YIELD RESPONSE OF WHEAT TO THE APPLICATION OF LIME AND PHOSPHOROUS

MAHMUDA MOTMAINNA

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA -1207

JUNE, 2014

YIELD RESPONSE OF WHEAT TO THE APPLICATION OF LIME AND PHOSPHOROUS

By

MAHMUDA MOTMAINNA
Reg. No.: 07-2254

A Thesis

Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE (MS.)
IN
AGRONOMY
SEMESTER: JANUARY-JUNE, 2014

APPROVED BY

(Prof. Dr. Md. Abdullahil Baque)	**(Prof. Dr. Md. Fazlul Karim)**
Supervisor	**Co-supervisor**

(Prof. Dr. H. M. M. Tariq Hossain)
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY

Sher-e Bangla Agricultural University

Dhaka-1207, Bangladesh

CERTIFICATE

This is to certify that the thesis entitled **" YIELD RESPONSE OF WHEAT TO THE APPLICATION OF LIME AND PHOSPHOROUS"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of ***MASTER OF SCIENCE (MS.) IN AGRONOMY,*** embodies the results of a piece of *bona fide* research work carried out by **Mahmuda Motmainna,** Registration. No.: **07-2254** under my supervision and guidance. No part of this thesis has been submitted for any other degree or 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.

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

Dated :

Dhaka, Bangladesh

(Prof. Dr. Md. Abdullahil Baque)

Supervisor

DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENT

Alhamdulillahi Rabbil Al-Amin, all praises are due to the almighty Allah Rabbul Al-Amin for His gracious kindness and infinite mercy in all the endeavors the author to let her successfully completes the research work and the thesis leading to Master of Science.

The author would like to express her heartfelt gratitude and most sincere appreciations to her Supervisor Dr. Md. Abdullahil Baque , Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for his valuable guidance, advice, immense help, encouragement and support throughout the study. Likewise grateful appreciation is conveyed to Co-supervisor Professor Dr. Md. Fazlul Karim, Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for constant encouragement, cordial suggestions, constructive criticisms and valuable advice to complete the thesis.

The author would like to express her deepest respect and boundless gratitude to all the respected teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for their valuable teaching, sympathetic co-operation, and inspirations throughout the course of this study and research work.

The author expresses as her heartfelt gratitude to National science and information and communication technology, Ministry of Science and Technology, Government of the people's republic of Bangladesh to provide the scholarship to continue the research for the betterment of the nation.

The author wishes to extend her special thanks to Shamim, Mousumi, Sajib, Soma and Konok for their help during experimentation. Special thanks to all other friends for their support and encouragement to complete this study.

The author is deeply indebted and grateful to her parents, brothers and other relatives for their moral support, encouragement and love with cordial understanding.

Finally the author appreciates the assistance rendered by the staff of the Department of Agronomy and farm, Sher-e-Bangla Agricultural University, Dhaka-1207, who have helped her during the period of research work.

Author

YIELD RESPONSE OF WHEAT TO THE APPLICATION OF LIME AND PHOSPHOROUS.

ABSTRACT

A field experiment was conducted at Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November 14, 2012 to March, 2013 in rabi season with a view to find out the yield response of wheat (BARI gom 26) to the application of lime and phosphorous . The experiment comprised of three levels lime *viz.* (i) L_0 = no lime (control), (ii) L_1 =1t ha^{-1}, and (iii) L_2 = 2 t ha^{-1} and four phosphorus levels viz. (i) P_0 = no P_2O_5 (control), (ii) P_1 = 48 kg P_2O_5 ha^{-1},(iii) P_2 = 77 kg P_2O_5 ha^{-1} and (iv) P_3 = 106 kg P_2O_5 ha^{-1}. The experiment was laid out in a split-plot design with three replications where lime were placed in the main plot and phosphorus fertilizers were in sub-plots . Experimental results indicated that different lime levels had the significant effect on plant height, dry weight $plant^{-1}$, relative water content (RWC), water saturation deficit (WSD) , water retention capacity (WRC), effective tillers $plant^{-1}$, spike length, spikelets $spike^{-1}$, grains $spike^{-1}$, grain yield, straw yield and harvest index. The highest grain yield (3.09 t ha^{-1}) was recorded at 2 t ha^{-1} that mainly attributed by the maximum effective tillers $plant^{-1}$, spikelets $spike^{-1}$, grains $spike^{-1}$ and 1000-grain weight. Among the different phosphorus levels , 77 kg P_2O_5 ha^{-1} gave the highest grain yield (3.16 t ha^{-1}) and it was mainly attributed by the maximum effective tillers $plant^{-1}$, maximum spikelets $spike^{-1}$, maximum grains $spike^{-1}$ and 1000-grain weight. The interaction effect of lime and phosphorus levels showed significant response on yield attributing characters of wheat .The highest plant height (85.20 cm), effective tillers m^{-2} (223.30), spike length (17.73 cm), spikelets $spike^{-1}$ (20.67) grains $spike^{-1}$ (64.33), 1000 grain weight (42.50 g) were observed with interaction of lime and phosphorus treatment. Again, the maximum grain yield (3.87 t ha^{-1}) was found with the interaction of 2 t ha^{-1} lime and 77 kg P_2O_5 ha^{-1} and straw yield (6.437 t ha^{-1}) with the interaction of 2 t ha^{-1} lime and 106 kg P_2O_5 ha^{-1}.These results suggest that the interaction of 2 t $ha^{-1}$of lime with 77 kg ha^{-1} phosphorus is suitable for enhancing grain yield of BARI Gom 26 under high acidic soil.

