combined application of organic and inorganic fertilizers. Overall, the treatment T_6 (50%RFD + CD 2.5 t ha^{-1} + PM 1.5 t ha^{-1} + Com 2.5 t ha^{-1}) was found to be the best combination of organic and inorganic fertilizers for obtaining the maximum yield as well as the economic yield of BINA dhan7.

Gitari *et al*. (2015) conducted an experiment to determine the effect of agricultural lime and goat manure on soil acidity and maize growth parameters using soils from Kavutiri–Embu County. The results were measured on soil parameters (soil pH and exchangeable acidity). Results generally showed that soil acidity decreased with increasing levels of manure and lime. The treatment with 12.5 Mg ha^{-1} of lime and 10 Mg ha^{-1} of manure was the best for reducing effect on soil acidity by enhancing the soil pH (6.3).

Pandey *et al.* (2014) reported that the nutrient uptake by seed was higher in combination of organic and chemical fertilizer. Uptake of NPK kg ha^{-1} was maximum under in–organic level of 150:80:60 kg NPK ha^{-1} and was followed by inorganic level of 100:60:40 kg, NPK ha^{-1} along with organic sources i.e. blending of N with cow dung urea (T_9), poultry manure (T_{10}) or slow release nitrogen (T_{12}). Thus it was concluded that use of inorganic fertilizer with different organic fertilizers sources are better for sustaining growth, yield and nutrient uptake by hybrid rice.

Whalen *et al.* (2002) reported that the crop production in acid soils can be improved greatly by adjusting the pH to near neutrality. Macronutrient uptake by wheat was generally improved by liming and manure applications, and micronutrient uptake was related to the effects of lime and manure on soil pH. The nutrient value of manure was calculated based on the quantities of plant–

available N, P and K in fresh manure. At distances less than 40 km, it is economical to substitute fresh cattle manure for agricultural lime to increase soil pH of acidic soils. Crops vary in their tolerance to soil acidity, and hence in their response to the amelioration of soil acidity.
Brancher (1999) carried out a pot experiment in greenhouse, with rice cv. BRIRGA 409 sown in A or Cg horizons of a low humic clay soil mined with cattle manure, rice straw, NPK or lime alone in all possible combinations of 2, 3 or 4 components. They showed that addition of NPK and for lime with or wheat manure reduced Fe concentration in above ground plant parts grown on the Cg horizons while manure alone increased Fe concentration.

2.2.2.2 Effect of compost alone or in combinations with chemical fertilizer
Sardar *et al*. (2015) found that the higher pH was observed in treatments receiving paddy straw and organic carbon (%) was also higher in the respective plots where vermi–compost and paddy straw was applied. Regarding available P_2O_5, there was an increasing trend up to 13–20 kg ha^{-1} in vermi–compost and green manure applied plots. In case of available K_2O, there was a decrease value in all treatments were observed. So there was a positive balance of P and negative balance of K

Zhu *et al*. (2014) studied to determine the crop responses to biochar addition and to understand the effect of biochar addition N use efficiency. Seven acidic red soils varying in texture, pH, and soil nutrient were taken from southern China and subjected to four treatments: zero biochar and fertilizer as a control (CK), 10 g kg^{-1} biochar (BC), NPK fertilizers (NPK), and 10 g kg^{-1} biochar plus NPK fertilizers (BC+NPK). ^{15}N–labeled fertilizer was used as a tracer to assess N use efficiency. After a 46–d pot experiment, biochar addition increased soil pH and available P, and decreased soil exchangeable Al^{3+}, but did not impact soil available N and cation exchange capacity (P > 0.05). The N use efficiency and N retained in the soil were not significantly affected by biochar application except for the soil with the lowest available P (3.81 mg kg^{-1}) and highest exchangeable Al^{3+} (4.54 cmol kg^{-1}). The results of this study implied that the liming effect of biochar improved plant growth through alleviating Al toxicity and P deficiency, especially in poor acidic red soils.

Sukristiyonubowo *et al*. (2013) conducted an experiment on rice production and nutrient status in postharvest soil. The soil was highly weathered especially ultisols and oxisols are mainly granted for extending newly opened wetland rice areas originated from dry land, besides potential acid sulphate soil from wet land. These soils have low pH or acidic, low natural level of major plant nutrients, and they have Al, Mn and Fe in toxic levels. Application of 2 ton ha^{-1} $year^{-1}$ dolomite, 2 ton ha^{-1} $season^{-1}$ rice straw compost and mineral fertilizers (200 kg urea, 100 kg SP–36 and 100 kg KCl ha^{-1} $season^{-1}$) improve the soil chemical properties.

The paper of Obiri–Nyarko (2012) concisely reviews the causes and effects of soil acidity and the approaches used to ameliorate acid soils for sustained crop production in Ghana. They found that the combination of lime and organic materials, however, are considered the most effective management option considering their availability and long term effectiveness. There is also the need to limit or curtail practices such as injudicious application of fertilizers that produce acidulating effects, and practices that can greatly deteriorate the soil's inherent fertility

Oluwatoyinbo *et al*. (2009) revealed that addition of compost to lime reduced the soil acidity more than either sole lime or sole compost applications. Combined application of compost and lime increased the available P and the exchangeable K; Ca and Mg. Liming of acid soils in the tropics can be complimented with compost application to achieve greater release of K, P and Mg along with increase in release of Ca.

Yung–Yu (2005) conducted a pot experiment to evaluate the effects of the application of two Merent kinds of composts: pea–rice hull compost (PRC) and cattle dung–tea compost (CTC) on rice growth. The soil used for the study was an Oxisol. These composts Mered in their nitrogen composition, as well as in their effect on nutrient uptake of nitrogen , phosphorus , potassium of rice plants. At the most active tillering and heading stages of the plants of the first crop, the amount of nutrients absorbed from the CHEM treatment were found to be higher than those in the other treatments. The values of nutrient uptake of the rice plants with the PRC treatment were the highest among all the treatments at the maturity stage. In the plants of the second crop, the values of N and K uptake from the PRC treatment were the highest among all the treatments at the heading and maturity stages.

A comparison of corncob compost with lime on plant growth was studied by Ren-shih and Sun-ho (1997) in acid red soil with pH of 4.07. Lettuce, pea, and corn were selected as test plants for their varying tolerance to acid soil. Soil amendments were 1, 2, and 4 cmol calcium carbonate ($CaCO_3$) kg^{-1} and 5, 10, and 20 g corncob compost kg^{-1} soil. Results showed higher manganese than aluminum content of the shoot in all check group plants. Reduced shoot Mn content increased shoot dry weight in all test plants, regardless of acid soil tolerance or soil treatment. The higher the test plant resistance to soil acidity, the weaker the detoxification effect of corncob compost was on Al uptake when compared with the check group. Liming was more effective at reducing shoot Mn content than corncob compost with the exception of the more acidity sensitive lettuce. Shoot P content, however, increased with corncob compost from enhanced organic matter rates. Corncob compost treatments significantly increased shoot dry weight over liming in the acid soil. This study demonstrated an environmentally acceptable use for an agricultural waste.

2.2.2.3 Effect of poultry manure alone or in combinations with chemical fertilizer

Hossain (2013) studied on nutrient availability in soil, grain and straw of rice due to five different treatments *viz.* T_1 (NPK), T_2 (NPK+ FYM), T_3 (NPK+ Vermi–compost), T_4 (NPK+ Rotten Rice Straw) and T_5 (NPK+ Poultry Manure). The amount of P, S, organic C and microbial biomass of post harvest soil was higher in plots having organic fertilizer treatments. N and K content in post harvest soil were not significantly changed. The pH value in treatments having organic fertilization was increased, which indicates that organic fertilizers reduce soil acidity. The percentage of organic C was highest in T_2 and was statistically similar to T_3, T_4 and T_5. The lowest organic C was observed in control T_1. It indicated that the amount of organic matter was higher in those plots which were treated with organic fertilizers. Use of organic fertilizer improves soil environment over the use of chemical fertilizers.

From the study of Meena and Singh (2012) it was found that the application of poultry manure resulted improved values regarding soil organic carbon, uptake of available NPK and soil biological properties compared to varying doses of vermicompost, FYM and over the control treatment. Physical properties of soil viz. bulk density and water stable aggregates were not affected due to nitrogen management through organic sources.

A field experiment was conducted by Meena *et al*. (2010) to study the effect of various sources (farmyard manure, vermicompost and poultry manure) and rates of organic manures (100, 125 and 150% recommended nitrogen dose) on yield, quality of rice, table pea, onion. Application of poultry manure resulted improved values of soil organic carbon, NPK uptake and soil biological properties compared to varying doses of vermicompost and farmyard manure and over the control. Physical properties of soil, viz bulk density and water stable aggregates were not affected due to nitrogen management through organic sources.

Ireri (2009) determine on the effects of agricultural lime in combination with farmyard manure (FYM) on soil properties (exchangeable acidity, pH, and microbial biomass) and maize growth. The treatments include: goat manure at 3 levels (0, 5 and 10 Mg ha^{-1}) and agricultural lime ($CaCO_3$) at 6 rates (0, 2.5, 5, 7.5, 10, and 12.5 Mg ha^{-1}). Results of this study indicate that soil acidity decreased with increase in manure and lime levels. The treatment $M_{10}L_{12.5}$ + 10 Mg ha^{-1} of manure and 12.5 Mg ha^{-1} of lime– recorded the highest pH of 6.3 and 5.9 for greenhouse and field trials, respectively. From the study, it was concluded that combining 10 Mg ha^{-1} of FYM and 12.5 Mg ha^{-1} of agricultural lime could be a promising alternative amendment for acid soil management strategy for increased maize production at Kavutiri and other related soils in Kenya

2.2.2.4 Effect of lime alone or in combinations with chemical fertilizer

MacKinnon *et al*. (2015) found that the responses to applied lime will occur at rates ranging from 0.5 t ha^{-1} to 4 t ha^{-1}. Normal application rates of lime of 1–2 t ha^{-1} to a soil of pH 4.8 can raise the soil pH by 0.6–1.0 pH units. This pH will gradually decline over the next 10 years. Applying lime at 3–4 t ha^{-1} can raise the pH from 4.8 to 6.3. This pH gradually declines over a 12 year period but the lime effect may still be present after this. Lime can be applied at any time of the year; best results are achieved if it is incorporated.

Two greenhouse experiments were conducted by Fageria and Knuppto (2014) on the changes in the chemical properties of an Oxisol. The lime rates used were 0, 0.71, 1.42, 2.14, 2.85, and 4.28 g kg^{-1} soil. Lime as well as gypsum application significantly changed extractable calcium , magnesium , hydrogen +aluminum , base saturation, and effective cation exchange capacity. In addition, liming also significantly increased pH, extractable phosphorus and potassium , calcium saturation, magnesium saturation, and potassium saturation. Optimum acidity indices for the grain yield of upland rice were pH 6.0, Ca 1.7 $cmol_c$ kg^{-1}, base saturation 60%, and calcium saturation 47%. In addition, upland rice can tolerate 42% of acidity saturation.

Azman *et al.* (2014) reported that the acid sulphate soils are low pH and high exchangeable Al that adversely affect on plant growth. In this study, the acid sulphate soil was treated with ground magnesium limestone , hydrated lime and liquid lime at specified rates. Prior to treatments, the pH of water sample in the rice field was 3.7, while Al concentration was 878 µM. Thus, rice plants grown under these conditions would suffer from H^{+} and Al^{3+} stress without amelioration, thus retard and/or minimize rice growth and yield.

Athanasea *et al*. (2013) conducted an experiment under soil acidity to highlighting the most causes of soil acidification, lime quality and lime requirement at Sub–Sahara Africa. Soil acidity affects crops in many ways and its effects are mostly indirect, through its influence on chemical factors such as aluminium and manganese toxicity, calcium , phosphorus and magnesium deficiencies and biological processes. The application of lime believed to enhance soil health status through improving soil pH, base saturation, Ca and Mg. It reduces Al and Mn toxicity and increases both P uptake in high P fixing soil and plant rooting system.

The importance of lime to ameliorate acidity on paddy field has been reviewed by Sadiq and Babagana (2012). Most of the authors showed that in acid sulfate soils, high content of Al caused adverse effect to rice growth. Application of lime precipitates Al and Fe in the soil. With applications of lime, basalt, organic fertilizer and/or their combinations at appropriate rates, acid sulphate soils are able to be ameliorated (Shazana *et al*., 2011).

The practice of liming acid soils is not common in Sub–Saharan Africa, perhaps as a result of limited knowledge on lime effectiveness, availability and high hauling costs of liming materials. A field study conduced by Okalebo *et al*. (2009) in western Kenya in 2005–2006 showed significant effects ($p<0.05$) of lime at 2 t ha^{-1} combined with phosphorus at 26 kg P ha^{-1} and nitrogen at 75 kg N ha^{-1}. The soil pH was raised to the range of 5.8 to 6.5 (by lime), while available phosphorus increased above 10 mg P ha^{-1} (the critical level).

A pot experiment was conduced by Ping *et al*. (2008) to investigate the effects of seven amendments on the growth and uptake of heavy metals from a paddy soil that was contaminated by copper and cadmium. The found that the limestone application decreased the Cu and Cd concentrations in grain. Cd concentration in grain was slightly reduced in the treatments of Chinese milk vetch and zinc sulfate. Cu and Cd in grain and straw were dependent on the available Cu and Cd in the soils, and soil available Cu and Cd were significantly affected by the soil pH

Fageria and Baligar (2008) reported that the soil acidity produces complex interactions of plant growth-limiting factors involving physical, chemical, and biological properties of soil. Soil erosion and low water-holding capacity are major physical constraints for growing crops on tropical Oxisols. Liming is a dominant and effective practice to overcome these constraints and improve crop production on acid soils. Lime is called the foundation of crop production or "workhorse" in acid soils. Soil pH, base saturation, and aluminum saturation are important acidity which can be reduced by the application of liming rates and reducing plant constraints on acid soils. In addition, crop responses to lime rate are vital tools for making liming recommendations for crops grown on acid soils.

Kisinyo *et al*. (2005) reported that the soil acidity and phosphorus deficiency are the major cause of acidic or poor Leucaena leucocephala establishment in tropical soils. A greenhouse experiment was conducted to determine the effects of lime as $CaCO_3$ and phosphorus as TSP on soil pH, P availability, leucaena nodulation, shoot growth, P and N contents. Both L and P had significant effects on P availability, shoot, weight, P and N, and nodule number, weight and N. Lime significantly ($P<0.05$) increased soil pH. Phosphorus decreased it, though not significantly. Based on the results, it is clear that acidity, P deficiency and poor nodulation limit leucaena establishment and growth in acid soils.

Rahman *et al*. (2002) investigated the effect of lime on rice production under the acidic alluvial soils of Dinajpur, Bangladesh. Result revealed that the soil pH, available P and B, exchangeable Ca and Mg contents in the soil taken after rice harvest were increased significantly by adding lime at the rate of 2 t ha^{-1}. Available Zn content in the soil was not affected by liming up to 2 t ha^{-1}.

Glaser *et al*. (2002) found that the rapid turnover of organic matter leads to a low efficiency of organic fertilizers applied to increase and sequester C in soils of the humid tropics. Charcoal was reported to be responsible for high soil organic matter contents and soil fertility of anthropogenic soils (Terra Preta) found in central Amazonia. Higher nutrient retention and nutrient availability were found after charcoal additions to soil, related to higher exchange capacity, surface area and direct nutrient additions. Shen and Shen (2001) reported that the application of $CaCO_3$ (Lime) markedly increased Ca concentration and decreased the concentrations of P and Mn in soil solution.

Increases in soil P availability due to liming have been reported by Curtin and Syers (2001) under glasshouse and field trials. In a laboratory study, they examined the effects of lime on labile P fractions in six New Zealand soils that varied in P–retention capacity. The soils (5.1–5.5 initial pH in water) were incubated with four rates of $CaCO_3$ to raise pH incrementally to a maximum of 6.5. Subsequently, P was applied to give three P levels in each soil. Averaged across P treatments, increase in pH ranged from 3 to 7 mg kg^{-1}. Liming also tended to depress water–extractable P. Decreases in extractable P suggest that liming increased phosphate adsorption. In limed soil, exchangeable Ca and pH increase simultaneously so that shifts in this equilibrium may be small and unpredictable.

Haynes and Mokolobate (2001) reported that the high rates of lime and fertilizer–P are characteristically required to obtain high crop yields on highly weathered acid soils. The increase in pH has been attributed to a number of causes including oxidation of organic acid anions present in decomposing residues, ammonification of residue N, specific adsorption of organic molecules produced during decomposition and reduction reactions induced by anaerobiosis. As organic residues decompose, P is released and this can become adsorbed to oxide surfaces. This will, in turn, reduce the extent of adsorption of subsequently added P thus increasing P availability. The practical implication of the processes discussed is that organic residues could be used as a strategic tool to reduce the rates of lime and fertilizer P required for optimum crop production acidic, P–fixing soils. Further research is, therefore, warranted to investigate the use of organic residues in the management of acid soils.

Khan *et al*. (1994) reported that the highest N content of rice was obtained by the application of leaching plus basic slag (12.5 g kg^{-1}) and leaching plus lime (7.5 g kg^{-1}) treatments. The highest P, Ca, and Mg contents were obtained by the application of leaching plus lime treatment at the rate of 7.5 g kg^{-1} and the maximum content of K was recorded after basic slag treatment at the rate of 7.5 g kg^{-1}. Leaching, lime and basic slag treatments led to a decrease of the Fe, Mn, and Zn concentrations in the plants and soil solutions (leachates). The addition of lime, basic slag, or MnO_2 exerted a significant effect ($p \leq 0.05$) on the decrease of the S content, increase of the soil solution pH, and optimization of some element concentrations in the plants and soil solutions.

Furrow application of lime increased the yields of rice and pea over farmer's practice or 100% RDF. This might be due to the increase in soil pH to neutrality by liming which restricted the fixation of P, S and B, and consequently enhanced their availability in the acid upland soil. Beneficial effect of furrow application of lime in red soils of Jharkhand was reported by Mathur *et al*. (1991).

The effect of liming on reducing B availability to plants is well known in agricultural crops, and it is at least partly caused by increased absorption of B in the soil as the pH increased (Gupta *et al*., 1985).

2.3 Liming and its advantages in acidic soils

Liming acidic soils enhance the activities of beneficial microbes in the rhizosphere and hence improve root growth by the fixation of atmospheric nitrogen because neutral pH allows more optimal conditions for free-living N fixation (Stephen *et al*., 2011). Application of lime at an appropriate rate brings several chemical and biological changes in the soils, which are beneficial or helpful in improving crop yields on acid soils (Fageria and Baligar, 2008). They also reported that the calcium released from applied lime in soil has been reported to enhance plant resistance to several plant pathogens, including Erwinia Phytophthora, R. solani, Sclerotium rolfsii, and Fusarium oxysporum.