LIST OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

Wheat (*Triticum aestivum*) is an important cereals crop of tropical and subtropical regions of the world. Wheat production is the third largest cereal production in the world, after maize and rice (FAO, 2013). Among the cereal crops, wheat is next to rice in Bangladesh. Although, rice is the staple food of Bangladesh but its total production is not sufficient enough to feed the increasing population. Wheat can be a good supplement of rice and it can play a vital role to feed the increasing population. According to USDA (2014) one cup whole wheat grain contains 33% Protein, 29% Carbohydrate, 5% Fat. About 65% of wheat crop is used for food, 17% for animal feed and 12% in industrial applications (FAO, 2013). It has been predicted that demand for wheat in the developing world is projected to increase 60% by 2050 from now (CIMMYT, 2013). In Bangladesh about 3.58 lac hectare of land is covered by wheat producing 9.95 lac metric ton with an average yield of 2.78 t ha^{-1} during the year 2012-2013 (BBS, 2013). It is a future challenge for Bangladesh to better exploit the potential of the production of wheat crop to meet the country's grain food requirement without endangering the environment (Kamaruzzaman, 2013).

The yield of wheat in Bangladesh is low. There are several reasons that can explain the yield variation, which cover both biotic and abiotic factors. Among the biotic factors, unavailability of high yielding varieties (Rerkasem *et al.,* 1993), incidence of diseases and pests (Hossain *et al.,* 1995) and abiotic factors such as high temperature (Orakwue, 1984), moisture stress (Bingham, 1966) and nutrient deficiency (Rerkasem *et al*., 1991; Jahiruddin *et al.,* 1992; Islam *et* al., 1999) are responsible for lower productivity of wheat in the tropics and sub-tropics. Among these factors, the most dominating factor that is a vital barrier for crop productivity is problem soil like acidic soil, saline soil etc (Kamaruzzaman, 2013). There are different types of problem soils in Bangladesh. These soils restrict the growth of plants and make crop production difficult and sometimes impossible. Special management practices need to be applied in such soils for economic crop production. Acid soil in Bangladesh is one of the problematic soils. The potential of acid soil for crop production is limited due to less availability of phosphorus and toxicity of aluminum (Kamaruzzaman, 2013).

Out of 30 agro-ecological regions of Bangladesh, 15 are from medium to strongly acidic in soil reaction, ranging from a p^H 4.5 to 5.5 (BARC, 2005). Soil acidic condition is a major constraint for P solubility and utilization of P by the crops. Because in strongly acidic conditions, phosphorus reacts with active iron and aluminum, resulting formation of insoluble phosphates which is unavailable for crops. This conversion of soluble phosphate into a more insoluble form is termed as phosphate fixation (Yuan *et al,* 1960; Mandal and Khan, 1972). They also reported that more than 80 percent of applied P is converted into unavailable forms within a very short period. Under acidic conditions, calcium and magnesium supply is reduced and plant growth suffers.

Liming is an important management practice in acid soils. Improvement of these acid soils should also aim at eliminating the toxic effects of Al and Mn. The harmful effects of soil acidity can be eliminated by raising p^H by adding suitable quantity of lime. Liming helps in raising the base saturation of the soil and inactivation of iron, aluminium and manganese in the soil solution (Kamprath, 1970). Thus minimize phosphate fixation by iron and aluminium. It is noted that calcium ions play a major role in p fixation when soil reaction goes above p^H 8.0.

Liming also promotes the decomposition of organic matter by making condition more favorable for the growth of microorganisms. The bacteria that fixed nitrogen from the air both non -symbiotically and in the nodules of legumes are specially stimulated by the application of lime. The successful growth of most soil microorganisms depends upon lime that satisfactory biological activities cannot be expected if phosphorus, calcium and magnesium levels are low (Kamaruzzaman, 2013).

The effect of liming on phosphate adsorption availability in acid soils was studied by Haynes (1992). He concluded that the adsorption of phosphate by amphoteric soil surfaces generally decreased slowly as the p^H increased from 4.0 to 7.0. He also stated that liming can increase phosphate availability by stimulating mineralization of soil organic phosphorus. Exogenous application of lime had a higher maximum adsorption capacity for phosphorus than the no liming to the soil. considering great potentiality of liming to manage acidic soil regarding increase in P utilization efficiency. Hence, this study was undertaken to increase wheat productivity through external application of various levels of lime and P.

Therefore, the objectives of this study:

- To study the response of wheat variety to external application of different levels of lime and P.
- To explore the combined effect of different levels of lime and P on water relation behavior of wheat.
- To examine the combined effect of different levels of lime and P on growth and yield attributes of wheat.

CHAPTER 2
REVIEW OF LITERATURE

Wheat (*Triticum aestivum*) is the most important and widely cultivated crop of the entire world.It has been established as the second most economic food grain crop to minimize the gap between food production and import in Bangladesh. This chapter presents a comprehensive review of the works which have been done in Bangladesh and many other countries of the world with regards to the effect of lime and phosphorus on growth and yield of wheat. An emphasis has been given to the literature that has been published in the last two decades.

2.1Effect of lime and phosphorus on growth characters

2.1.1 Effect on plant height

Kamaruzzaman *et al*. (2013) carried out the effect of lime on yield contributing characters of wheat. There were six lime treatments viz.T_1: Control, T_2: 0.5 t lime ha^{-1}, T_3: 1.0 t lime ha^{-1}, T_4: 1.5 t lime ha^{-1}, T_5: 2.0 t lime ha^{-1}, and T_6: 2.5 t lime ha^{-1}.Dolochun ($CaCO_3$) was used as the liming material. Every plot received 140.0 kg N, 25.0 kg P, 106.0 kg K, 3.06 kg S, 3.6 kg Zn and 0.6 kg B ha^{-1} from urea, TSP, M0P, gypsum, zinc sulphate (monohydrate) and boric acid, respectively. Available K, P, Ca and Mg were significantly increased due to application of lime which was mainly associated with increased wheat yields. Plant height of wheat progressively increased with increase in lime rates. The plant height ranged from 0.88 m in T_1 (control) treatment to 1.10 in T_4 treatment. The highest plant height recorded in T_4 was significantly comparable to those obtained in T_5 and T_6, but T_4 and T_5 treatments are statistically identical. All the treatments T_1, T_2, T_3 and T_6 differed statistically from each other in terms of plant height. On the other hand, another observation of this result where plant height was highest in the treatment T_4 (1.1m) and grain yield also highest was found in same treatment T_4 (4.73 t/ha). The application of 0.5 t lime ha^{-1} significantly increased most of the growth parameters of wheat compared to that without any lime application. 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. Thus, the application of 1.50 t lime ha^{-1} is enough for satisfactory yield of wheat.

Khan *et al.* (2010) laid out a field experiment with a view to find out the effect of different phosphatic fertilizers on growth attributes of wheat. Phosphorus was applied at the rate of 40 and 80 kg P ha^{-1} in the form of SSP, TSP, NP and DAP. It was concluded from the study that phosphorus application at the rate of 80 kg P ha^{-1} as single super phosphate (SSP) showed better results as compared to triple super phosphate (TSP), nitrophos (NP) and diammonium phosphate (DAP) on phosphorus deficient soil .The results showed that the maximum plant height (91.67 cm) was recorded in treatment T_6 (80 kg P ha^{-1} as SSP), while it was minimum (75.33 cm) in treatment T_1 (control). Plant height was significantly affected among all the various P sources application. It also increased linearly with the increased level of phosphorus application.

Rahman *et al.* (2002) was carried out a field trail to study adaptability of wheat varieties in strongly acidic soils 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 wheat varieties used in this study were Shatabdi, Sufi, Sourav, Bijoy, Prodip, BARI Gom-25 and BARI Gom-26. The soil of the locations were strongly acidic and lime application in such a soil increased soil p^H resulting increase in nutrient availability and thereby favoured plant growth and tillering of wheat .Thus the lime induced higher plant growth and more tiller formation might contribute to higher spikes/m^2 compared to non-limed plots. Generally root growth is restricted in low p^H soil due to iron and aluminum toxicity, but lime application in such a soil make the soil environment favourable for root growth of wheat by reducing the toxicity of Fe and Al. The result indicated that most of the growth characters and yield components of wheat were significantly improved by liming. 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.