Liming raises soil pH, base saturation, and Ca and Mg contents, and reduces aluminium concentration in acidic soils (Fageria and Stone, 2004). Fageria and Baligar (2004) also reported that liming acidic soils improved the use efficiency of P, and other micronutrients by upland rice genotypes. In this study, efficiency of these nutrients was higher under a pH of 6.4 than with pH 4.5. The liming improves efficiency of nutrients through soil acidity management for improving their availability, and enhanced root system. Finally, liming has been promoted as mitigation option for lowering soil N_2O emissions when soil moisture content is maintained at field capacity (Clough *et al*., 2004).

The liming of acidic soils result in the release of P for plant uptake; this effect is often referred to as ''P spring effect'' of lime (Bolan and Hedley, 2003). Soil microbiological properties can serve as soil quality indicators. Soil acidity restricts the activities of beneficial microorganisms, except fungi, which grow well over a wide range of soil pH (Brady and Weil, 2002). Liming is an important practice to achieve optimum yields of all crops grown on acid soils. According to Kaitibie *et al*. (2002), liming is the most widely used long-term method of soil acidity amelioration, and its success is well documented (Scott *et al*., 2001).

Therefore, liming provides calcium, which can contribute to build up plant resistance to some pathogens. Since soil pH has a potential effect on N_2O production pathways, and the reduction of N_2O to N_2, it has been suggested that liming may provide an option for the mitigation of N_2O emission from agricultural soils (Stevens *et al*., 1998). The acidic soils are naturally deficient in total and plant available phosphorus. This is because significant portions of applied P are immobilized due to precipitation of P as insoluble Al phosphate or chemisorptions to Al oxide and clay minerals (Nurlaeny *et al*., 1996).

According to McBride (1994), increasing soil pH through liming can significantly affect the adsorption of heavy metals in soils. Soil properties such as organic matter content, clay type, redox potential, and soil pH are considered the major factors that determine the bioavailability of heavy metals in soil (Treder and Cieslinski, 2005). Hence, liming certainly helps in reducing availability of heavy metals to crop plants. Soil acidity is also responsible for low nutrient use efficiency by crop plants.

Increase in availability of P in the pH range of 5.0 to 6.5 is associated with release of P ions from Al and Fe oxides, which is responsible for P fixation (Fageria, 1989). But at high pH (> 6.5) soluble P precipitate as Ca phosphate (Naidu *et al*., 1990). It can also suppress pathogens and producing phytohormones; enhancing root surface area to facilitate uptake of less mobile nutrients such as P and micronutrients and mobilizing and solubilising unavailable nutrients (Fageria *et al*., 1990). Haynes (1984) reported that calcium forms rigid linkages with pectic chains and thus promotes the resistance of plant cell walls to enzymatic degradation by pathogens.

CHAPTER 3
MATERIALS AND METHODS

The present experiment was conducted at the net house of the Department of Soil Science, Sher–e–Bangla Agricultural University (SAU), Dhaka–1207, during the *Boro* season from October 2013 to May, 2014 with a view to studying the effect of individual or mixed use of different types of fertilizer and manure(s) and regional acidic red soil on the performance of growth variability, yield potentialities and nutrient management practices of rice. Details of different materials used and methodologies followed to conduct the studies are presented in this chapter.

3.1 Site Description

3.1.1 Geographical Location

The experimental area was situated at $23^{0}77^{0}$N latitude and $90^{0}33^{0}$E longitude at an altitude of 8.6 meter above the sea level .

3.1.2 Agro–Ecological Region

The experimental net house belongs to the Agro–ecological zone of "The Madhupur Tract", AEZ–28 (Anon., 1998).

3.1.3 Soil

Two different acidic soils were collected from AEZ 28 by considering the difference of soil texture, pH and organic matter. The soil 1 and soil 2 of the experiment were collected from village Bhatgaon and Goari of Upazilla Bhaluka, Mymensingh belongs to the AEZ No. 28, Madhupur Tract, classified as Deep Red Brown Terrace Soils in Bangladesh soil classification system. A sampling device (Rhizon MOM 10 cm length, 2.5 mm OD, Rhizosphere Research Products, Wageningen, and The Netherlands) was buried diagonally in the middle of the soil of each pot for collecting soil solution. Soil samples were analyzed for both physical and chemical properties in the laboratory of SAU, Dhaka, Bangladesh. The texture of soil–1 was silt loam having pH 5.4 and contains organic matter 0.62%, total N 0.08%, available P

3.6 ppm, available K 0.08 meq 100 g^{-1}. The soil–2 of the experiment belongs to the AEZ No. 28, Madhupur Tract in Bangladesh. The soil texture was silt loam having pH 5.5 and contains organic matter 0.52%, total N 0.08%, available P 1.10 ppm, available K 0.083 meq 100 g^{-1}. The soils were analyzed following standard methods. Particle–size analysis of soil was done by Hydrometer method and soil pH was measured with the help of a glass electrode pH meter using soil water suspension of 1:2.5.

3.1.4 Climate

The study area has sub tropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April–September) and scanty rainfall associated with moderately low temperature during the Rabi season (October–March).

Table 3.2 Monthly record of air temperature, rainfall and relative humidity of the experimental site during the period from October 2013 to May 2014

Months	Air temperature		Relative humidity (%)	Rainfall (mm) (Total)
	Maximum	Minimum		
October, 2013	25.80	16.00	78	00
November, 2013	22.40	13.50	74	00
December, 2013	24.50	12.40	68	00
January, 2014	27.10	16.70	67	30
February, 2014	31.40	19.60	54	21
March, 2014	35.60	24.20	53	37
April, 2014	34.40	21.90	61	21
May, 2014	32.10	21.30	63	27

Source: Bangladesh Meteorological Dept (Climate & weather division) Agargoan, Dhaka – 1212

3.2 Details of the experimental materials

The variety BRRI dhan29 was used as a planting materials for the present study. Besides, two sets of the experimental materials included in the experiment were as follows:

3.2.1 Soil (2)

Two different acidic soils were collected from the Upazilla Bhaluka under the AEZ–28 and use as a treatment of the study. They are as follows:

S_1: Soil of Bhatgaon and **S_2:** Soil of Goari

3.2.2 Different types of fertilizer and manure treatments (8)

The fertilizer treatments were used in this experiment based on BARC fertilizer recommendation guide, 2012. Three types of organic manure (cowdung, compost and poultry manure) were used in this rice experiment. There were nine fertilizer or manure with and without lime treatments, namely

T_0: Control

T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (Recommended dose of chemical fertilizer)

T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime (dolomite) kg^{-1} soil (2 ton ha^{-1})

T_3: 50% NPKSZn + 5 ton cowdung ha^{-1}

T_4: 50% NPKSZn + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil (2 ton ha^{-1})

T_5: 50% NPKSZn + 5 ton compost ha^{-1}

T_6: 50% NPKSZn + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil (2 ton ha^{-1})

T_7: 50% NPKSZn + 3.5 ton poultry manure ha^{-1} and

T_8: 50% NPKSZn + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil (2 ton ha^{-1})

There were 18 (2×9) treatments combination as S_1T_0, S_1T_1, S_1T_2, S_1T_3, S_1T_4, S_1T_5, S_1T_6, S_1T_7, S_1T_8, S_1T_9, S_2T_0, S_2T_1, S_2T_2, S_2T_3, S_2T_4, S_2T_5, S_2T_6, S_2T_7, S_2T_8 and S_2T_9.

3.3 Growing of crops

3.3.1 Seed collection

Healthy and vigorous seeds of BRRI dhan29 were collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur and Research Laboratory of the Department of Soil Science, SAU, Dhaka.

3.3.2 Seed sprouting

Healthy seeds were collected by specific gravity method. The selected seeds were soaked for 24 hours and then these were kept in gunny bags. The seed started sprouting after 48 hours and almost all seeds were sprouted after 72 hours.

3.3.3 Preparation of seedling tray and seed sowing

Two of each 24 × 12 × 6 inches tray (length, width and depth, respectively) were selected for sowing the sprouting seeds and kept in the net house of the Department of Soil Science, SAU, Dhaka for raising seedlings. Those tray were prepared by 72 kg soil of each location of Bhatgaon and Goari village at Bhaluka Upazilla. The collected soil of those locations were cleaning, wetting by proper irrigation and leveling with ladder. Sprouted seeds were sown in the wet soil of those tray on 3 December 2013. Proper care was taken to raise the seedlings in the nursery tray. Weeds were removed and irrigation was given in the seed tray as and when necessary.

3.4 Experimental design

Design: Randomized Complete Block (RCB)

Factor A: Soil (2)

Factor B: Different types of fertilizer and manure as treatments (9)

Treatment combinations: 18

Replication: 3

Total number of pots: 54

3.4.1 Layout of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications where three blocks were assigned in this experiment. Each block was sub–divided into eighteen unit pots. The treatments were randomly distributed to the unit pots in each block. The total number of pots was 54 (18×3).

3.5 Preparation of experimental pot

There were 54 earthen pots of each (9 fertilizer treatments x 2 soils x 3 replications) were used for the experiment where the sizes of each pot was (18″height x16″diameter). The collected experimental 756 kg soil from the two villages (378 kg for each village) of Bhaluka Upazilla were kept in the net house and the pieces of soil were broken down by khurpi. Later on those soils were properly mixed with fertilizer(s) as per treatments of the study where the RDCF of NPKSZn were used as fertilizer recommendation guide of BARC (2012). One week later, the fertilizer treated soil were kept in experimental pot while 14 kg treated soil were used in each pot. Immediately after final pot preparation, the pot layout was made on January 5, 2014 according to experimental specification. Individual pot was cleaned and finally leveled with the help of laddering.

3.6 Uprooting of seedlings

The seed trays were made wet by application of water on the previous day before uprooting the seedlings. The seedlings were uprooted carefully without causing dry injury to the roots. The uprooted seedlings were kept on soft mud under shade.

3.7 Transplanting of seedlings

On 7 January, 2014, 35 day–old two seedlings were transplanted in the pot . Gap filling was made up to 7 days after transplanting to maintain similar plant population density for every pot.

3.8 Application of fertilizers

The fertilizer treatments were used in this experiment based on BARC fertilizer recommendation guide, 2012. Three types of organic manure (cowdung, compost and poultry manure) were used in this rice experiment. The required amount of dolomite was applied at the rate of 2 ton ha^{-1} and dolomite was applied and treatment wise fertilizer and manure were also applied in pots. The water management was continuous flooding (2–3 cm water) during the growing period of rice. The required amount of manures ($N_{150}P_{30}K_{70}S_{20}Zn_3$), TSP, MP, gypsum, zinc sulphate and one third urea were applied during final soil preparation by considering the fertilizer treatments and weight of soil in the pot. The fertilizer and manures were mixed in the soils of the pot.

3.9 Intercultural Operations

3.9.1 Thinning and Gap Filling

After one week, thinning was done to maintain the constant population number. After transplanting the seedlings in the pots, gap filling was done whenever it was necessary using the seedling.

3.9.2 Weeding

The crop was infested with some weeds during the early stage of crop establishment. Two hand weeding were done for every method, first weeding was done at 15 days after transplanting followed by second weeding at 15 days after first weeding. Weeds were also removed by hand.

3.9.3 Application of Irrigation Water

The water management was continuous flooding (2–3 cm water) during the growing period of rice in the pot. This was done to keep the soil well aerated, to allow better root growth. From panicle initiation (PI) to hard dough stage, a thin layer of water (2–3 cm) was also kept on the plots.

3.9.4 Plant Protection Measures

Plants were infested with rice stem borer (*Scirphophaga incertolus*) and leaf hopper (*Nephotettix nigropictus*) to some extent which were successfully controlled by Diazinone @ 1 ml 1 liter^{-1} of water on February 03 and by Ripcord @ 1 ml 1 liter^{-1} of water for the pots on February 20 and March 25, 2014. Crop was protected from birds and rats during the grain filling period. Field trap and foxtoxin poisonous bait was used to control the rat. For controlling the birds watching was done properly, especially during morning and afternoon.

3.10 Harvesting

The crop was harvested at maturity on the month of May 2014 while grain colour was turned yellow.

3.11 Soil and crop sampling for data collection

A sampling device (Rhizon MOM 10 cm length, 2.5 mm OD, Rhizosphere Research Products, Wageningen, and The Netherlands) was buried diagonally in the middle of the soil of each pot for collecting soil solution. Soil pore–water samples were collected for each crop at 30 and 60 days after transplantation of rice and analyzed for pH, N, P and K contents. The harvested crop was threshed pot–wise. Grain and straw yields were recorded separately pot–wise and moisture percentage was calculated after sun drying. Dry weight for both grain and straw were also recorded. The yield and yield components were also measured. Total tiller, Effective tiller, non effective tiller, plant height, panicle length, filled grain, unfilled grain, 1000 grain wt, grain yield and straw yield were measured. The grain and straw samples from every pot were also determined for N, P, K and S contents following standard methods.

3.12 Data collection

The data on the following growth, yield, yield contributing and nutrient content of grain and straw of the crop were recorded:

Growth, yield and yield contributing characters

i) Plant height (cm)
ii) Number of effective tillers hill^{-1}
iii) Number of non–effective tillers hill^{-1}
iv) Panicle length (cm)
v) Number of filled grains panicle^{-1}
vi) Number of un–filled grains panicle^{-1}
vii) 1000–grain weight (g)
viii) Grain yields (g pot^{-1})
ix) Straw yields (g pot $^{-1}$)

Nutrient characters

Nutrient content of nitrogen , phosphorus , potassium and sulphur in rice grain.

3.12.1 Plant height (cm)

The plant height was measured from the ground level to the top of the panicle. All the plants were measured and average for each pot.

3.12.2 Number of effective tillers hill^{-1}

The panicles which had at least one grain was considered as effective tiller. The number of effective tillers of 5 hills was recorded and expressed as effective tillers number hill^{-1}.

3.12.3 Number of non–effective tillers hill^{-1}

The tiller having no panicle was regarded as non-effective tiller. The number of non-effective tillers was recorded and was expressed as non–effective tiller number hill^{-1}.

3.12.4 Panicle length

Panicle length was measured by a meter scale from the basal node of the rachis to the apex of each panicle from all the plants of a hill and their average was recorded and converted in cm.

3.12.5 Number of filled grains panicle^{-1}

Filled grain was considered to be filled if any kernel was present there in. Number of filled grain was recorded from all the panicles of a hill and converted into filled grains panicle^{-1}.

3.12.6 Number of unfilled grain panicle^{-1}

Number of unfilled grains panicle^{-1} means the absence of any kernel inside in and such grains present on each panicle were recorded.

3.12.7 Thousand–grain weight (g)

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 12% moisture and the mean weight were expressed in gram.

3.12.8 Grain yield (g pot^{-1})

Grain yield was determined from all the plants pot and expressed as g pot^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital oven.

3.12.9 Straw yield (g pot^{-1})

Straw yield was determined from all the plants of each pot. After threshing, the sub–sample was oven dried to a constant weight and finally converted to g pot^{-1}.

3.13 Chemical analysis of plant sample

Plant samples were analyzed for chemical properties in the laboratory of Soil Science Dept of SAU, Dhaka. The properties studied included total P, K and S. The grain (PKS) concentration have been presented in Table 3.2. The soil was analyzed by standard methods:

3.13.1: Collection and preparation of plant samples

Grain samples were collected after threshing for N,P,K and S analysis. The plant samples were dried in an oven at 70^{0C} for 72 hours and then ground by a grinding machine (Wiley-mill) to pass through a 20-mesh sieve. The samples were stored in plastic vial for analysis of N,P,K and S. The methods were as follows.

3.13.1 Total nitrogen

Total nitrogen in rice grain was determined by Micro Kjeldahl method where grain was digested with 30% H_2O_2, conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se powder in the ratio of 100:10:1). Nitrogen in the digest was estimated by distillation with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with 0.01N H_2SO_4 (Bremner and Mulvaney, 1982).

Rice grain samples were digested by nitric acid and perchloric acid solution for determination of P K S.

3.13.2 Total phosphorus (P) determination in grain

Plant sample (grain) was digested by diacid (Nitric acid and Perchloric acid) mixture and P content in the digest was measured by blue color development (Olsen et.al.,1954). Phosphorus in the digest was determined by using 1 ml grain sample from 100 ml digest by using developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with standard P curve.(Page *et al.*,1982).

3.13.3 Potassium Determination in grain

Five ml of digest sample was taken and diluted to 50 ml volume to make desired concentration so that the flame photometer reading of samples were measured within the range of standard solutions. The concentrations were measured by standard curves.

3.13.4 Sulphur Determination

Sulphur content was determined from the digest of the plant samples (grain) . The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6 N HCl) and $Bacl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelength (Hunter,1984)

3.14 Statistical Analysis

Data recorded for yield and yield contributing characters including the nutrient content and uptake were compiled and tabulated in proper form for statistical analyses. Analysis of variance was done with the help of MSTAT–C computer package programme developed by Russel (1986). The mean differences among treatment were tested with Duncan's Multiple Range Test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS

Results obtained from the present study regarding the influence of organic (cowdung, compost and poultry) and inorganic (RDCF and lime or dolomite) mixed use of fertilizers on growth, yield and yield attributes of *Boro* rice under net house condition are presented and discussed in this chapter. After observing the field performance, further investigation was also observed on the aspect of nutrient quality of the obtained grain and straw of the study. The results have been presented in Tables 4.1 through 4.7 and Figures 4.1 to 4.8. The grain, straw yield with yield contributing characters and nutrient concentrations of the rice cultivars have been presented and discussed under separate heads and sub–heads as follows:

4.1 Responses of regional acidic soil and different types of fertilizer on the pore–water Phosphorus (P) concentrations during boro rice growing period

Effect of regional acidic soil on the pore water P concentration on the pore water P concentration.