Mclay *et al*. (1993) evaluated the effect of lime on wheat growth in pots containing an acidic subsoil. Lime treatments increased shoot and root growth 2 to 3 fold and decreased the concentration of total Al and the calculated activities of all Al species. It is suggested that lime increased plant growth by increasing the p^H and markedly decreasing the concentration of Al in the soil solution, enabling plants to take up other nutrients from the soil. The results indicate that subsurface incorporation of lime would be the best method for improving wheat growth on yellow sand plain soils in Western Australia if an economic method for incorporation of lime into the subsoil could be developed.

Uzoho *et al*. (2010) carried out Maize (Zea mays) response to phosphorus and lime on gas flare affected soils. Response of maize to phosphorus and lime was evaluated on two gas flare affected sites. The experimental design was a 2 x 2 x 4 factorial of 2 sites (S_1 and S_2), 2 P rates (0 and 30 kg P_20_5 ha^{-1}) and 4 lime rates (0, 1, 1.5 and 2.0 t ha^{-1}) in a CRD and replicated 3 times. Plant height, leaf area, dry matter yield, nutrient uptake (N and P) and residual soil properties (p^H, Ca, Mg and P) increased with treatments up to 30 kg P_20_5 ha^{-1} and 1.5 t ha^{-1} lime combined rates in both sites.

Reeve and Sumner (1970) obtained that maximum growth of sorghum by applying lime to eight Oxisols to reduce the Al extractable with 0.2 N NH_4Cl, to 0.2 cmol (p^+) kg^{-1}. They found the following relationship to calculate the lime requirement. Lime requirement=1.54 (EAI) Where, EAI is the 'Extractable Aluminum Index' obtained by extracting 5 g soil with 50 ml of 0.2 N NH_4Cl. This relationship provided an appropriate estimate of lime necessary for neutralization of acidity to obtain a good crop growth. On an average, the amount of lime necessary for maximum growth and control of the exchangeable Al was approximately one-sixth of the requirement to raise the soil p^H to 6.5. The lime applied to raise the soil p^H to 6.5 had adverse effect on P availability.

Muhammad *et al*. (2010) evaluated the effect of different phosphatic fertilizers on growth attributes of wheat. Among all the elements required by a plant, phosphorus (P) is one of the most important nutrients for crop production and emphasis is being given on the sufficient use of P fertilizer for sustainable crop production. Phosphorus was applied at the rate of 40 and 80 kg P ha^{-1} in the form of SSP, TSP, NP and DAP. A basal doze of 100 kg N and 60 kg K ha^{-1} was applied as urea and murate of potash (MOP) respectively. All the growth parameters of wheat were significantly improved by addition of P application. It was concluded from the study that phosphorus application at the rate of 80 kg P ha^{-1} as single super phosphate (SSP) showed better results as compared to triple super phosphate (TSP), nitrophos (NP) and diammonium phosphate (DAP) on phosphorus deficient soil of Balkasr area.

Holloway *et al.(* 2001) reported that plant height also contributed a significant impact on enhancing the straw yield. Higher plant height (91.67cm) was noted in treatment where 80 kg P ha^{-1} as SSP, while farmer practice had attained minimum (75.33 cm) plant height. Hence DAP and SSP had enhanced higher plant height as compared to TSP, NP and DAP.

Baon *et al.(*1992) observed that phosphorous had a significant impact on various cereal crops growth attributes as these are paradox for the yield enhancing factors. They also suggested for application of phosphatic fertilizers at early growth stages to support the lateral growth stages for enhancing crop productivity as per their potential.

Chaudhury *et al*. (1999) conducted a field experiment conducted in Assam showed that lime sludge applied at 25 per cent of LR (lime requirement) at seven days before sowing of wheat cv. Sonalika was more effective in enhancing p^H, CEC, base saturation and in reducing total acidity, exchange acidity, exchangeable Al^{3+} at maximum tillering stage and harvesting stage of wheat, than lime applied at the same rate at ten days and three days before sowing. Further, application of 25 percent lime sludge at seven days before sowing significantly enhanced the availability of N, P, K, Ca and Mg in the soil compared to ten days and three days before sowing.

Christopher *et al*. (2011) evaluated the corn production as affected by phosphorus enhancers, phosphorus source and lime .This study examined the effects of liming application (0 Mg ha^{-1} and recommended rate), P source [non-treated control and a broadcast application of diammonium phosphate (DAP) or triple superphosphate (TSP)] on corn (*Zea mays* L.) production. The P enhancers did not affect plant population, silage dry weights, grain moisture, yield, protein, oil, or starch concentrations at either location. At Portageville, P enhancers did not affect plant N, P, K uptake and apparent P recovery efficiency (APRE). At Novelty, neither P enhancer paired with DAP increased P uptake over the non-treated control. TSP treated with Avail ® increased P uptake 8.6 kg ha^{-1} compared to the non-treated control and 7.1 kg ha^{-1} compared to P_2O_5-Max ®. In 2010 at Novelty, TSP treated with Avail ® increased K uptake 150 kg ha^{-1} compared to the non-treated TSP and 100 kg ha^{-1} compared to P_2O_5-Max® . Plant population was 4,800 plants ha^{-1} greater in the non-limed control compared to the recommended rate. Grain yield increased 0.34 Mg ha^{-1} with TSP compared to the non-treated control

Renata *et al*. (2013) laid out a field experiment with a view to find out the effect of differentiated phosphorus fertilization on winter wheat yield and quality. The effects of differentiated rates of phosphorous applied together with a fixed level of nitrogen and magnesium fertilization were investigated. Correlation analysis on relationships between grain yield and nutrient content in wheat leaves at the beginning of stem elongation stage (BBCH31) showed significant relationships for phosphorous, calcium, magnesium, zinc and manganese. Regression analysis proved that the content of zinc in leaves at the BBCH31 stage was the main factor which determined winter wheat grain yield.

Furthermore, mineral fertilization significantly increased the content of protein and gluten when compared with the control objects, whereas no significant differences were observed among the fertilized objects. Statistically significant relationships were found between leaf content of N, P, Mg, Zn and Mn at BBCH31 and the accumulation of protein and gluten in wheat grain. Protein and gluten in grain depended on the content of magnesium in leaves at the beginning of stem elongation stage. Weather conditions as a factor significantly influenced grain size uniformity while mineral fertilization had no influence on this trait.

2.1.2 Effect on leaf area index

Armando (2010) evaluated the effect of lime and phosphorus fertilizer application on the response of four wheat genotypes varying in tolerance to soil acidity. The main plots contained the 3 rates of limestone (0, 6.5, and 13.0 t/ha), the sub-plots the 3 rates of phosphorus (0, 30, and 90 kg P_2O_5/ha), and the sub-sub-plots the 4 wheat genotypes.IAC-60 and IAC-5 were more efficient for grain yield than IAC-24 and Anahuac whereas IAC-60 was more responsive to lime and P than the other genotypes. In general, the Al-tolerant materials were shown to be more responsive to lime and P, which may be due to the fact that they are more adapted to low fertility soils. Increasing rates of lime and P brought about an increase in N, P, K, Ca, and Mg, and a decrease in Mn and Al concentration in the flag leaf of the wheat plants. The flag leaf Al in the Al-tolerant genotypes was much lower than in the non-tolerant ones.

2.1.3 Effect on number of tillers per plant

Islam *et al.* (2012) carried out an experiment to find out the effect of lime on yield contributing characters of Wheat in Barind tract of Bangladesh. There were six lime treatments viz.T_1: Control, T_2: 0.5 t lime ha^{-1}, T_3: 1.0 t lime ha^{-1}, T_4 : 1.5 t lime ha^{-1}, T_5 : 2.0 t lime ha^{-1}, and T_6 : 2.5 t lime ha^{-1}. Liming effect on number of tillers $plant^{-1}$ was found statistically highly significant. The highest number of tillers $plant^{-1}$ (4.77) was found in T_4. The lowest number of tillers plant^{-1} (1.88) was found in T_1.The number of tillers plant^{-1} in T_5 was identical to those found in T_6 and also identical was found in $T_1$and T_2. The treatment was superior to T_4, T_5 and T_6 in recording the number of tillers plant^{-1}. The number of tillers plant^{-1} in T_4 and T_6 was statistically superior to tillers plant^{-1} recorded in T_1, T_2, T_3 and T_5 treatments. The number of tillers plant^{-1} of wheat was affected due to changes in soil properties through liming. The grain yield of wheat was also found in highest in the treatment of T_4 (4.77 t/ha). The grain yield of wheat was positively correlated with number of tillers plant^{-1} characters.

Chaudhury *et al.* (1999) conducted a field experiment conducted in Assam showed that lime sludge applied at 25 per cent of LR (lime requirement) at seven days before sowing of wheat cv. Sonalika was more effective in enhancing p^H, CEC, base saturation and in reducing total acidity, exchange acidity, exchangeable Al^{3+} at maximum tillering stage and harvesting stage of wheat, than lime applied at the same rate at ten days and three days before sowing. Further, application of 25 percent lime sludge at seven days before sowing significantly enhanced the availability of N, P, K, Ca and Mg in the soil compared to ten days and three days before sowing.

Bhagat (2004) who reported that basal application of the recommended dose of DAP produced significantly higher number of effective tillers m^{-1} row length which ultimately increased the grain and straw yields.

Renu *et al.* (2005) also found that the number of tillers per plant was less where no fertilizer was applied as compared to phosphorus fertilizer application in case of wheat crop.