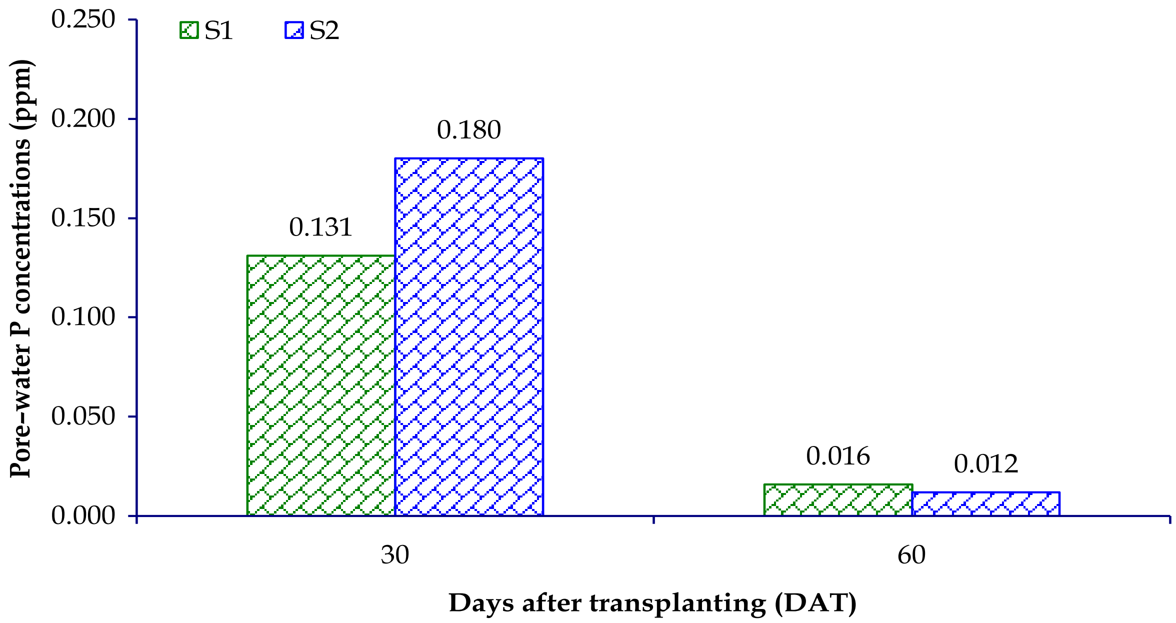
The pore–water P concentrations were significantly affected in two soils. The lower concentrations of available P were observed in both acidic soils and the pore–water P level decreased sharply in both soils with increasing days after transplantation. The higher levels of pore–water P (0.180 ppm) was found in soil of Goari (S_2) compared (0.131 ppm) to the soil of Bhatgaon (S_1) at 30 DAT. In contrast, the availability of P concentrations of the collected pore water of Bhatgaon and Goari were 0.016 and 0.012 ppm, respectively where Bhatgaon showed higher P concentration than Goari. However, obtained result of both acidic soils showed decreased tendency from 30 DAT to 60 DAT during Boro rice cultivation (Fig. 4.1).

Effect of different types of fertilizers on the pore water P concentration:

The availability of P in studied soil pore–water were influenced significantly due to the effect of organic–inorganic based fertilizer where their effect significantly decreased the P concentrations in soil pore–water from 30 DAT to 60 DAT concerning all fertilizer treatments of the study (Fig. 4.2). Among the treatments, the higher pore–water P concentration (0.264 ppm) was found at 30 DAT (Fig.4.2) in fertilizer treatment where 50% RDCF were used in mixed with 5 to compost ha^{-1} and 2 ton lime ha^{-1} (T_6). Almost similar level of P concentration (0.260 ppm) was found in the lime applied treatment T_8 (50% NPKS + 3.5 ton poultry manure ha^{-1}+ 2 ton lime ha^{-1}) while lowest P concentration (0.020 ppm) was found in T_0 treatment where fertilizer was not applied. Lower levels of pore-water P concentrations were found at 60 DAT with an average ranges of 0.006 (T_o) to 0.024 ppm (T_6).

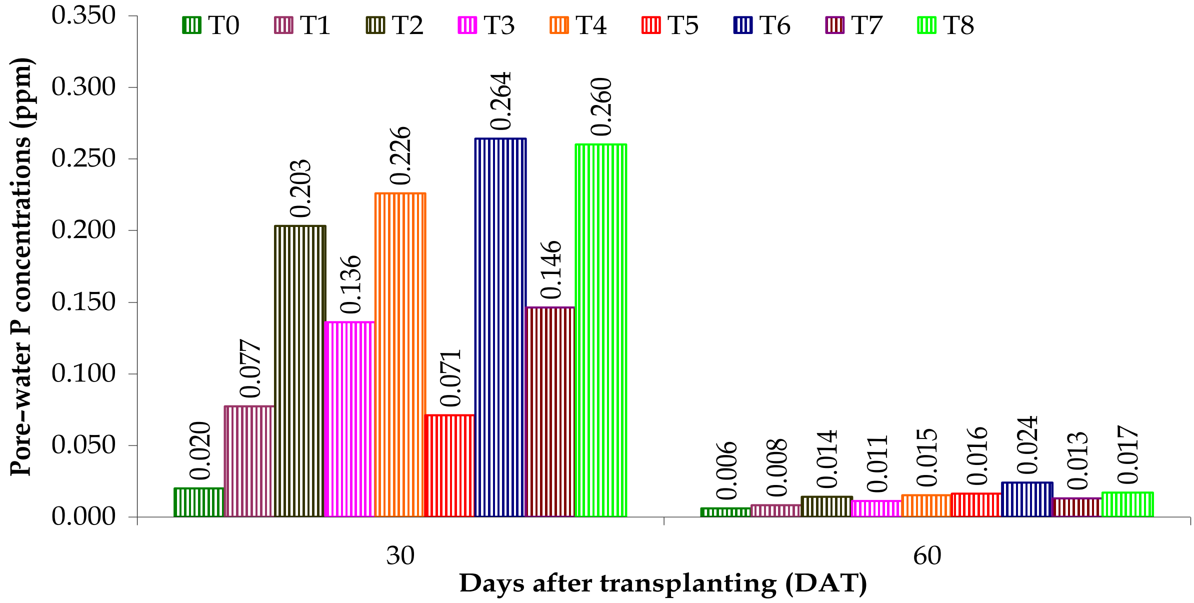
Interaction effects of regional acidic soil and different types of fertilizers

However, the interaction effect of acidic soils and fertilizer was significantly influenced the pore–water P concentrations at 30 DAT but the P concentrations of the pore–water at 60 DAT did not differed significantly (Table 4.1) . Obtained result from the Table 4.1 it was found that the pore–water P concentrations gradually decreased from 30 DAT to 60 DAT due to whole interaction treatments. The pore–water P concentrations varied from 0.005 (S_1T_0) to 0.032 ppm (S_1T_6) at 60 DAT due to different treatments of interaction but whole treatments were statistically more or less similar due to non significant difference. At 30 DAT, the highest pore–water P concentration (0.400 ppm) was found from the soil of Goari treated by 50% RDCF along with 5 ton cowdung t ha^{-1} + 2 ton lime ha^{-1} (S_2T_4) followed by (0.380 ppm) the same soil treated by 50% RDCF along with 5 ton cowdung t ha^{-1} + 2 ton lime ha^{-1} (S_2T_6). The without fertilizer treated soil of Bhatgaon (S_1T_0) showed the lowest pore–water P concentration (0.004 ppm) in the present study (Table 4.1).



S_1: Red soil of Bhatgaon, Bhaluka, Mymensingh and S_2: Red soil of Goari, Bhaluka, Mymensingh

Fig. 4.1 Effect of acidic soil on pore–water P concentrations at different days after transplanting of *Boro* rice



T_0: Control

T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (Recommended dose of chemical fertilizer)

T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime kg^{-1} soil

T_3: 50% NPKS + 5 ton cowdung ha^{-1}

T_4: 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil

T_5: 50% NPKS + 5 ton compost ha^{-1}

T_6: 50% NPKS + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil

T_7: 50% NPKS + 3.5 ton poultry manure ha^{-1} and

T_8: 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil

Fig. 4.2 Effect of different types of fertilizers on pore–water P concentrations at different days after transplanting of *Boro* rice

Table 4.1 Interaction effect of acidic red soil and different types of fertilizers on the pore–water P concentration

Soil and Fertilizer Treatment	Phosphorus concentration(ppm)	
	30 DAT	60 DAT
S_1T_0	0.004 q	0.005
S_1T_1	0.049 o	0.007
S_1T_2	0.274 d	0.015
S_1T_3	0.184 g	0.013
S_1T_4	0.051 n	0.015
S_1T_5	0.048 o	0.019
S_1T_6	0.148 h	0.032
S_1T_7	0.201 f	0.015
S_1T_8	0.222 e	0.019
S_2T_0	0.037 p	0.006
S_2T_1	0.104 j	0.009
S_2T_2	0.132 i	0.013
S_2T_3	0.087 m	0.010
S_2T_4	0.400 a	0.015
S_2T_5	0.095 k	0.014
S_2T_6	0.380 b	0.016
S_2T_7	0.090 l	0.011
S_2T_8	0.299c	0.015
SE(±)	**0.009**	**NS**

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

S_1: Red soil of Bhatgaon, Bhaluka, Mymensingh and S_2: Red soil of Goari, Bhaluka, Mymensingh

T_0: Control
T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (Recommended dose of chemical fertilizer)
T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime kg^{-1} soil
T_3: 50% NPKSZn + 5 ton cowdung ha^{-1}
T_4: 50% NPKSZn + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil
T_5: 50% NPKSZn + 5 ton compost ha^{-1}
T_6: 50% NPKSZn + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil
T_7: 50% NPKSZn + 3.5 ton poultry manure ha^{-1} and
T_8: 50% NPKSZn + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil

4.2 Responses of regional acidic soil and organic–inorganic based fertilizer on growth, yield and yield attributes of rice

4.2.1 Plant height

Effect of acidic soils

Plant height was recorded at harvest and it did not differed significantly due to the effect of regional acidic soil. As a result, the plant grown under both the regional acidic soils produced statistically more or less similar height due to non significant difference (Fig. 4.3).

Effect of different types of fertilizers

Plant height at harvest varied significantly due to the effect of different types of fertilizers treatments (Fig. 4.4). Fig. 4.4 revealed that all the treatments recorded significantly higher plant height over the control (T_0). Fig. 4.4 revealed that the tallest plant of 70.42 cm was found from the treatment T_6 receiving of 50% RDCF + 5.0 ton compost ha^{-1} + 2 ton lime ha^{-1} which was statistically close among the whole treatments T_1 (68.60), T_7 (67.83), T_8 (67.94), T_5 (67.83), T_3 (67.19) T_2 (except T_4 (65.19 cm) and T_0 (53.98 cm). On the other hand, the plant grown without fertilizer showed the lowest plant height of 53.98 cm in the present study.

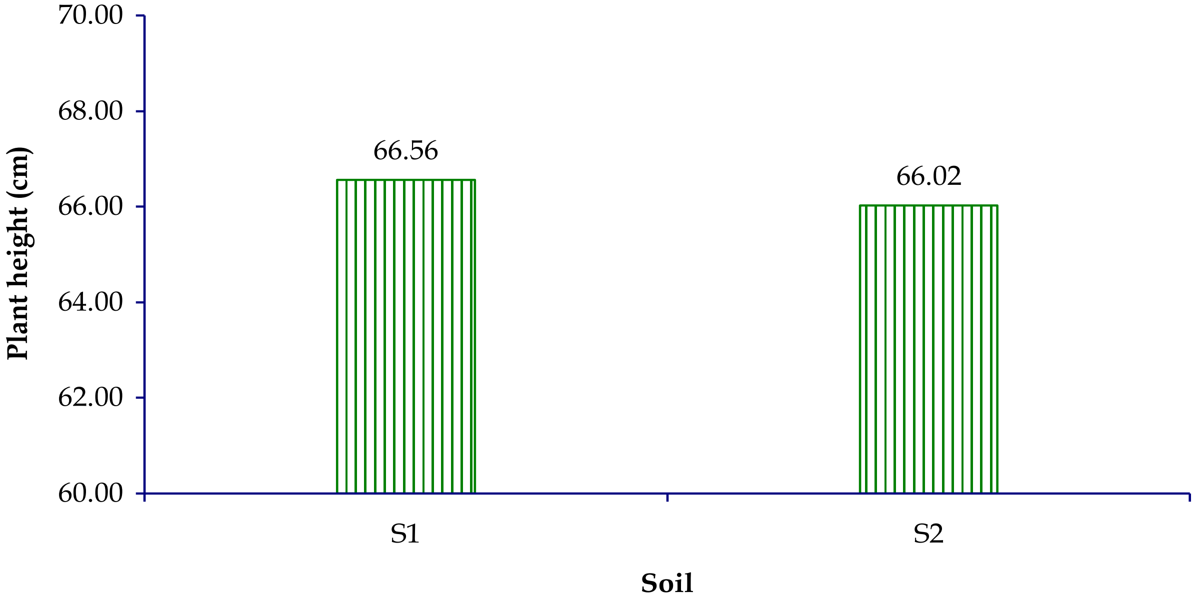
Interaction effects of regional acidic soil and different types of fertilizers

Analysis of variance data on plant height at harvest did not vary significant due to the effect of interaction of regional acidic soil and organic–inorganic based fertilizer. As a result, both regional acidic soil in combination with whole treatments of the study produced statistically more or less same height of plant due to non significant variation. However, it was varied from 52.74 (S_1T_0) to 72.85 cm (S_1T_2) (Table 4.4).

4.2.2 Number of effective tillers hill^{-1}

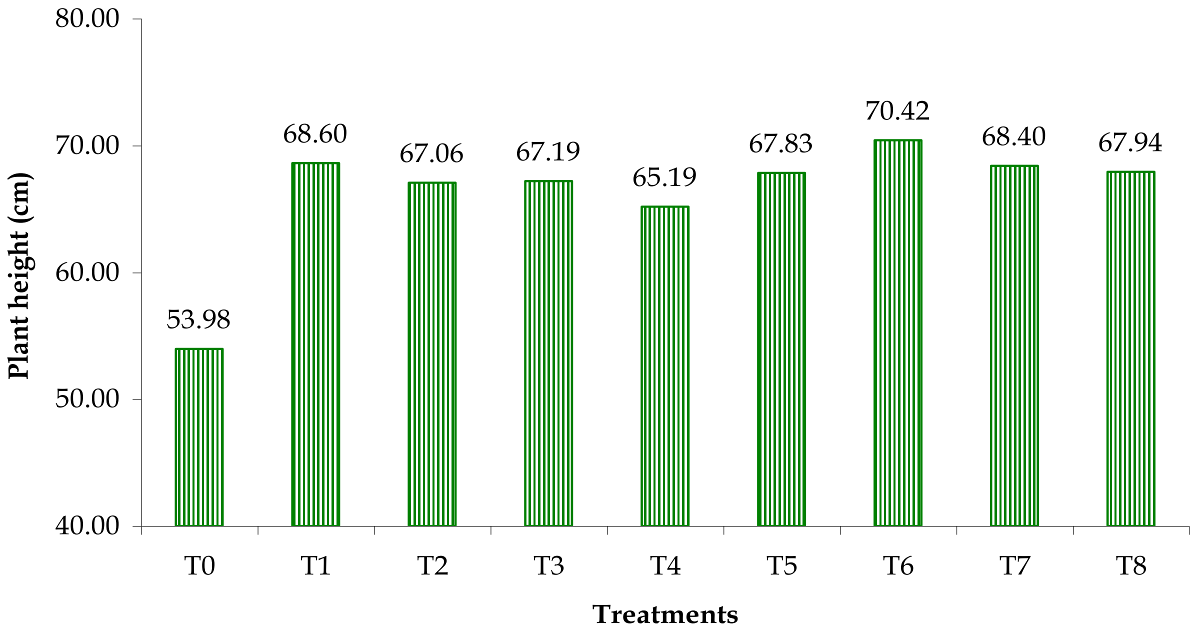
Effect of regional acidic soil

The effective tillers i.e. ear bearing tillers is an important parameter which affect the yield of rice. A rice plant may produce a number of tillers during its early growth stages but not all of them become effective i.e., they do not bear panicles.



S_1: Red soil of Bhatgaon, Bhaluka, Mymensingh and S_2: Red soil of Goari, Bhaluka, Mymensingh

Fig. 4.3 Effect of acidic soil on plant height at different days after transplanting of *Boro* rice



T_0: Control
T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (Recommended dose of chemical fertilizer)
T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime kg^{-1} soil
T_3: 50% NPKS + 5 ton cowdung ha^{-1}
T_4: 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil
T_5: 50% NPKS + 5 ton compost ha^{-1}
T_6: 50% NPKS + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil
T_7: 50% NPKS + 3.5 ton poultry manure ha^{-1} and
T_8: 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil

Fig. 4.4 Effect of different types of fertilizers on plant height at different days after transplanting of *Boro* rice

So, this character is directly related to yield of rice. Number of effective tillers hill^{-1} had shown significant difference between the studied regional acidic soil .Between the regional acidic soil, the plant grown under Bhatgaon soil produced more number of effective tillers hill^{-1} (22.11) than the regional acidic soil of Goari (18.48) (Table 4.2).

Effect of different types of fertilizers

Different types of fertilizers had significant influence on number of effective tillers hill^{-1}. The maximum number of effective tillers hill^{-1} (27.17) was produced from the RDCF of NPKSZn while cowdung, compost, poultry manure and lime were absent (T_1) while RDCF along with 2 ton lime ha^{-1} (T_2) showed statistically same number of effective tillers hill^{-1} (26.33) and it was also statistically close to 50% RDCF + 3.5 ton poultry manure along with (T_7) or without (T_8) lime (24.50 and 23.17, respectively). On the other hand, the lowest number of effective tillers hill^{-1} (5.17) was found while soil was not treated with any fertilizer (T_0) (Table 4.3).

Interaction effects of regional acidic soil and different types of fertilizers

Number of effective tillers hill^{-1} did not differed significantly due to the effect of interaction between regional acidic soil and organic–inorganic based fertilizer .The non significant variation result from the Table 4.4 revealed that the productive tillers varied from 4.67 to 31.67 where only RDCF ($N_{150}P_{30}K_{70}S_{20}Zn_3$) showed the highest and without fertilizer (T_0) recorded the lowest number of effective tillers hill^{-1} but their variation was not statistically significant (Table 4.4).

4.2.3 Number of non effective tillers hill^{-1}

Effect of regional acidic soil

The non effective tillers hill^{-1} significantly influenced due to the effect of regional acidic soil (Table 4.2). As evident from the Table 4.2, the plant grown under Bhatgaon soil showed significantly the highest number of non effective tillers hill^{-1} (8.41) compared the soil of Goari (5.82) (Table 4.2).