Daniel *et al.* (2010) laid out a field experiment with a view to finding out effects of phosphorus nutrition on tiller emergence in wheat**.** Phosphorus (P) deficiency limits the yield of wheat, particularly by reducing the number of ears per unit of area because of a poor tiller emergence. The objectives of this work were to determine whether tiller emergence under low phosphorus availability is a function of the availability of assimilates for growth or a direct result of low P availability, to establish a quantitative relation between an index of the availability of P in the plant and the effects of P deficiency on tiller emergence, and to provide a better understanding of the mechanisms involved in tiller emergence in field-grown wheat. Treatments consisted of the combination of three levels of P fertilization 0, 60 and 200 kg P_2O_5 ha^{-1}, and two levels of assimilate availability, a control (non-shaded) and 65% of reduction in incident irradiance from seedling emergence until the end of tillering (shaded). Phosphorus treatments significantly modified the pattern of growth and development of the plants. Shading reduced the growth and concentration of water-soluble carbohydrates in leaves and stems. At shoot P concentrations less than 4.2 g P kg^{-1} the heterogeneity in the plant population increased with respect to the number of plants bearing a certain tiller. At a shoot P concentration of 1.7 g P kg^{-1} tillering ceased completely. Phosphorus deficiency directly altered the normal pattern of tiller emergence by slowing the emergence of leaves on the main stem (i.e. increasing the phyllochron) and by reducing the maximum rate of tiller emergence for each tiller.

Rahim *et al.* (2010) evalvated that the effect of phosphorus application and irrigation scheduling on wheat yield and phosphorus use efficiency .The highest number of tillers m^{-2} (307.38) was obtained with 81 kg P_2O_5 ha^{-1} thus recommending higher rate (111 kg P_2O_5 ha^{-1}) was not judicious. Tillering in wheat increased significantly with the increase in number of phosphorus level.

Turk and Tawaha (2002) reported that Band application of P also significantly affected the number of tillers m^{-2} as compared to broadcast application.

Khan *et al*. (2012) carried out A field trail to study the effect of different phosphatic fertilizers on growth attributes of wheat. Phosphorus was applied at the rate of 40 and 80 kg ha^{-1} P in the form of SSP, TSP, NP and DAP. A basal doze of 100 kg N and 60 kg K ha^{-1} was applied as urea and murate of potash (MOP) respectively. It was concluded from the study that phosphorus application at the rate of 80kg P ha^{-1} as single super phosphate (SSP) showed better results as compared to triple super phosphate (TSP), nitrophos (NP) and diammonium phosphate (DAP) on phosphorus deficient soil The results revealed that the maximum numbers of tillers per plant (6.67) were found in the treatment T_6 (80 kg ha^{-1}P as SSP) and minimum numbers of tillers per plant (3.00) in treatment T_1 (control). Different P sources showed significant effect on number of tillers per plant while the number of tillers per plant increased with the increased level of phosphorus application. At both P fertilizer levels applications, Single Super Phosphate (SSP) resulted in maximum number of tillers per plant as compared to Triple Super Phosphate (TSP), Nitrophos (NP) and Diammonium Phosphate (DAP).

Jamwal *et al*. (2004) evaluated that the yield of a crop is dependent upon the combined effect of many factors. Among these factors, the number of tillers per plant has a vital position, controlling yield of wheat. The more the number of tillers, the better will be the stand of crop, which ultimately increases the yield.

2.1.4. Effect on dry matter production

Mamun *et al*. (2005) conducted to determine the direct and residual effects of phosphate rock (PR) on the growth and yield of wheat cv. Kanchan during Rabi season of 2004-2005 at the Bangladesh Agricultural University farm, Mymensingh. The treatments were: T_1: control (0 kg P ha^{-1}), T_2: PR (26 kg P ha^{-1}), T_3**:** TSP (26 kg P ha^{-1}), and T_4: PR (210 kg P ha^{-1} applied in previous crop to cover 6 succeeding crops). Dry matter yield at panicle initiation (PI) stage was significantly influenced by the treatments. Effective tillers hill^{-1} and grains panicles^{-1} varied significantly with P treatments. The highest grain yield (3.10 t ha^{-1}) and straw yield (5.54 t ha^{-1}) were found in T_3 treatment. Economic analysis demonstrated that the highest net benefit of Tk. 24,788 ha^{-1} was obtained in T_3 treatment which was followed by Tk. 22,964 ha^{-1} and Tk.12,292 ha^{-1} in T_4 and T_2, respectively. The highest net benefit was obtained from T_3 treatment due to higher grain and straw yields.