Table 4.2 Effects of acidic red soil types on yield contributing characters of boro rice

Soil	Number of effective tiller hill^{-1}	Number of non–effective tiller hill^{-1}	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})
S_1	22.11 a	8.41 a	66.25	24.81	35.15 a	54.37 a
S_2	18.48 b	5.82 b	62.65	22.65	30.52 b	44.22 b
SE(±)	**0.73**	**0.02**	**NS**	**NS**	**1.08**	**1.84**

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

S_1: Red soil of Bhatgaon, Bhaluka, Mymensingh and S_2: Red soil of Goari, Bhaluka, Mymensingh

Table 4.3 Effects of different types of fertilizers on yield contributing characters of boro rice

Fertilize treatments	Number of effective tiller hill^{-1}	Number of non–effective tiller hill^{-1}	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})
T_0	5.17 e	3.83 b	32.14 b	29.24	4.00 d	7.67 f
T_1	27.17 a	8.17 a	65.57 a	22.42	41.67 a	71.00 a
T_2	26.33 a	7.17 ab	68.53 a	22.15	41.67 a	57.33 bcd
T_3	17.67 d	7.67 a	76.57 a	20.95	32.33 bc	41.67 e
T_4	20.83 bcd	6.17 ab	63.78 a	25.62	30.67 c	48.33 cde
T_5	18.83 cd	7.00 ab	67.92 a	23.40	30.33 c	46.33 cde
T_6	19.00 cd	6.33 ab	74.83 a	22.08	36.83 abc	44.67 de
T_7	24.50 ab	9.50 a	66.62 a	23.37	39.00 ab	59.33 abc
T_8	23.17 abc	8.17 a	64.10 a	24.33	39.00 ab	67.33 ab
SE(±)	**1.55**	**1.06**	**4.14**	**2.15**	**2.30**	**3.90**

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

T_0: Control
T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (Recommended dose of chemical fertilizer)
T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime kg^{-1} soil
T_3: 50% NPKSZn + 5 ton cowdung ha^{-1}
T_4: 50% NPKSZn + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil
T_5: 50% NPKSZn + 5 ton compost ha^{-1}
T_6: 50% NPKSZn + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil
T_7: 50% NPKSZn + 3.5 ton poultry manure ha^{-1} and

T_8: 50% NPKSZn + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil

Effect of different types of fertilizers

Number of non–effective tillers $hill^{-1}$ differed significantly due to the application of different types of fertilizer and manure (Table 4.3). The maximum non–effective tillers $hill^{-1}$ (9.50) was obtained from the treatment T_7 having 50% RDCF along with 3.5 ton poultry manure which was statistically identical to the treatment of only RDCF (T_1), 50% RDCF + 3.5 ton poultry manure + 2 ton lime ha^{-1} (T_8) and 50% RDCF + 5.0 ton cowdung manure (T_3) (8.17, 8.17 and 7.67). Rest of the treatments (T_2, T_5, T_6 and T_4) also showed statistically identical with each other (7.17, 7.00, 6.33 and 6.17, respectively) and statistically close to T_7, T_8 and T_1. Without fertilizer or control treatment recorded the lowest number of non–effective tillers $hill^{-1}$ (3.83) in this study.

Interaction effects of regional acidic soil and different types of fertilizers

There was a significant variation was found due to the interaction effects of regional acidic soil and different types of fertilizers in respect of non–effective tillers $hill^{-1}$ (Table 4.4). From the Table 4.4, it was found that the maximum number of non effective tillers $hill^{-1}$ (10.67) was recorded from the soil of Bhatgaon receiving of 50% RDCF along with 3.5 ton poultry manure ha^{-1} (S_1T_7) which was statistically close with the whole interaction treatments of the study except S_2T_0, S_1T_0, S_2T_0, S_1T_2, S_2T_5 and S_2T_6. However, the soil of Goari showed lowest number of non–effective tillers $hill^{-1}$ (3.00) while it did not receive any fertilizer (S_2T_0) but it was also statistically close to S_1T_0, S_2T_0, S_1T_2, S_2T_5 and S_2T_6 (4.67, 5.00, 5.33 and 5.00, respectively) (Table 4.4).

4.2.4 Panicle length

Effect of regional acidic soil

Analysis of variance data on panicle length did not differed due to the effect of regional acidic soil (Fig. 4.5). However, the soil of Bhatgaon showed slightly longer panicle (21.68 cm) than the soil of Goari (21.55 cm) in this study (Fig. 4.5).

Table 4.4 Effect of acidic red soil types and different types of fertilizers on yield contributing characters of Boro rice

Interaction treatments	Plant height(cm)	Panicle length (cm)	No. of effective tiller hill^{-1}	No. of non–effective tiller hill^{-1}
S_1T_0	52.74	19.02	4.67	4.67 bc
S_1T_1	72.85	22.43	31.67	10.00 ab
S_1T_2	68.68	22.57	31.00	9.33 ab
S_1T_3	67.47	22.13	19.67	9.67 ab
S_1T_4	65.60	22.08	23.00	6.00 abc
S_1T_5	67.83	22.22	20.67	8.67 ab
S_1T_6	68.48	21.63	19.67	7.67 abc
S_1T_7	67.63	21.24	25.67	10.67 a
S_1T_8	67.71	21.76	23.00	9.00 ab
S_2T_0	55.21	18.39	5.67	3.00 c
S_2T_1	64.35	20.82	22.67	6.33 ab
S_2T_2	65.43	21.62	21.67	5.00 bc
S_2T_3	66.91	21.53	15.67	5.67 abc
S_2T_4	64.78	21.70	18.67	6.33 abc
S_2T_5	67.83	21.93	17.00	5.33 bc
S_2T_6	72.35	23.00	18.33	5.00 bc
S_2T_7	69.17	22.79	23.33	8.33 abc
S_2T_8	68.17	22.13	23.33	7.33 abc
SE(±)	**NS**	**NS**	**NS**	**1.49**

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

S_1: Red soil of Bhatgaon, Bhaluka, Mymensingh and S_2: Red soil of Goari, Bhaluka, Mymensingh

T_0: Control
T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (Recommended dose of chemical fertilizer)
T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime kg^{-1} soil
T_3: 50% NPKS + 5 ton cowdung ha^{-1}
T_4: 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil
T_5: 50% NPKS + 5 ton compost ha^{-1}
T_6: 50% NPKS + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil
T_7: 50% NPKS + 3.5 ton poultry manure ha^{-1} and
T_8: 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil

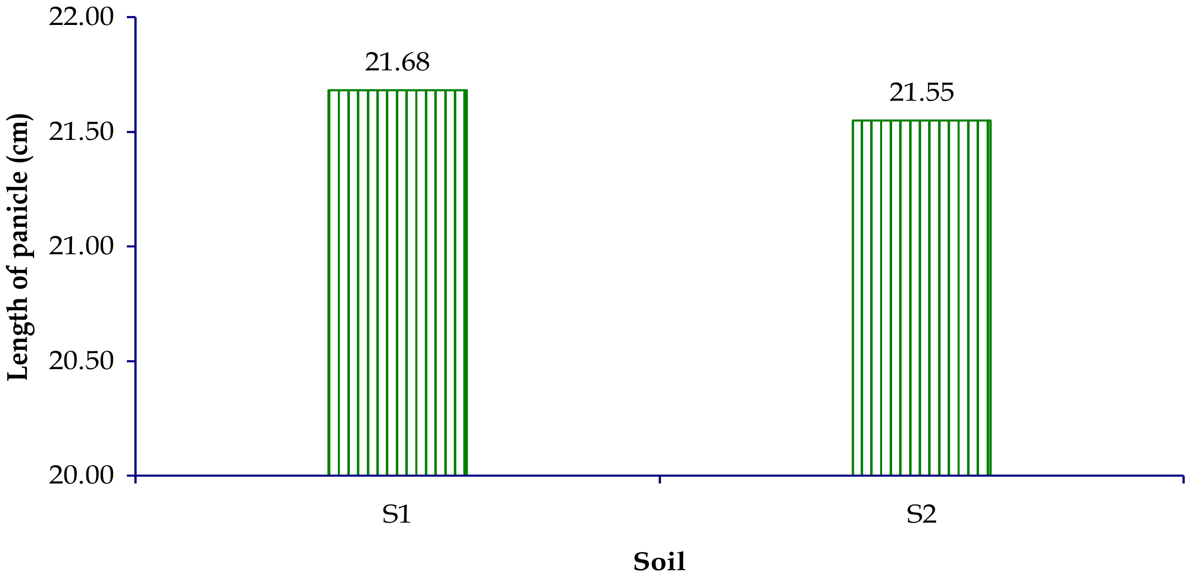
Table 4.4 Contd. Effect of acidic red soil and different types of fertilizer on yield contributing characters and yield of Boro rice

Interaction treatments	No. of filled grains panicle^{-1}	1000 grain weight (g)	No. of unfilled grains panicle^{-1}	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})
S_1T_0	30.56	16.69e	32.11	2.67	7.33
S_1T_1	70.93	19.70cd	25.73	46.33	83.33
S_1T_2	73.57	19.93cd	22.97	49.00	65.33
S_1T_3	72.27	22.40a	22.73	36.00	47.33
S_1T_4	70.03	19.92cd	25.47	32.67	50.67
S_1T_5	67.40	20.08cd	26.50	28.67	58.00
S_1T_6	70.80	20.43bcd	22.40	38.00	48.00
S_1T_7	72.20	19.18cd	22.00	38.67	57.33
S_1T_8	68.53	20.07cd	23.37	44.33	72.00
S_2T_0	33.72	15.66e	26.37	5.33	8.00
S_2T_1	60.20	18.50d	19.10	34.00	58.67
S_2T_2	63.50	19.20cd	21.33	37.33	49.33
S_2T_3	80.87	20.10cd	19.17	28.67	36.00
S_2T_4	57.53	22.04ab	25.77	28.67	46.00
S_2T_5	68.43	22.33ab	20.30	32.00	34.67
S_2T_6	78.87	20.98abc	21.77	35.67	41.33
S_2T_7	61.03	18.82d	24.73	39.33	61.33
S_2T_8	59.67	21.06abc	25.30	33.67	62.67
SE(±)	**NS**	**0.39**	**NS**	**NS**	**NS**

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

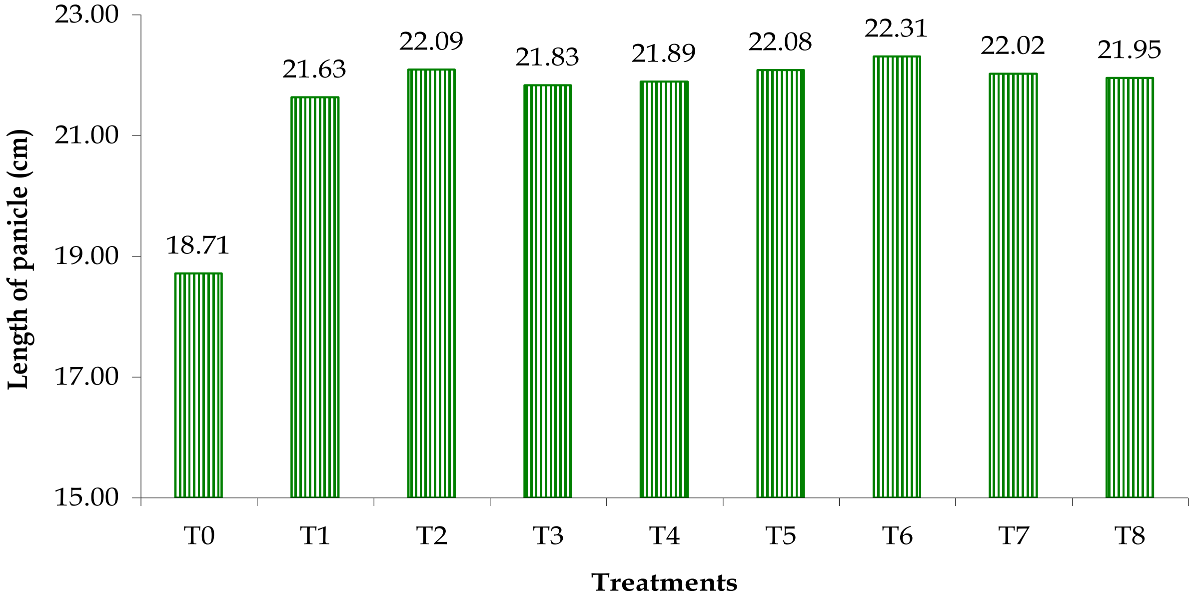
S_1: Red soil of Bhatgaon, Bhaluka, Mymensingh and S_2: Red soil of Goari, Bhaluka, Mymensingh

T_0: Control
T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (Recommended dose of chemical fertilizer)
T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime kg^{-1} soil
T_3: 50% NPKS + 5 ton cowdung ha^{-1}
T_4: 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil
T_5: 50% NPKS + 5 ton compost ha^{-1}
T_6: 50% NPKS + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil
T_7: 50% NPKS + 3.5 ton poultry manure ha^{-1} and
T_8: 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil



S_1: Red soil of Bhatgaon, Bhaluka, Mymensingh and S_2: Red soil of Goari, Bhaluka, Mymensingh

Fig. 4.5 Effect of regional acidic soil on length of panicle of *Boro* rice at harvest



T_0: Control
T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (Recommended dose of chemical fertilizer)
T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime kg^{-1} soil
T_3: 50% NPKS + 5 ton cowdung ha^{-1}
T_4: 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil
T_5: 50% NPKS + 5 ton compost ha^{-1}
T_6: 50% NPKS + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil
T_7: 50% NPKS + 3.5 ton poultry manure ha^{-1} and
T_8: 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil

Fig. 4.6 Effect of different types of fertilizers on length of panicle of *Boro* rice at harvest

Effect of different types of fertilizers

However, length of panicle was significantly influenced by the effect of different organic–inorganic based fertilizer but all the treatments produced statistically same length of panicle except control or without fertilizer treatment (Fig. 4.6). As a result, the longest panicle (22.31 cm) was obtained from the treatment T_6 having 50% RDCF along with 5 ton compost ha^{-1} and 2 ton lime ha^{-1} and it was statistically identical to T_1, T_2, T_3, T_4, T_5, T_7 and T_8 (21.63, 22.09, 21.83, 21.89,22.08, 22.02 and 21.95 cm, respectively). As well as the without fertilizer or control (T_0) showed the lowest length of panicle (18.71 cm) which was statistically differed from other all treatments of the study (Fig. 4.6).

Interaction effects of regional acidic soil and different types of fertilizers

Length of panicle of the present study did not vary significant due to the interaction effect of regional acidic soil and organic–inorganic based fertilizer (table 4.4). This result revealed that all the treatments of the interaction were produced statistically identical or same length of panicle due to non significant variation. However, it was varied from 18.39 (S_2T_0: soil of Goari receiving no fertilizer) to 23.00 cm (S_2T_6: soil of Goari receiving of 50% RDCF along with 5.0 ton compost and 2 ton lime ha^{-1}).

4.2.5 Number of filled grains panicle^{-1}

Effect of regional acidic soil

However, filled grain panicle^{-1} varied from 66.25 (Bhatgaon) to 62.65 (Goari) due to the effect of regional acidic soil but this variation was not statistically different between them due to non significant variation (Table 4.2).

Effect of different types of fertilizers

Number of filled grains panicle^{-1} varied significantly due to the effect of organic–inorganic based fertilizer with an average ranges from 32.14 to 74.83 (Table 4.3). From the Table 4.3 it was also found that all the treatments (T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8) except T_0 (control or without fertilizer) produced statistically same number of filled–grains panicle^{-1} (65.57, 68.53, 76.57, 63.78, 67.92, 74.83, 66.62 and 64.10, respectively) where the ranges were $T_3>T_6>T_2>T_5>T_1>T_8>T_4$. As a result without fertilizer or control (T_0) treatment obtained the lowest number of filled grain panicle^{-1} (Table 4.3).

Interaction effects of regional acidic soil and different types of fertilizers

Number of filled grains panicle^{-1} was not significantly influenced due to the effect of interaction of regional acidic soil and organic–inorganic based fertilizer. However, it was varied from 30.56 (S_1T_0) to 80.00 (S_2T_3) but they were numerically similar due to non significant variation (Table 4.4).

4.2.6 Number of un–filled grains panicle^{-1}

Effect of regional acidic soil

Both the soil of Bhatgaon and Goari were produced statistically same number of unfilled grains panicle^{-1} (24.81 and 22.65, respectively) due to non significant variation.

Effect of different types of fertilizers

Un–filled grains panicle^{-1} differed significantly from 20.95 to 29.24 due to the effect of fertilizer treatments .Among the fertilizer treatments, the maximum number of unfilled grains panicle^{-1} was recorded from the control (T_0) treatment while the minimum number of unfilled grains panicle^{-1} was obtained from the treatment T_3 receiving of 50% NPKS along with 5.0 ton cowdung ha^{-1} (Table 4.3).

Interaction effects of regional acidic soil and different types of fertilizers

All the treatments of interaction between regional acidic soil and organic–inorganic based fertilizer produced numerically same number of unfilled–grains panicle^{-1} due to non significant variation. However, it was varied from 19.10 to 32.11 where lowest value was for the regional acidic soil of Goari receiving of RDCF of NPKSZn (S_2T_1) and the highest value was for the regional acidic soil of Bhatgaon having no fertilizer (S_1T_0) (Table 4.4).

4.2.7 1000–grain weight

Effect of regional acidic soil

The effect of regional acidic soil on 1000–grain weight was not statistically significant .As a result, both Bhatgaon and Goari soil produced statistically same (19.82 and 19.85 g, respectively) weight of 1000–grain (Fig. 4.7).

Effect of different types of fertilizers

Different types of fertilizer was significantly influenced the weight of 1000–grain weight in this study. However, the treatment T_3 (50% NPKSZn along with cowdung @ 5.0 ton ha^{-1}), T_4 (T_3+ 2 ton lime ha^{-1}) T_5 (50% NPKS + 5.0 ton compost ha^{-1}) and T_6 (T_5 + 1.0 g lime kg^{-1} soil or 2 ton lime ha^{-1}) produced statistically same weight of 1000–grain (21.25, 20.98, 21.21 and 20.71 g, respectively) but the treatment T_3 had more productive than that of other treatments. On the other hand, control treatment obtained the lowest weight of 1000–grain (16.18 g) which was statistically differed from other all treatments of the study (Table 4.3).

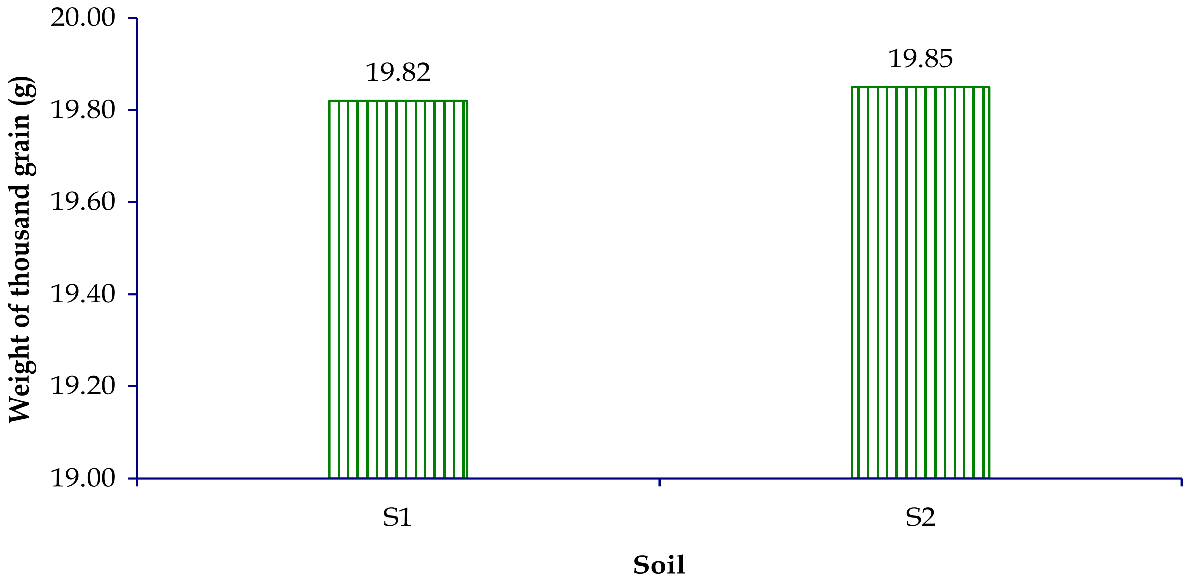
Interaction effects of regional acidic soil and different types of fertilizers

The effect of interaction between regional acidic soil and organic–inorganic based fertilizer found to be the insignificant variation in respect of 1000–grain weight. However, the regional acidic soil of Bhatgaon receiving of RDCF along with 5 ton cowdung ha^{-1} showed significantly the highest weight of 1000–grain (22.40 g) followed by the soil of Goari receiving of 50% RDCF along with 5.0 ton compost ha^{-1} (22.33 g) and the same soil receiving of 50% RDCF along with 5.0 ton cowdung ha^{-1} and 2 ton lime ha^{-1} (22.04 g). On the other hand, the soil of Goari also showed the lowest weight of 1000–grain (15.66 g) while it did not receive any fertilizer (S_2T_0) and it was also numerically similar (16.69 g) to the soil of Bhatgaon under no fertilizer application (S_1T_0) (Table 4.4).

4.2.8 Grain yield

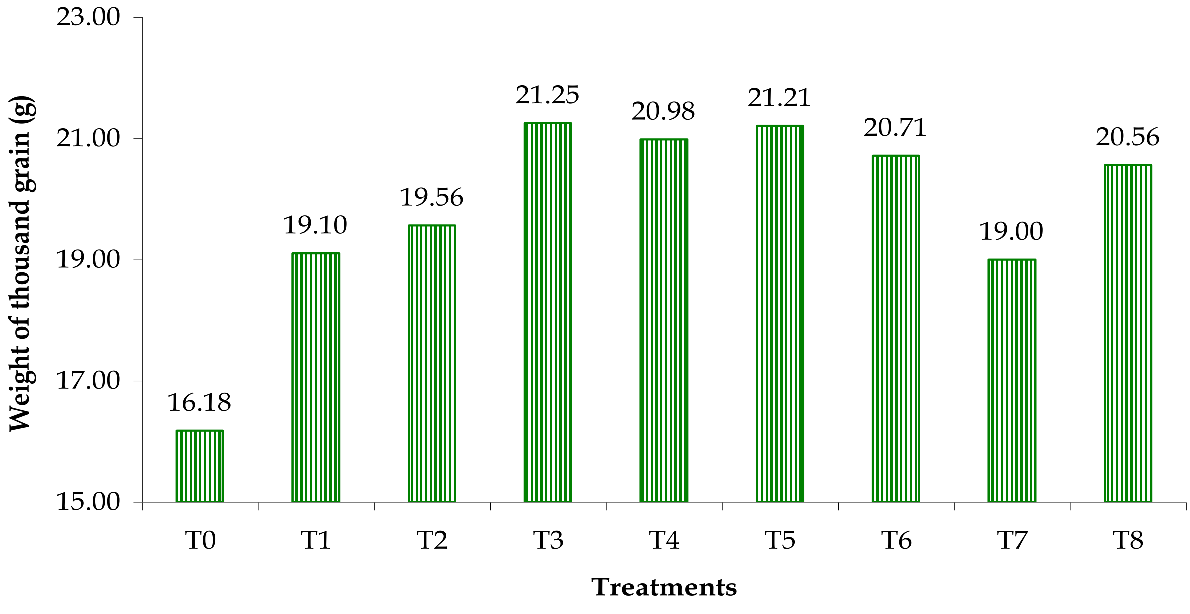
Effect of regional acidic soil

There was a significant difference among the regional acidic soil in respect of grain yield.



S_1: Red soil of Bhatgaon, Bhaluka, Mymensingh and S_2: Red soil of Goari, Bhaluka, Mymensingh

Fig. 4.7 Effect of regional acidic soil on 1000–grain weight of *Boro* rice at harvest



T_0: Control
T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (Recommended dose of chemical fertilizer)
T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime kg^{-1} soil
T_3: 50% NPKS + 5 ton cowdung ha^{-1}
T_4: 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil
T_5: 50% NPKS + 5 ton compost ha^{-1}
T_6: 50% NPKS + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil
T_7: 50% NPKS + 3.5 ton poultry manure ha^{-1} and
T_8: 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil

Fig. 4.8 Effect of different types of fertilizers on 1000–grain weight of *Boro* rice at harvest

Between the soil, the highest grain yield (35.15 g pot^{-1}) was produced from the regional acidic soil of Bhatgaon compared the soil of Goari (30.52 g pot^{-1}) (Table 4.2).

Effect of different types of fertilizers

A significant variation was found for the character of grain yield due to the effect of organic–inorganic based fertilizer (Table 4.3). Among the treatments, only RDCF chemical/inorganic fertilizer of $N_{150}P_{30}K_{70}S_{20}Zn_3$ (T_1) and 50% RDCF of NPKSZn along with lime 2 ton ha^{-1} (T_2) produced same grain yield of 41.67 g pot^{-1} while it was statistically close toT7(50% RDCF of NPKSZn + 3.5 ton poultry manure(39.00), (T_8 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil), t6 (50% RDCF + 5.0 ton compost ha^{-1} along with lime 2 ton $ha^{-1)}$. (36.83 g pot^{-1}). Similarly, control or without fertilizer recorded the lowest yield of grain (4.0 g pot^{-1}) which was statistically differed from other treatments (Table 4.3).

Interaction effects of regional acidic soil and different types of fertilizers

The grain yield of the present study varied from 2.67 to 49.00 g pot^{-1} where the highest grain yield was produced from the soil of Bhatgaon treated by 50% RDCF along with only lime 2 ton ha^{-1} (S_1T_2) and the lowest was obtained from the same soil while it did not received any fertilizer (S_1T_0). However, Table 4.4 showed variation in grain yield but they were not statistically differed among the interaction treatments due to non significant variation (Table 4.4).

4.2.9 Straw yield

Effect of regional acidic soil

Statistical analysis of variance data showed significant difference between the regional acidic soil regarding straw yield (Table 4.2). The regional acidic soil of Bhatgaon recorded the highest yield of straw (54.37 g pot^{-1}) than that of the soil of Goari (44.22 g pot^{-1}).

Effect of different types of fertilizers

Straw yield was significantly influenced by the Effect of different types of fertilizers where it was varied from 7.67 to 71.00 g pot^{-1} (Table 4.3). The highest yield of straw was produced from the application of only inorganic/chemical fertilizer of $N_{150}P_{30}K_{70}S_{20}Zn_3$ and it was statistically close to the application of 50% $N_{150}P_{30}K_{70}S_{20}Zn_3$ + 3.5 ton poultry manure ha^{-1} along with (T_8) and without lime (T_7) (67.33 and 59.33 g pot^{-1}, respectively). On the other hand, without fertilizer (T_0) showed the lowest yield of straw (Table 4.3).

Interaction effects of acidic soil and different types of fertilizers

The yield of straw of the present study was also showed non significant difference among the interaction effects between studied regional acidic soil and organic– inorganic based fertilizer (Table 4.4). However, it varied from 7.33 (S_1T_0: the soil of Bhatgaon with no fertilizer) to 83.33 g pot^{-1} (S_1T_1: Soil of Bhatgaon having RDCF of $N_{150}P_{30}K_{70}S_{20}Zn_3$) but it was statistically identical due to non significant variation (Table 4.4).

4.3 Responses of acidic soil and organic–inorganic based fertilizer on grain nutrient contents

Effect of regional acidic soil

The P, K and S content of the Boro rice grain were analyzed in this study where P, K and S contents were significantly affected by the effect of soil (Table 4.5) This result revealed that the soil of Bhatgaon had more nutrients than that of the soil of Goari as well as the highest N, P, K and S content (1.316, 0.079, 0.524 and 0.119%, respectively) was produced in rice grain of Bhatgaon than that of the rice grain of Goari (1.246, 0.038, 0.407 and 0.115%, respectively (Table 4.5).

Effect of different types of fertilizers

Effect of different types of fertilizer significantly influenced the N, P, K and S content of boro rice grain while 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil (T_8) was the best treatment for getting the higher nutrient content in boro rice grain(Table 4.6).

Table 4.5 Effects of acidic red soil types on N, P, K and S content in Boro rice grain

Soil	N (%)	P (%)	K (%)	S (%)
S_1	1.316 a	0.079 a	0.524 a	0.119 a
S_2	1.246 b	0.038 b	0.407 b	0.115 b
SE(±)	**0.0605**	**0.0055**	**0.0247**	**0.0055**

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

S_1: Red soil of Bhatgaon, Bhaluka, Mymensingh and S_2: Red soil of Goari, Bhaluka, Mymensingh

Table 4.6 Effects of different types of fertilizers on N, P, K and S content in Boro rice grain

Fertilize treatments	N (%)	P (%)	K (%)	S (%)
T_0	1.055 d	0.033 d	0.113 b	0.058 f
T_1	0.695 e	0.056 bc	0.518 a	0.117 d
T_2	1.323 bc	0.054 c	0.478 a	0.098 e
T_3	1.357 b	0.068 ab	0.513 a	0.098 e
T_4	1.262 bc	0.061 abc	0.513 a	0.141 b
T_5	1.403 b	0.064 abc	0.497 a	0.131 bc
T_6	1.328 bc	0.062 abc	0.505 a	0.123 cd
T_7	1.203 c	0.058 abc	0.513 a	0.102 e
T_8	1.902 a	0.070 a	0.538 a	0.169 a
SE(±)	0.128	0.0117	0.0524	0.0117

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

T_0: Control
T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (Recommended dose of chemical fertilizer)
T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime kg^{-1} soil
T_3: 50% NPKSZn + 5 ton cowdung ha^{-1}
T_4: 50% NPKSZn + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil
T_5: 50% NPKSZn + 5 ton compost ha^{-1}
T_6: 50% NPKSZn + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil
T_7: 50% NPKSZn + 3.5 ton poultry manure ha^{-1} and
T_8: 50% NPKSZn + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil

In the present study, 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} treated soil obtained the highest N content (1.902%) while only NPKSZn (RDCF) recorded the lowest N content (0.695%) in rice grain. In case of P content, the highest P content (0.07%) was recorded from rice grain which were treated by 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil (T_8) closely followed by T_3 (50% NPKS + 5 ton cowdung ha^{-1}), T_4 (50% NPKSZn + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil), T_5 (50% NPKSZn + 5 ton compost ha^{-1}), T_6 (50% NPKSZn + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil), T_7

(50% NPKSZn + 3.5 ton poultry manure ha^{-1} and), treated soil (0.068%). On the other hand, with out fertilizer treated soil recorded the lowest P content (0.033%) in grain. Similarly, K content varied from 0.113 (control) to 0.538% (50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil). However, 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil (T_8) treated soil showed the highest grain K content (0.538%) but rest of the treatment except control produced statistically same K content while control treatment showed the lowest K content. In contrast, 50% NPKS + 3.5 ton poultry manure ha^{-1} + 1.0 g lime kg^{-1} soil treated soil further produced the highest S content (0.169%) followed by 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil (T_4) treated soil (0.141%) while without treated soil obtained the lowest S content (0.058%) in this study (Table 4.6). The results indicate that grain nutrient accumulation increased by application of manure and lime in combination with fertilizer.

Table 4.7 Effect of acidic red soil types and organic–inorganic fertilizers on N,P,K and S content of Boro rice

Interaction treatments	N (%)	P (%)	K (%)	S (%)
S_1T_0	0.560 g	0.049 fgh	0.075 d	0.067 f
S_1T_1	0.820 ef	0.085 abc	0.617 a	0.120 de
S_1T_2	1.680 cd	0.072 cde	0.553 a	0.120 de
S_1T_3	1.853 bc	0.103 a	0.580 a	0.120 de
S_1T_4	1.960 b	0.091 ab	0.567 a	0.127 de
S_1T_5	1.820 bc	0.080 bcd	0.560 a	0.133 cd
S_1T_6	0.760 f	0.063 def	0.567 a	0.110 e
S_1T_7	0.857 ef	0.078 bcd	0.587 a	0.120 de
S_1T_8	1.537 d	0.087 abc	0.613 a	0.150 bc
S_2T_0	1.550 d	0.017 k	0.150 c	0.050 g
S_2T_1	0.570 g	0.027 jk	0.420 b	0.114 e
S_2T_2	0.967 e	0.037 ghij	0.403 b	0.076 f
S_2T_3	0.860 ef	0.033 hijk	0.447 b	0.075 f
S_2T_4	0.563 g	0.030 ijk	0.460 b	0.156 b
S_2T_5	0.987 e	0.047 fghi	0.433 b	0.129 de
S_2T_6	1.897 b	0.060 ef	0.443 b	0.136 cd
S_2T_7	1.550 d	0.037 ghij	0.440 b	0.084 f
S_2T_8	1.967 b	0.053 fg	0.463 b	0.187 a
SE(±)	0.181	0.0166	0.0741	0.0166

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT

S_1: Red soil of Bhatgaon, Bhaluka, Mymensingh and S_2: Red soil of Goari, Bhaluka, Mymensingh

T_0: Control
T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (Recommended dose of chemical fertilizer)
T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime kg^{-1} soil
T_3: 50% NPKSZn + 5 ton cowdung ha^{-1}
T_4: 50% NPKSZn + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil
T_5: 50% NPKSZn + 5 ton compost ha^{-1}
T_6: 50% NPKSZn + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil
T_7: 50% NPKSZn + 3.5 ton poultry manure ha^{-1} and
T_8: 50% NPKSZn + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil

Interaction effects of regional acidic soil and different types of fertilizers

Effect of acidic soils and different types of fertilizer showed significant variation on N, P, K and S content rice grain (Table 4.7). The data on N, P, K ans S content have been shown in Table 4.7 where it was found that the soil of Goari treated by 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil recorded the highest N content (1.967%) followed by the soil of Bhatgaon treated by 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil (1.960%) while it was the lowest in without treated soil of Bhatgaon (0.560%) and it was numerically same (0.570%) to the soil of Goari treated by NPKSZn. The soil of Bhatgaon treated by 50% NPKS + 5 ton cowdung ha^{-1} (S_1T_3) recorded the highest P (0.103%) which was closely followed by the interaction treatment of the same soil treated by 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil (S_1T_4) (0.091%), S_1T_8 (0.087) while without treated soil of Goari (S_2T_0) took the lowest P content in rice grain (0.017). However, the soil of Bhatgaon treated by RDCF of NPKSZn (S_1T_1) showed the highest K content (0.617%) but it was statistically similar among other whole fertilizer treated soil of Bhatgaon except control (S_1T_0) while whole fertilizer treated soil of Goari also showed lower and statistically identical grain K content in this study except S_2T_0. On the other hand, without fertilizer treated soil of Bhatgaon (S_2T_0) obtained the lowest K content (0.075%) followed by the whiteout treated soil of Goari (0.150%). In case of S content, 50% NPKS + 3.5 ton poultry manure ha^{-1}+ 1.0 g lime kg^{-1} soil treated soil of Goari (S_2T_8) found to be the highest S content in rice grain in this study while without fertilizer treated grain produced the lowest S content (0.050%) (Table 4.7).

4.4 Correlation and regression studies

4.4.1 Grain yield and pore-water P concentrations

The relationship between grain yield and pore-water P concentrations at 30 DAT has been found out. The correlation co-efficient (r^2=0.4619) was found positive significant correlation. The line of regression of Y (grain yield) on X (pore-water P concentration) having equation Y= 7.4275Ln(X) + 49.533 is shown in Fig. 4.9. The positive slope indicates that the grain yield and pore-water P concentration are directly correlated i.e., increase in pore water P concentration in an increase in grain yield of rice.

4.4.2 Grain yield and plant height

The relationship between grain yield and plant height has been found out. The correlation co-efficient (r^2=0.8044) was found positive significant correlation. The line of regression of Y (grain yield) on X (plant height) having equation Y= 132.9Lm(x)-524.17 is shown in Fig. 4.10. The positive slope indicates that the grain yield and plant height are directly correlated i.e., increase in plant height in an increase in grain yield of rice.