Sarker *et al*. (2014) reported the influence of lime and phosphorus on growth performance and nutrient uptake by indian spinach (*Basella alba* L.) grown in soil. Both lime and P applied alone or in combination had significant effects ($P < 0.001$) on these yield parameters. The trend of treatments effect was similar on both fresh and dry weight. Maximum dry weight of shoot (17.12 g·pot^{-1}) was obtained from 2000 kg lime followed by 1000 kg lime. Untreated control plants (without lime) gave the lowest value (5.29 g·pot^{-1}) and it was statistically identical with 500 kg lime. Application of 1000 kg lime increased dry weight of root progressively giving maximum (3.27 g·pot^{-1}) followed by 2000 kg lime. Plants grown without lime gave the lowest root weight (1.35 g·pot^{-1}). Both the shoot and root dry weights were higher in pots treated with 150 kg P. However, difference in shoot and root dry weight due to 100 and 150 kg P was not statistically significant. Although lime and P increased shoot and root yield, this effect was boosted by combining lime with P applied. Application of 2000 kg lime with 150 kg P increased shoot yields by 52-fold and root yields by 28-fold over control . Increased dry matter yield of Indian spinach due to liming is attributed to the beneficial effect of ameliorating the soil, which increased the Ca-saturation and availability of major nutrients, especially nitrogen. Higher vegetative growth in Indian spinach must have caused efficient extraction of nutrients resulting in higher dry matter production .A maximum yield in the study was obtained at the application of 2000 kg lime with 150 kg P indicating that the soil was effectively neutralized and calcium ions retained on exchange complex.

2.1.5 Effect on relative water content (RWC)

Siddique *et al*., (2000) reported that under deficit water condition relative water contents (RWC) of the leaf and leaf water potential also reduced, which had significant effect on photosynthesis.

Erickson *et al*. (1991) reported that RWC of leaf signals the internal water balance of plant tissue leading to changes in tissue water content and thereby its dry weight.

Raza (2013) also found that RWC were significantly reduced by creating water stress and more reduced RWC were recorded when crop faced deficit water at flower initiation stage. Water deficit lowered the leaf turgor, thus causing reduction in leaf expansion rate. This led to the reduced assimilatory surface of the crop which ultimately adversely affected yield and yield contributing factors.

Ashraf *et al*. (1998) reported that water deficit has strong damaging effect on the plants and it reduced the uptake of P and Ca by plants. More reduced P and Ca (62 and 34%, respectively) uptake was recorded in the plants where drought was created at flower initiation and at tillering stage, respectively. Water stress has the adverse effect on P uptake; P uptake decreased with decreasing soil moisture in wheat genotypes.

2.2 Effect of lime and phosphorus on yield contributing characters

2.2.1 Effect on spike length (cm)

Lombi *et al. (*2004) showed that the effect of phosphorous application to various crops. Spike length was recorded maximum (10.00 cm) in 80 kg P ha^{-1} as SSP application and was noted minimum (5.00 cm) was found in control treatment. Different P sources and levels significantly affected spike length. However, amongst low level, NP resulted in maximum spike length while at high level SSP resulted in maximum spike length as compared to TSP, NP and DAP. He also found that spike length of the cereal crops is the major factor to feed the livestock for the sustainability of the food web. They observed that basal application of the recommended dose of DAP produced significantly taller spike length that ultimately increased the grain and straw yields.

Kamaruzzaman *et al.* (2013) evaluated the effect of lime on yield contributing characters of wheat in barind tract of Bangladesh. There were six lime treatments viz.T_1: Control, T_2: 0.5 t lime ha^{-1}, T_3: 1.0 t lime ha-^{1}, T_4: 1.5 t lime ha-1, T_5: 2.0 t lime ha^{-1}, and T_6: 2.5 t lime ha^{-1}. Dolochun ($CaCO_3$) was used as the liming material. Spike length of wheat was found significantly different due to the increasing amount of lime application. Spike length of wheat ranged from 6.35 to 11.82 cm, tallest spike was found in T_4 treatment which is not statistically similar to others treatment. The treatment T_5 recorded the spike length of 10.08 cm which was comparable to those found in T_3 and T_6 treatments. The treatment T_4 was statistically superior to T_3, T_5 and T_6 treatments in terms of spike length. The grain yield of wheat was positively correlated with spike length characters.

Khan *et al*. (2010) carried out a field experiment to study the effect of different phosphatic fertilizers on growth attributes of wheat. Phosphorus was applied at the rate of 40 and 80 kg P ha^{-1} in the form of SSP, TSP, NP and DAP. A basal doze of 100 kg N and 60 kg K ha^{-1} was applied as urea and murate of potash (MOP) respectively. It was concluded from the study that phosphorus application at the rate of 80kg P ha^{-1} as single super phosphate (SSP) showed better results as compared to triple super phosphate (TSP), nitrophos (NP) and diammonium phosphate (DAP) on phosphorus deficient soil The data pertaining to spike length indicated that it was maximum (10.00 cm) in treatment T_6 (80 kg P ha^{-1} as SSP) while recorded minimum (5.00 cm) in farmer practice. Various P sources and levels application to wheat spike length varied significantly. The data concluded from the results that among low P level application, Nitrophos had enhanced more spike length. Among all high P level application, Single Super Phosphate had produced more spike length as compared to TSP, NP and DAP.