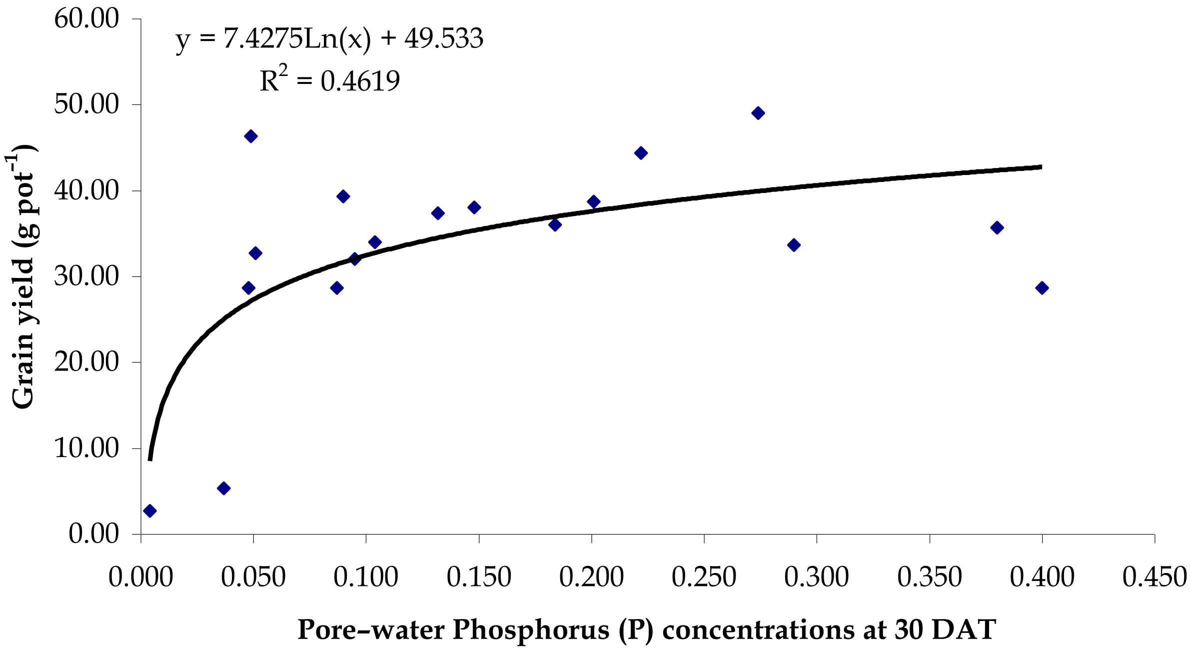


Fig. 4.9 Relationship between pore-water P concentration and grain yield of rice

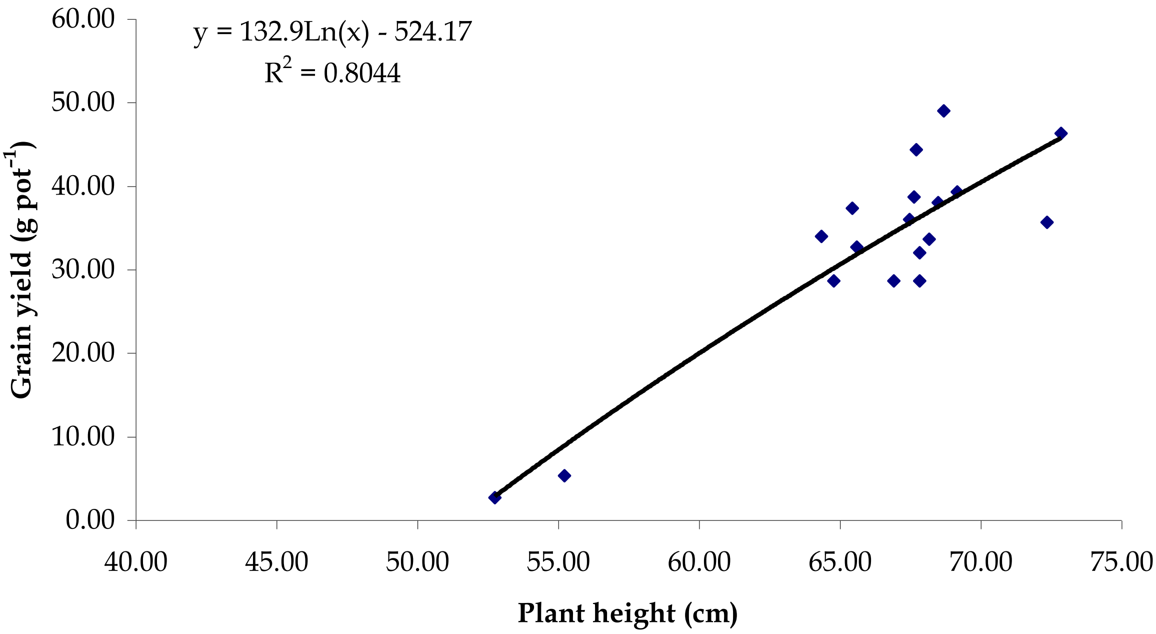


Fig. 4.10 Relationship between grain yield and plant height of rice

4.4.3 Grain yield and number of effective tillers hill^{-1}

The relationship between grain yield and number of effective tillers hill^{-1} has been found out in fig. 4.11 and the correlation co–efficient (r^2=0.9097) value showed positive significant correlation between them. The line of regression of Y (grain yield) on X (number of effective tillers hill^{-1}) having equation Y= 22.765Ln(x)–33.673 is shown in Fig. 4.11. From the 4.11, it was found the slope represent positive correlation between grain yield and number of effective tillers hill^{-1}. These results indicated that the both characters are directly correlated i.e. increase in number of effective tillers hill^{-1} in an increase in grain yield of rice.

4.4.4 Grain yield and number of filled grains panicle^{-1}

From the line of regression Fig. 4.12 it was found that there was positive significant correlation between the number of filled grains panicle^{-1} and grain yield. The correlation co–efficient (r^2=0.7245) value proved positive significant correlation between them. The line of regression of Y (grain yield) on X (filled grains panicle^{-1}) having equation Y= 39.029Ln(x)–128.69 is shown in Fig. 4.12. From the 4.12, it was found the slope represent positive correlation between grain yield and number of filled grains. These results indicated that the both characters are directly correlated i.e. increase in number of filled grains panicle-1 in an increase in grain yield of rice.

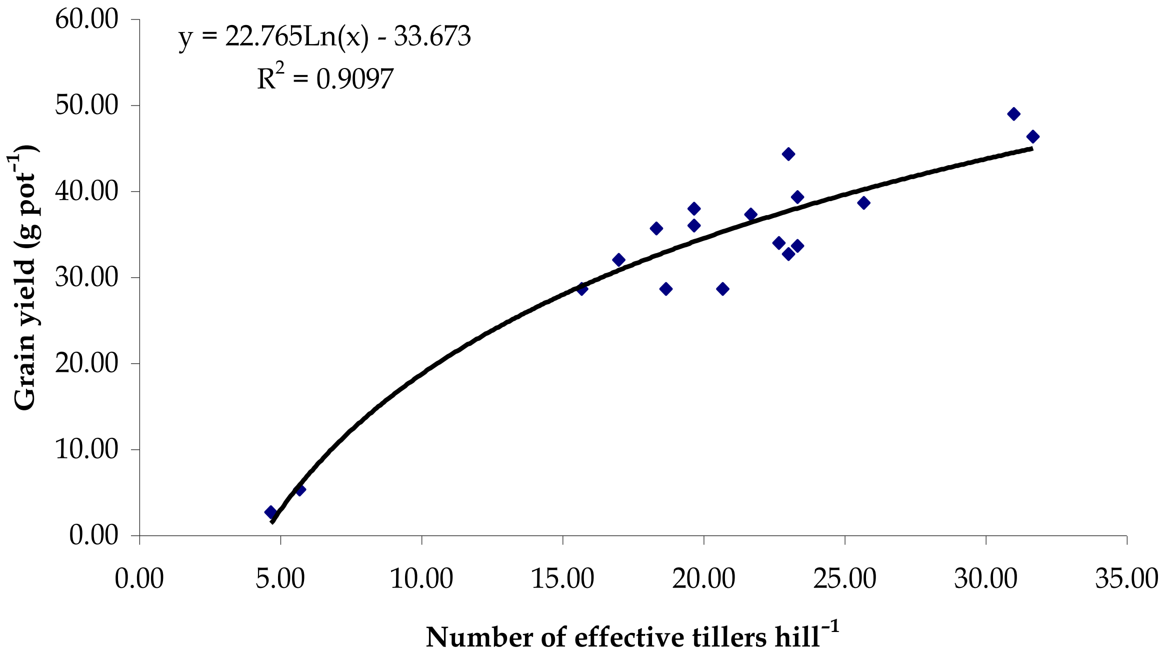


Fig. 4.11 Relationship between number of effective tillers hill^{-1} and grain yield of rice

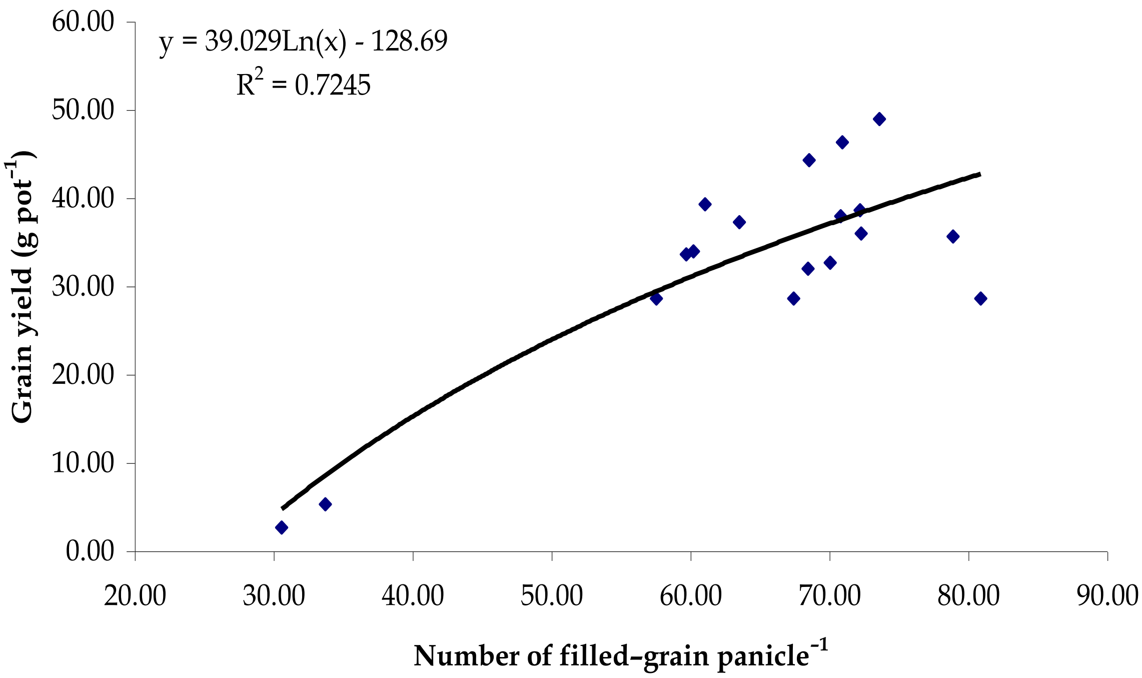


Fig. 4.12 Relationship between dry number of filled grains panicle^{-1} and grain yield of rice

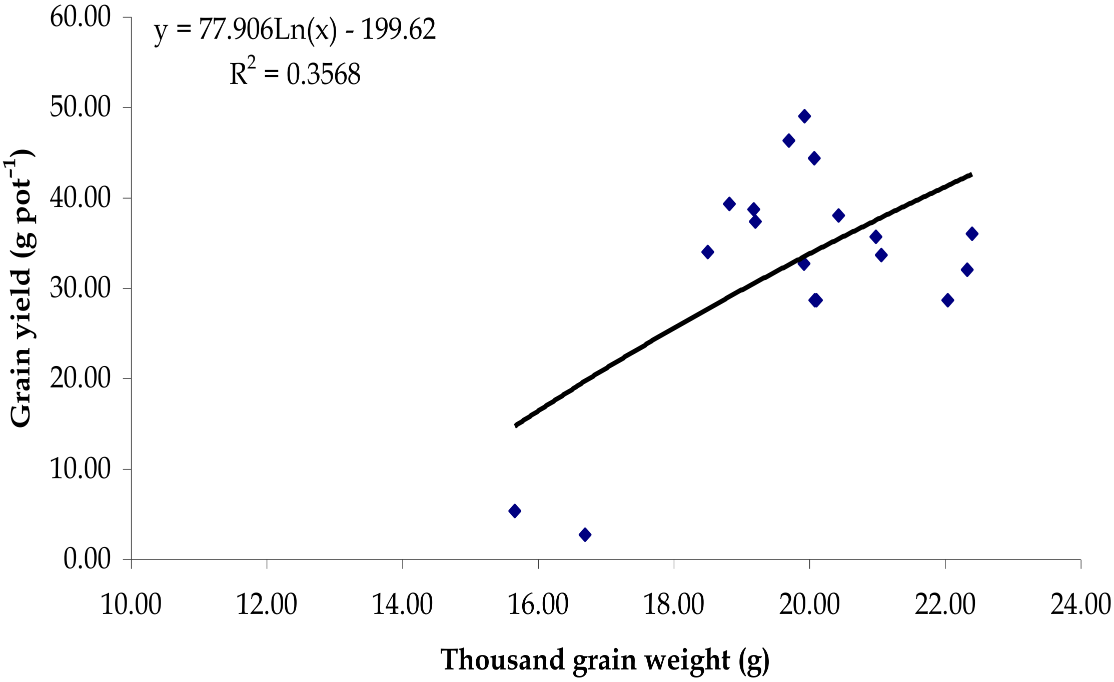


Fig. 4.13 Relationship between thousand grain weight and grain yield of rice

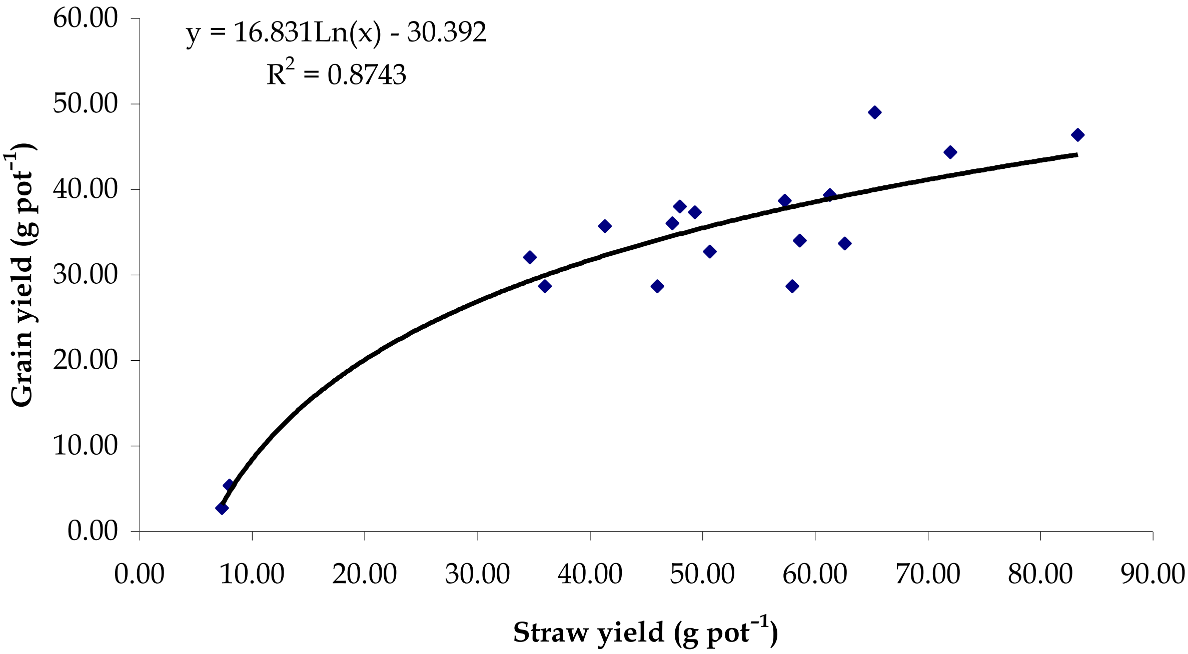


Fig. 4.14 Relationship between straw and grain yield of rice

4.4.5 Thousand grain weight and grain yield

The relationship between thousand grain weight and grain yield has been presented in Fig. 4.13. The correlation co–efficient value of them are r^2=0.3568. The line of regression of Y (Grain yield) on X (thousand grain weight) having equation Y= 77.906Ln(x)–199.62 is shown in Fig. 4.13. The positive slope indicates that the grain yield and thousand grain weight are directly correlated i.e., increase in thousand grain weight in an increase in grain yield of rice.

4.4.6 Straw yield and grain yield

The relationship between straw yield and grain yield has been found out. The correlation co–efficient biological yield and grain yield (r^2=0.8743) was found significant. The line of regression of Y (grain yield) on X (straw yield) having equation Y= 16.831Ln(x)–30.392 is shown in Fig. 4.14. The positive slope indicates that the straw yield and grain yield are directly correlated i.e., increase in straw yield in an increase in grain yield of rice.

CHAPTER 5
DISCUSSION

The present study was conducted to identify the most optimum levels of mixed organic manures(s) and inorganic fertilizer along with or without lime for getting the more production of rice by enhancing the soil fertility status under acidic red paddy soil through organic amendments. It will also enhance the farmer knowledge for extending the rice production under the AEZ–28 and developed sustainable agriculture. For aiming this point, nine different fertilizer and manure treatments along with or without lime were used for evaluating the productivity of rice and pore–water P concentration along with the status of soil fertility of two acidic red soil. Considering the aim of the study, the overall discussion on the result with some interpretations are mentioned below:

Pore water: From the observing result of pore–water P concentrations, it was found that the pore–water P concentrations were decreased in all the treatments with increasing time. The effect of different types of fertilizer and manure had highly significant on pore–water P concentration while it was the highest in the those treatment where fertilizer, manure and lime were applied together. This was found might be due their conjugal application increased the macro and micro nutrient to the soil which ultimately enhance the P concentration in soil pore–water.

Plant height: Plant height is a vertical spatial distribution of plant. It is one of the most efficient trait for greater yield of rice which was also directly related to straw yield incase of the tallest plant produce the higher yield of straw. Plant height was statistically significant among the different types of fertilizer where 50% RDCF along with compost and lime in acidic soil showed comparatively better result than that of cowdung and poultry manure. The soil used in this study was acidic containing low pH along with deficient in N, P and other chemical properties which can reduce the plant growth of any crops. But lime application can increased soil pH and utilize ions sush as Ca2+, Mg2+, K+,S etc. in soil and resulting the proper growth. The same observation was also obtained by Kisinyo *et al.* (2005) who also found the application of lime had more capable to creates favourable conditions for plant growth by enhancing soil pH and utilizing the soil ions along with soil macro and micro nutrient. Similarly, Fageria and Baligar (2008) also reported that the application of lime at an appropriate rate brings several chemical and biological changes in the soils, which are beneficial or helpful in improving crop growth and yields on acid soils. Besides, this was also found which might be due to the effect of compost fertilizer along with lime were more effective on stimulating the plant growth and various physiological processes including cell division and cell elongation of the plant. These findings are in agreement with that of Gitari *et al*. (2015) who also found that 12.5 Mg ha^{-1} of lime and 10 Mg ha^{-1} of manure in acidic soil had the best for maize plant height in present of NPK. The findings of the present study was also similar to the study of Whalen *et al*. (2002). They also reported that the lime and manure application (4 g $CaCO_3$ kg^{-1} and 40 g manure kg^{-1}) produced more vegetative growth of wheat.

Number of effective tillers $hill^{-1}$: The effective tillers i.e. ear bearing tillers is an important parameter which affect the yield of rice. A rice plant may produce a number of tillers during its early growth stages but not all of them become effective i.e., they do not bear panicles. So, this character is directly related to yield of rice. Obtained result of the present study revealed significant variation among the different types of fertilizer and manure along with lime regarding productive tillers production in acid soil while Pandey *et al*. (2014); Naing *et al*. (2010); Yung–Yu (2005) were also found significant variation for effective tillers due to fertilizer (inorganic) and manure (organic) lime application in acidic soil. In this study, only RDCF or RDCF along with lime was the adequate level for producing the more productive tillers while organic manure were absent which indicated that chemical fertilizer along with lime can be enhance the soil pH of acid soil and also had more capability to utilize the ions along with macro and micro nutrient and make more favorable growth condition of plant. Thus the rice plant producing more effective tillers hill^{-1}. Besides, plant can collect sufficient nutrient from the soil and produce more effective tillers. These results are also in line with Rahman *et al*. (2002) who also found that lime application may influence nutrient levels in the acidic alluvial soils of Bangladesh during rice–wheat cropping system while recommended dose of chemical fertilizer were applied together. So, this findings was fully supported the present findings in this study. This findings of Fageria and Baligar (2008) also supported the present findings.

Number of non effective tillers hill^{-1}: However, non–effective tiller is a yield contributing characters but it has negative effect on grain yield incase non–effective tiller means unfilled panicle as well as unfilled grains which are directly related to reduce grain yield. The variation in production of non effective tillers was found due to the variation in type of different types of fertilizer and manure in this study while poultry manure along with 50% RDCF produced highest number of non–effective tillers compared control or only RDCF which might be due to the studied soil did not utilize proper macro nutrient in acidic soil which can be supply the sufficient nutrient to the soil while plant can be grown perfectly. However, may be there were no researcher who found more non–effective tillers in combined application of organic and inorganic fertilizer compared control but many researchers found significant variation in non–effective tillers due to the effect of organic and inorganic based fertilizer and manure application such as Malika *et al*. (2015); Gitari *et al*. (2015); Pandey *et al*. (2014); Naing *et al*. (2010) and more other scientists of the home and abroad found significant variation for non–effective tillers hill^{-1}.

Panicle length: Length of panicle is the most important characters for greater production of rice in case of the longest panicle bears more grains which ultimately enhanced the final yield. The length of panicle of the present study had statistically signficiant due to the effect of organic–inorganic based fertilizer with or whiteout lime. Present study showed that the 50% NPK and compost showed longest panicle while lime was applied together. This was found might be due to the application of lime utilize the soil pH of the studied acidic soil and compost manure supply the more macro and micro nutrient to the soil which ultimately enhance the higher growth of plant during reproductive stage and found to be the longest panicle. Such the same findings of the present study were also found by Sukristiyonubowo *et al*. (2013) who also found that the combined addition of organic matter (straw compost), lime and mineral fertilizer improve the grain yield of rice by enhancing the length of panicle. This result was also may be more or less similar with the findings of Singh *et al*. (2011). In the study of Fageria and Baligar (2008) also found similar findings with the present study.

Number of filled grains panicle^{-1}: Filled grain are directly related to grain yield which might be due to the more filled grains confirm the greater production. Filled grains panicle^{-1} of the present study was significant due to the application of different types of fertilizer and manure with or without lime. In this study, cowdung manure along with 50% NPKS were more efficient for the production of filled grains than that of individual or combined application of compost, poultry manure and lime application. This was found might be due to the cowdung manure in present of 50% NPKS had more capable for utilize the soil nutrients and other growth condition as favorable for filled grains production of *Boro* rice grain. Similarly, Pandey *et al.* (2014) found that the NPK fertilizer conjunction with cowdung resulted higher number of filled grains followed by poultry manure. Therefore, this result are in agreement with the findings of the present study and this findings was fully supported the findings of Naing *et al*. (2010) who found that FYM cattle manure and inorganic fertilizers increased grain panicle^{-1} which enhanced the final grain yield.

Number of un–filled grains panicle^{-1}: The results of the present study revealed significant variation in un–filled grains production due to different types of fertilizer and manure while cowdung manure along with 50% NPKS produced more unfilled grains panicle^{-1} compared other treatments of the study along with control in this study. However, this treatment produced more filled grains also but it was also showed more unfilled grains which might be due to the total grains were also higher in this treatments. Such the same findings may be dissimilar with the findings of the whole researchers (such as Gitari *et al*., 2015; Sardar *et al*., 2015; Hossain, 2013; Sukristiyonubowo *et al*., 2013; Arif *et al*., 2014; Meena and Singh, 2012; Fageria and Knuppto, 2014; Kamruzzaman *et al.,* 2013; Rahman *et al*., 2013 where all of them are conducted their experiment with organic and inorganic based fertilizer along with or without lime in acidic soil) of the home and abroad which might be due to none of them are found more un–filled grain in organic and inorganic mixed use of fertilizer compared untreated or control.

Thousand–grain weight: Thousand grains weight represents grain size and it was ultimately related to the grain yield. In the present study, it was found that the application of cowdung along with 50% NPKS were highly effective to produce more filled grain which ultimately resulted the larger grain as well as the heaviest grain. Besides, cowdung manure may supply the proper nutrient to the soil which ultimately produced the heaviest grain also. Naing *et al*. (2010) also reported that the effect of organic and inorganic fertilizers had highly significant on 1000 grain weight while FYM cattle manure and inorganic fertilizers increased the weight of 1000 grain by utilizing the soil nutrients properties in acid soil.

Grain yield: This result showed that the lime application along with 50% NPKS had more productive organic–inorganic based mixed use of fertilizer than that of other fertilizer which might be due to the more effective tillers and longer panicle were obtained. Similar findings was also found by Asrat *et al*. (2014) who also found significant variation on grain yield while the combined application of 5 t manure and 2.2 t ha^{-1} lime increased grain yield by 279%. Besides, the soil used in this study was acidic (low pH), deficient in N and P which was too low to sustain high crop production. Kisinyo *et al.* (2005) also found same result with the present study who also reported that the application of liming creates favourable conditions for growth of living organisms, it improves plant growth and N_2 fixation in tree legumes and confirmed the greater production of legumes. Stephen *et al*. (2011) also reported that the application of liming in acidic soils enhance the activities of beneficial microbes in the rhizosphere and hence improve root growth by the fixation of atmospheric nitrogen because neutral pH allows more optimal conditions for free-living N fixation which enhanced the crop production. Application of lime at an appropriate rate brings several chemical and biological changes in the soils, which are beneficial or helpful in improving crop yields on acid soils are also reported by Fageria and Baligar (2008). Such the same effect of liming were also occurred in this study which ultimately resulted the greater production of rice.

Straw yield: However, RDCF of inorganic fertilizer produced more straw yield in this study but lime application also produced statistically same production of straw which might be due to the application of lime or RDCF (NPKSZn) had more effective to produced the tallest plant, more tillers and longest panicle which ultimately enhanced the final straw yield. Similarly, Asrat *et al*. (2014) also found significant variation on straw yield where 5 t manure and 2.2 t ha^{-1} lime showed better result among the whole yield attributes which resulted the highest straw yield which was 187% more than next one. Besides, lime application had more effective for proper growth of plant in this study under acid soil and produced tallest plant which ultimately maximizing the straw yield. Such the same observation were also obtained by Whalen *et al*. (2002) the straw yield was highly influenced by the application of lime in acid soil. This result was also supported the findings of Sukristiyonubowo *et al*. (2013); Fageria and Baligar (2008).

Correlation and regression studies: In the present study, correlation study were done where all the relationship between grain yield and other growth and yield attributing characters were significant and their slope showed positive effect among them. All the line of regression of Y was grain yield and X was other characters where their positive slope indicated that the grain yield increased significantly with the increasing selected relationship other characters. This result indicated that organic and inorganic based fertilizer along with lime had more influential effect on grain. Similarly, Gitari *et al*. (2015) also found that linear correlation analyses showed that the treatment of lime and manure had the best for maize yield along with highest root length, plant height and dry biomass weight obtained. Asrat *et al*. (2014) also examine the effects of integrated use of lime, manure and mineral P fertilizer on acid soils where combined application of 5 t manure and 2.2 t ha^{-1} lime was strong positive correlation and found to be economical feasible to improve wheat yield.

CHAPTER 6

SUMMARY

The present experiment was conducted at the Net House of the Department of Soil Science, SAU, Dhaka during October, 2013 to May 2014 to evaluate the growth, yield, yield attributes and integrated nutrient management as influenced by the singly or their interaction effect of regional acidic soil and organic–inorganic based fertilizer. Two acidic red soil of tow villages at Bhaluka Upazilla *viz.* S_1: Bhatgaon and S_2: Goari and nine (09) treatments of organic–inorganic based fertilizer such as T_0: control, T_1: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF: Recommended dose of chemical fertilizer), T_2: $N_{150}P_{30}K_{70}S_{20}Zn_3$ (RDCF) + 1.0 g lime kg^{-1} soil, T_3: 50% NPKS + 5 ton cowdung ha^{-1}, T_4: 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil, T_5: 50% NPKS + 5 ton compost ha^{-1}, T_6: 50% NPKS + 5 ton compost ha^{-1} + 1.0 g lime kg^{-1} soil, T_7: 50% NPKS + 3.5 ton poultry manure ha^{-1} and T_8: 50% NPKS + 3.5 ton poultry manure ha^{-1} + 1.0 g lime kg^{-1} soil were used for the present study as level factor A and B, respectively. The two factors experiment was laid out in Randomized Completely Block Design (RCBD) method with three replications and analysis was done by the MSTAT–C package program whereas means were adjudged by DMRT at 5% level of probability. The size of pot was 18x16 inches where one hill were in each pot. In case of the effect of regional acidic soil, pore–water P concentration, number of effective and non–effective tillers hill^{-1}, grain and straw yield were statistically significant where the soil of Bhatgoan showed the highest pore–water P concentration at 60 DAT (0.016 ppm), highest number of effective and non–effective tillers hill^{-1} (22.11 and 8.41, respectively), and highest yield of grain and straw (35.15 and 54.37 g pot^{-1}, respectively) compared the soil of Goari while soil of Goari showed the highest pore–water concentration at 30 DAT (0.180 ppm) than that of the soil of Bhatgoan. Among other characters of the study such as plant height, panicle length, number of filled and un–filled grains panicle^{-1} and 1000–grain weight of numerically more or less same between (the soil of

Bhatgaon and Goari) the regional acidic soil due to non signifciant difference. The rice grain of Bhatgaon soil also contain more N, P, K and S content (1.316, 0.079, 0.524 and 0.119%, respectively) than Goari (1.246, 0.038, 0.407 and 0.115%, respectively).

In case of the effect of different types of fertilizers, all the characters were influenced significantly while treatment T_6 (50% NPKS + 5 ton compost ha^{-1} + 1.0 g lime ka^{-1} soil) showed the highest pore water concentrations (0.264 and 0.024 ppm) at 30 and 60 DAT, respectively where without fertilizer or control treatment obtained the lowest pore water P concentrations (0.020 and 0.006 ppm, respectively). Similarly, T_6 further recorded the tallest plant (70.42 cm) and longest panicle (22.31) while highest weight of 1000–grain (21.25 g) and highest number of filled and lowest number of unfilled grains (76.57 and 20.95, respectively) were produced from 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime ka^{-1} soil (T_4). However, shortest plant and panicle (53.98 and 18.71 cm, respectivel), lowest weight of 1000 grain (16.18 g), minimum number of filled and highest number of unfilled grains $panicle^{-1}$ (32.14 and 29.24, respectively) were obtaiend from the without fertilizer or control treatment. Number of non–effective tillers $hill^{-1}$ was the highest (9.50) in 50% NPKS + 3.5 ton poultry manure ha^{-1} (T_7) and lowest in control treatment (3.83) in this study. The highest number of effective tillers $hill^{-1}$ (27.17) was recorded in only recommended dose of $N_{150}P_{30}K_{70}S_{20}Zn_3$ which further produced the highest yield of grain and straw (41.67 and 71.00 g pot^{-1}) in this study. However, same highest grain yield (41.67 g pot^{-1}) was also found in recommended dose of $N_{150}P_{30}K_{70}S_{20}Zn_3$ along with 1.0 g lime kg^{-1} soil. Similarly, N, P, K and S content in rice grain had highest (1.902, 0.070, 0.538 and 0.169%, respectively) in those rice grain which was treated by 50% NPKS + 3.5 ton poultry manure ha^{-1} + 1.0 g lime ka^{-1} soil (T_8) while without fertilizer treated soil took the lowest content of P, K and S (0.033, 0.113 and 0.058%, respectively) in rice grain.

In case of the effect of interactions, whole interaction treatments between regional acidic soil and different types of fertilizers produced numerically same performance due to non significant difference regarding pore–water P concentration at 60 DAT, plant height, number of effective tillers hill^{-1}, panicle length, number of filled and un–filled grains panicle^{-1}, grain yield and straw yield with an average ranges of 0.005 (S_1T_0) to 0.032 ppm (S_1T_6), 55.74 (S_1T_0) to 72.85 cm (S_1T_1), 4.67 (S_1T_0) to 31.67 (S_1T_1), 18.39 (S_2T_0) to 23.00 cm (S_2T_6), 30.56 (S_1T_0) to 80.87 (S_2T_3), 19.10 (S_2T_1) to 32.11 (S_1T_0), 2.67 (S_1T_0) to 49.00 g pot^{-1} (S_1T_2) and 7.33 (S_1T_0) to 83.33 g pot^{-1} (S_1T_1), respectively. Rest of the traits of the study, the soil of Goari showed the highest pore–water P concentrations (0.400 ppm) and the soil of Bhatgaon recorded the highest weight of 1000–grain (22.40 g) while both soil receving of same 50% NPKS along with 5.0 ton cowdung ha^{-1} and 1.0 g lime kg^{-1} soil. On the other hand, the soil of Bhatgaon receiving of 50% NPKS along with 3.5 ton poultry manure ha^{-1} obtained the highest number of non–effective tillers hill^{-1}. However, the soil of Bhatgaon recorded the lowest pore–water P concentration (0.004 ppm) and lowest weight of 1000–grain (16.69 g) but the soil of Goari showed the lowest number of non–effective tillers hill^{-1} (3.00) while any level of organic or inorganic were absent in all cases. However, the grain of Goari soil treated by 50% NPKS + 3.5 ton poultry manure ha^{-1} + 1.0 g dolomite kg^{-1} soil showed the highest N content (1.967%) while without treated soil of Bhatgaon obtained the lowest N content (0.560%). Similarly, the grain of Bhatgoan soil treated by 50% NPKS + 5 ton cowdung ha^{-1} + 1.0 g lime kg^{-1} soil (S_1T_4) showed the highest P content (0.103%) and same soil treated by only RDCF of $N_{150}P_{30}K_{70}S_{20}Zn_3$ (S_1T_1) recorded the highest K content (0.617) but the highest S content in rice grain (0.187%) was recorded in those Goari soil which was treated by 50% NPKS + 3.5 ton poultry manure ha^{-1} + 1.0 g lime kg^{-1} soil (S_2T_8). On the other hand, without fertilizer treated soil of Bhatgaon produced the lowest K content (0.075%) in rice grain while without fertilizer treated soil of Goari took the lowest P and S content (0.017 and 0.050%, respectively) in rice grain of the present study.

CHAPTER 7
CONCLUSION

From the above findings of the present study, it may be concluded that the pore–water nutrient availability, rice yield, grain nutrient concentration varied with soils, fertilizer treatments and application of lime. The pore–water P concentrations decreased with increasing days after transplantation. Higher concentrations of pore–water P were found in the organic plus inorganic fertilizer and lime applied treatments. There was a significant and positive correlation observed between pore–water P concentrations and rice yields. Besides, most of the yield attributes were also positively correlated with grain yield of the present study. The higher morpho–physiological development of rice along with greater production were obtained in the collected soil of Bhatgaon compared Goari. The higher grain yields of boro rice was produced from T_2 (41.67) where dolomite was applied with RDCF fertilizer. However, most of the characters did not vary significant due to the interaction effects but the highest *Boro* rice yield (49.33 g pot^{-1}) was obtained in S_1T_2 (Bhatgoan Soil+RDCF+1.0 g. lime kg^{-1} soil) where lime was applied with RDCF. The highest yield obtained from S_1T_2 which was statistically similar with S_2T_8 (Gouri+50%NPKS+3.5 ton poultry manure ha^{-1}+1.0 g lime lg^{-1} soil) S_1T_8 (Bhatgoan Soil+3.5 ton poultry manure ha^{-1}+1.0 g lime lg^{-1} soil). Application of inorganic fertilizer plus manure and lime for rice cultivation significantly increased the grain nutrient level. The level of P and S in rice grain increased more with the application of inorganic fertilizer + lime due to cowdung and poultry manure, respectively. From the above concluding remarks of the present study it could be suggested that the farmer(s) of our country may apply organic manure or lime along with 50% NPKS for enhancing the production of boro rice in acidic red soil. Also, this result may create the opportunity for sustainable agriculture of safer production. Considering the above facts of the present study, the following recommendation may be suggested.

i. Further trials may be needed to ensuring the present performance of the study in same condition for adaptability;

ii. More types of soil and more other different levels of organi and inorganic mixed fertilizer may be needed to include for further study to make sure the findingds in different agro–ecological zones (AEZ) of Bangladesh and other country for regional adaptability and ensuring present performance.

REFERENCES

Ahmad F, Tan KH 1986: Effect of lime and organic matter on soybean seedlings grown in aluminum–toxic soil. *Soil Science Society of American Journal* **50** 656–661.

Abodolereza A, Racionzer P 2009: Food outlook: Global market analysis (December 2009). pp. 23-27. www.fao.org/docrep/012/ak341f/ak341f00.

Alam MS, Baki MA, Sultana MS, Ali KJ, Islam MS 2012: Effect of variety, spacing and number of seedlings per hill on the yield potentials of transplant aman rice. *International Journal of Agronomy. and Agricultural Research* **2(12)** 10–15.

Aulakh *et. al*, 2001: **Research Integrated Nutrient Management in Rice. Agri. Yellow Pages Resources (Fertilizers). Online available at:** http://www.indiaagronet. com/indiaagronet/technology_upd/contents/integrated_nutrient_management_i.htm

Arif M, Tasneem M, Bashir F, Yaseen G, Iqbal RM 2014: Effect of integrated use of organic manures and inorganic fertilizers on yield and yield components of rice. *Journal of Agricultural Research* **52(2)** 197–206.

Asrat M, Gebrekidan H, Yli–Halla H, Bedadi B, Negassa W 2014: Effect of integrated use of lime, manure and mineral P fertilizer on bread wheat (*Triticum aestivum*) yield, P uptake and status of residual soil P on acidic soils of Gozamin district, North–Western Ethiopia. *Journal of Agriculture, Forestry and Fisheries* **3(2)** 76–85.

Athanasea N, Vickya R, Jayneb MN, Sylvestre H 2013: Soil acidification and lime quality: sources of soil acidity, its effects on plant nutrients, efficiency of lime and liming requirements. *Agricultural Advances* **2(9)** 259–269.

Azman EA, Jusop S, Ishak CF, Ismail R 2014: Increasing rice production using different lime sources on an acid sulphate soil in Merbok, Malaysia. *Pertanika Journal of Tropical Agricultural Science* 37(2) 223–247.

BBS (Bangladesh Bureau of Statistics) 2012: Statistics Pocket Book of Bangladesh (20010–11). Bangladesh Bureau of Statistics Division, Govt. of the People's Republic of Bangladesh. p. 37.

Bolan NS, Hedley MJ 2003: Role of carbon, nitrogen and sulfur cycles in soil acidification. In Handbook of soil acidity. Rengel. Z, New York., pp. 29-56.

Brady NC, Weil RR 2002: The Nature and Properties of soils Prentice Hall, New Jersey.

BRRI (Bangladesh Rice Research Institute) 2011: Adhunik Dhaner Chash (in bengali). Bangladesh Rice Research Institute, Joydebpur, Gazipur, pp: 5.

Buri MM, Wakatsuki T, Issaka RN 2005: Extent and management of low pH soils in Ghana. *Soil Science and Plant Nutrition* **51(5)** 755–759.

Butterly C, Baldock JA, Tan C 2013: The contribution of crop residues to changes in soil pH under field conditions. *Plant and Soil* 366(1) 185–198.

Clough TJ, Kelliher FM, Sherlockand RR, Ford CD 2004: Lime and soil moisture effect on nitrous oxide emissions from urine patch. *Soil Science and Society of American Journal* 1600-1609.

China Bi L, Xia J, Liu K, Li D, Yu X 2014: Effects of long–term chemical fertilization trends of rice yield and nutrient use efficiency under double rice cultivation in subtropical. *Plant and Soil Environment* **60(12)** 537–543

Cui J, Zhu D, Liao S, Liu G, Ren L, Zhou W, Hamilton DP 2012: Effect of boron–doped goethite on soil acidity, different forms of manganese in red soil and the growth of rape (*Brassica napus* L.) seedlings. *Journal of Plant Nutrition* **35(13)** 1923–1936.

Dong W, Zhang X, Wang H, Dai X, Sun X, *et al*. (2012) Effect of different fertilizer application in the soil fertility of paddy soils in red soil region of Southern China. PLoS ONE 7(9): e44504. doi:10.1371/journal.pone.0044504.

Fageria NK 1989: Effect of phosphorus on growth, yield and nutrient accumulation in the common bean. *Journal of Tropical Agriculture* 249-255.

Fageria NK, Baligar VC 2004: Ameliorating soil acidity of tropical oxisols by liming for sustainable crop production Elsevier Inc. Academic press.

Fageria NK, Baligar VC 2008: Chapter 7: Ameliorating Soil Acidity of Tropical Oxisols by Liming For Sustainable Crop Production. *Advances in Agronomy* 345–399.

Fageria NK, Knuppto AM 2014: Influence of lime and gypsum on growth and yield of upland rice and changes in soil chemical properties. *Journal of Plant Nutrition* 37**(8)** 1157–1170.

Fageria NK, Stone LF 2004: Yield of common bean in no-tillage system with application of lime and zinc. Pesq. Agropec. Braas., 73-78.

Fageria NK, VC B, DG E 1990: Soil plant nutrient relationship at low pH stress. Crops as enhancers of nutrient use. Academic Press. California. pp. 475-507.

Gitari HI, Mochoge BE, Danga BO 2015: Effect of lime and goat manure on soil acidity and maize (*Zea mays*) growth parameters at Kavutiri, Embu County– Central Kenya. *Journal of Soil Science and Environmental Management* **6(10)** 275–283.

Glaser B, Lehmann J, Zech W 2002: Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal–a review. *Journal of Biology and Fertility of Soils* **35** 219–230.

Gupta UC, Jame YW, Campbell CA, Leyshon AJ, Nicholaichuk W 1985: Boron toxicity and deficiency: a review. Canandian J. Soil Sci., 65: 381–409NCDACS (North Carolina Department of Agriculture and Consumer Services). 2011. Plant Nutrients: Soil pH. Raleigh, USA. (http://www.ncagr.gov/cyber/ kidswrld/plant/nutrient. htm#top).

Haynes RJ 1984: Lime and phosphate in the soil–plant system. *Advanced Agronomy* 249–315.

Haynes RJ, Mokolobate MS 2001: Amelioration of Al toxicity and P deficiency in acid soils by additions of organic residues: a critical review of the phenomenon and the mechanisms involved. *Nutrient Cycling in Agroecosystems* **59** 47–63.

Hossain A, Sarker MAZ, Hakim MA, Islam T, Ali ME 2011: Effect of lime, magnesium and boron on wheat (*Triticum aestivum* L.) and their residual effects on mungbean (*Vigna radiata* L.). *International Journal of Agricultural Research, Innovation and Technology* **1(1&2)** 9–15.

Hossain MS 2013: Effect of organic amendmends with conventional NPK fertilizers on soil environment, microbial biomass growth and yield of wheat. MS Thesis, Department of Environmental Science, Bangladesh Agricultural University, Mymensingh, pp. 1–81.

Ireri GH 2009: Lime and manure application to acid soils and their effects on bio–chemical soil properties and maize performance at Kavutiri–Embu County. MSc Thesis in Integrated Soil Fertility Management (ISFM), School of Agriculture and Enterprise Development, Department of Agricultural Resource Management, Kenyatta University. A148/13220/2009

IRRI (International Rice Research Institute) 2010: http:// www.irri.org/about rice/ rice facts/what is rice?

Ju–mei LI, Ming–gang XU, Dao–zhu QIN 2005: Effects of chemical fertilizers application combined with manure on ammonia volatilization and rice yield in red paddy soil. *Journal of Plant Nutrition and Fertilizer* **11(1)** 51–56.

Scott *et. al*, 2001: Economics of lime and phosphorus application for dual purpose on winter wheat production in low pH soils. *Agronomy Journal* 1139-1145.

Kamaruzzaman M, Rasel SMM, Islam MN 2013: Effect of lime on yield contributing characters of wheat in Barind tract of Bangladesh. *Journal of Agriculture and Veterinary Science* **4(6)** 39–46.

Khan HR, Rahman S, Hussain MS, Adachi T 1994: Growth and yield response of rice to selected amendments in an acid sulfate soil. *Soil Science and Plant Nutrition* 40(2) 231–242

Kisinyo PO, Othieno CO, Okalebo JR, Kipsat MJ, Serem AK, Obiero DO 2005: Effects of lime and phoshorus application on early growth of Leucaena in acid soils. *African Crop Science Conference Proceedings* **7** 1233–1236.

Lal R 2008: Soils and sustainable agriculture. *A review, Agronomy, Sustainable Development* **28** 57–64

Liu M, Li ZP, Zhang TL, Jiang CY, Che YP 2011: Discrepancy in response of rice yield and soil fertility to long-term chemical fertilization and organic amendments in paddy soils cultivated from Infertile upland in subtropical China. *Agricultural Sciences in China* **10** 259–266.

MacKinnon G, Evans C, Scott B 2015: Acid soil management in low rainfall farming systems of central Western New South Wales. *A proceedings of Grain Research and Development Corporation (GRDC)*. pp. 1–4.

Mahamud JA, Haque MM, Hasanuzzaman M 2013: Growth, dry matter production and yield performance of T aman rice varieties influenced by seedling densities per hill. *International Journal of Sustainable Agriculture* **5(1)** 16–24.

Malika M, Islam MR, Karim MR, Huda A, Jahiruddin M 2015: Organic and inorganic fertilizers influence the nutrient use efficiency and yield of a rice variety BINA dhan7. *Academic Research Journal of Agricultural Science and Research* **3(7)** 192–200.

Mathur, B.S., Rana, N.K. and Lal, S. 1991: Effect of rhizosphere application of lime on crop yield, soil properties, nutrient uptake and economics. *Journal of the Indian Society of Soil Science 39*, 523–529

McBride MB 1994: Environmental Chemistry of Soils, Oxford University Press, New York.

Meena RN, Singh K. 2012: Effect of organic nitrogen management on yield and quality of produce in Rice–Vegetable based cropping system. *Indian Journal of Ecology* **39(1)** 76–81.

Meena RN, Singh SP, Singh K 2010: Effect of organic nitrogen nutrition yield, quality, nutrient uptake and economics of rice (*Oryza sativa*) – table pea (*Pisum sativum* var. *hortense*) – onion (*Allium cepa*) cropping sequence. *Indian Journal of Agricultural Sciences* 80(11) 1003–1006

Mobasser HR, Delarestaghi MM, Khorgami A, Tari DB, Pourkalhor H 2007: Effect of planting density on agronomical characteristics of rice (*Oryza sativa* L.) varieties in North of Iran. *Pakistan Journal of Biological Science* **10(18)** 3205–3209.

Naidu R, Syers JK, Tillman RW, Kirkman JH 1990: Effect of liming and added phosphate on charge characteristics of acid soils. *Soil Science Journal* 157-164.

Naing Oo A, Banterng P, Polthanee A, Trelo–Ges G 2010: The effect of different fertilizers management strategies on growth and yield of upland black glutinous rice and soil property. *Asian Journal of Plant Sciences* **9** 414–422.

Nambiar KKM 1991: Long-term fertility effects on wheat productivity. Wheat for the non traditional warm areas. *Proceedings International Conference, Mexico, DF (Mexico) CIMMYT* 1991. **5** 16-521.

Nayak DR, Jagadeesh Y, Babub, Adhya TK 2007: Long-term application of compost influences microbial biomass and enzyme activities in a tropical Aeric Endoaquept planted to rice under flooded condition. *Soil Biology and Biochemistry* **39** 1897–1906.

Obiri–Nyarko F 2012: Ameliorating soil acidity in Ghana: a concise review of approaches. *ARPN Journal of Science and Technology* **2(SI)** 143–153.

Okalebo JR, Othieno CO, Nekesa AO, Ndungu–Magiroi KW, Kifuko–Koech MN 2009: Potential for agricultural lime on improved soil health and agricultural production in Kenya. 9th African Crop Science, Conference Proceedings, Cape Town, South Africa, 28 September–2 October 2009 2009. Record Number: 20133232431. pp. 339–341.

Oluwatoyinbo FI, AKande MO, Makinde EA, Adediran J 2009: Growth and yield response of okra to lime and compost on an acid soil in the humid tropics. *Research Journal of Agriculture and Biological Sciences* **5(5)** 858–863.

Pandey D, Devendra, Payasi K, Pandey N 2014: Effect of organic and inorganic fertilizers on hybrid rice. *International Journal of Current Research* **6(5)** 6549–6551.

Paul KI, Black AS, Conyers MK 2001: Influence of fallow, wheat and subterranean clover on pH within an initially mixed surface soil in the field. *Biological and Fertility of Soils* **33** 41–52.

Ping LI, Xingxiang W, Taolin Z, Dongmei ZHE 2008. Effects of several amendments on rice growth and uptake of copper and cadmium from a contaminated soil. *Journal of Environmental Sciences* **20** 449–455

Pocknee S, Sumner ME 1997: Cation and nitrogen contents of organic matter determine its soil liming potential. *Soil Science and Society of Americal Journal* **61** 86–92.

Rahman MA, Barma NCD, Sarker MH, Sarker MMR, Nazrul MMI 2013: Adaptability of wheat varieties in strongly acidic soils of sylhet. *Bangladesh Journal of Agricultural Research* **38(1)** 97–104.

Rahman MA, Meisner CA, Duxbury JM, Lauren L, Hossain ABS 2002: Yield response and change in soil nutrient availability by application of lime, fertilizer and micronutrients in an acidic soil in a rice–wheat cropping system. 17th World Congress on Soil Science, 14–21 Aug., 2002, Thailand. Online available at http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.6.1281.

Rahman, M. A., J. Chikushi, J. G. Lauren, J. M. Duxbury, C. A. Meisner, and E. Yasunaga. 2005. Chemical control of soil environment by lime and nutrients to improve the productivity of acidic alluvial soils under rice–wheat cropping system. *Environmental Control in Biology* 43(4): 259–266.

Rattanapichai W, Kren J, Duangpatra P, Kanghae P 2013: Effects of soil conditioner on growth and yield of rice grown under acid sulfate soil. *Mendelnet* **2013** 147–151.

Ren-shih C, Sun-ho W 1997: Effect of corncob compost on plant growth in an acid red soil. *Communications in Soil Science and Plant Analysis.* 673–683.

Sadiq AA, Babagana U 2012: Influence of lime materials to ameliorate acidity on irrigated paddy fields: a review. *Academic Research International* **3(1)** 413–420.

Sardar G, Jana K, Ghosh S, Mallick GK 2015: Effect of different sources of organic matter on the yield of rice and soil health in red and lateritic zone of West Bengal, India. *Journal of Applied and Natural Science* **7(1)** 226 – 228.

Shazana, M. A. R. S., Shamshuddin. J., Fauziah, C. I., Syed O, S. R. 2011. Alleviating the infertility of an acid sulphate soil by using ground basalt with or without lime and organic fertilizer under submerged condition.

Shen QR, Shen ZG 2001: Effects of pig manure and wheat straw on growth of mung bean seedlings grown in aluminium toxicity soil. *Bioresource Technology* **76** 235–240.

Shen ZG, Wang JL, Guan HY 1993: Effect of aluminum and calcium on growth of wheat seedlings and germination of seeds. *Journal of Plant Nutrition* **16** 2135–2148.

Singh RN, Surendra S, Prasad SS, Singh VK, Pramod K 2011: Effect of integrated nutrient management on soil fertility, nutrient uptake and yield of rice–pea cropping system on an upland acid soil of Jharkhand. *Journal of the Indian Society of Soil Science* **59(2)** 158–163.

Smyth TJ, Cassel DK 1995: Synthesis of long–term soil management research on ultisols and oxisols in the Amazon. In: Lal R, Stewart BA. Soil management: experimental basis for sustainability and environmental quality. Advances in Soil Science. Boca Raton, Fla, pp 13–60

Stephen RJ, Laughlin RL, Malone JP 1998: Soil pH affects process reducing nitrate to nitrous oxide and di-nitrogen. *Soil Biology and Biochemistry* 1119-1126.

Sukristiyonubowo, Sipahutar IA, Vadari T, Sofyan A 2011: Management of inherent soil fertility of newly opened wetland rice field for sustainable rice farming in Indonesia. *Journal of Plant Breeding and Crop Science* **3(8)** 146–153.

Sukristiyonubowo, Wibowo H, Dariah A 2013: Management of acid newly opened wetland rice fields. *Global Advanced Research Journal of Agricultural Science* **2(7)** 174–180.

Suswanto T, Shamshuddin J, Syed Omar SR, Peli Mat, Teh CBS 2007: Alleviating an acid sulfate soil cultivated to rice (*Oryza sativa*) using ground magnesium limestone and organic fertilizer. *Soil Environment* **9**, 1–9.

Tang C, Sparling GP, McLay CDA, Raphael C 1999: Effect of short-term legume residue decomposition soil acidity. *Australian Journal of Soil and Research* **37** 561–573

Tang C, Yu Q 1999: Impact of chemical composition of legume residues and initial soil pH on pH change of a soil after residue incorporation. *Plant of Soil Science* **215** 29–38

UAE/FAO 2012: International exhibition to promote rice import & export. November 19th, 20th & 21st 2012, **Dubai, UAE (online available at: http://www.riceexhibition.com/market_info.php).**

Vetayasuporn S, 2012. Effects of Organic–Chemical Fertilizer on the Growth and Yield of Rice (Chai Nat 1). *Research Journal of Biological Sciences, 7: 265–269.*

Whalen JK, Chang C, Clayton GW, Carefoot JP 2000: Cattle manure amendments can increase the pH of acid soils. *Soil Science Society for American Journal* **64** 962–966.

Whalen, J. K. and Chang, C. 2001. Phosphorus accumulation in cultivated soils from long–term annual applications of cattle feedlot manure. Journal of Environmental Quality. 30: 229–237.

Whalen, J. K., Chang, C. and Clayton, G. W. 2002. Cattle manure and lime amendments to improve crop production of acidic soils in northern Alberta. Canadian Journal of Soil Science. 82: 227–238.

Wopereis MCS, Defoer T, Idinoba F, Diack S, Marie–Josèphe Dugué 2009: Technical Manual "Curriculum for Participatory Learning and Action Research (PLAR) for Integrated Rice Management (IRM) in Inland Valleys of Sub–Saharan Africa". Online available at: http://www.africarice.org/ publications/PLAR/techmanual/foreword.pdf

Xu K, Lei Y, Choi JK 2008: Kiitricha minuta n. sp., a peculiar hypotrichous ciliate (Ciliophora, Spirotrichea) from the Yellow Sea. *Journal of Eukaryot Microbiology* **55** 201–206.

Xu RK, Coventry DR, Farhoodi A, Schultz JE 2002: Soil acidification as influenced by crop rotations, stubble management, and application of nitrogenous fertiliser, Tarlee, South Australia. *Australian Journal of Soil and Research* **40** 483–496.

Yu GT, Qin SC 1998: Effect of organic manure on soil aluminum toxicity and nutrient absorption of winter wheat. *Plant Nutrition and Fertilizer Science* **4** 57–62.

Yung–Yu S 2005: Effect of application of different types of organic composts on rice growth under laboratory conditions. *Soil Science and Plant Nutrition* **51(3)** 443–449.

Zhang Yu–ping, Cao Wei–xing, Zhu De–feng 2009: Effects of potassium fertilizer rate on growth and yield formation of super high yielding rice in red paddy soil. *Chinese Journal of Rice Science* **23(6)** 633–638 .

Zhao L, Wu L, Wu M, Li Y 2011: Nutrient uptake and water use efficiency as affected by modified rice cultivation methods with irrigation. *Paddy Water Environ*ment **9** 25-32.

Zhu QH, Peng XH, Huang TQ, Xie ZB, Holden NM 2014: Effect of biochar addition on maize growth and nitrogen use efficiency in acidic red soils. *Pedosphere*. **24(6)** 699–708.