2.2.2 Effect on 1000-grain weight

Kamaruzzaman *et al.* (2010) reported that the effect of lime on yield contributing characters of wheat in barind tract of Bangladesh. There were six lime treatments viz.T_1: Control, T_2: 0.5 t lime ha^{-1}, T_3: 1.0 t lime ha^{-1}, T_4: 1.5 t lime ha^{-1}, T_5: 2.0 t lime ha^{-1}, and T_6: 2.5 t lime ha^{-1}.Liming had also shown significant effect on the 1000-grain weight of wheat. The 1000- grain weight of wheat varied from 29.0 g to 72.67 g. The 1000 grain weight for T_4 was highest (72.67 g) and the lowest was in T_1 (29.0 g). The 1000 grain weight for T_6 was in 2nd highest (57.67 g). The 1000 seeds weight and grain yield of wheat was affected due to changes in soil properties due to liming.

Samia (2007) and Basak (2010) reported that liming increased soil p^H and availability of nutrients which increased the yield components of wheat and mungbean finally higher yields of wheat and mungbean.

2.2.3 Effect on grain yield

Sultana *et al.* (2009) carried out a field experiment to study the effect of liming on soil properties, yield and nutrient uptake by wheat **.**There were eight treatments of liming material applied from dolomite ($CaCO_3.MgCO_3$). Yield and yield components of wheat were recorded at harvest and the grain and straw were analyzed for P, S, Ca and Mg contents. The post harvest soils were analyzed for p^H, available P, Ca and Mg. The application of different rates of lime to soil progressively increased soil p^H and increased availability of P, Ca and Mg in soils. The p^H of the post harvest soils was positively correlated with available Ca and Mg status of soils. The grain yields of wheat were positively correlated with soil p^H, available P, Ca and Mg contents of post harvest soils. Tiller number plant^{-1}, spikelets spike^{-1}, grains spike^{-1}, grain and straw yields were significantly affected by liming. The treatment T_5 (2.0 t lime ha-1) produced grain yield of 4659 kg ha- 1 which was statistically identical to those found in T_6, T_7 and T_8 treatments but higher to those in T_1, T_2, T_3 & T_4 treatments. Liming markedly increased S and Mg concentrations of wheat grain but the concentrations of P and Ca remained unaffected. Total uptake of P, S, Ca and Mg were increased due to application of lime which was mainly associated with increased wheat yields. The application of 2.0 t lime ha^{-1} appears to be optimum for desired soil p^H for wheat (>p^H 6.0), increased availability of nutrients and ultimately increased wheat yield.

Kisinyo *et al*. (2013) laid out a field experiment with a view to finding out the phosphorus sorption and lime requirements of Maize growing acid soils of Kenya. The study determined soil P sorption, lime requirements and the effects of lime on soil p^H, Al levels and available P on the main maize growing acids soils in the highlands east and west of Rift Valley (RV), Kenya. Burnt lime containing 21% calcium oxide was used. The base cations, cation exchange capacity and available P (< 10 mg P kg^{-1} bicarbonate extractable P) were low, except at one site in the highlands east of RV indicative with history of high fertilizer applications. Highlands east of RV soils had higher P sorption (343-402 mg P kg^{-1}) than the west (107-258 mg P kg^{-1}), probably because of their high Al^{3+} ions and also the energies of bonding between the soil colloids and phosphate ions. Highlands east of RV also had higher lime requirements (11.4-21.9 tons lime ha^{-1}) than the west (5.3-9.8 tons lime ha^{-1}).

Ranjha *et al. (*2010) evaluated that the effect of phosphorus application and irrigation scheduling on wheat yield and phosphorus use efficiency. Fertilizer P doses 0, 47, 81 and 111 kg P_2O_5 ha^{-1} were calculated by using adsorption isotherms and applied by broadcast and band placement. Four irrigations i.e. 0, 2, 3, 4 were applied at critical stages of wheat. Basal N: K=130:65 kg ha^{-1} were applied. Wheat grain yield increased from 1.58 Mg ha^{-1} to 3.94 Mg ha^{-1} with the use of P @ 81 kg P_2O_5 ha^{-1}. Band placement of P proved better over broadcast, whilst three irrigations at crown roots, booting, and grain development stages were sufficient to get maximum yield and improve phosphorus use efficiency.

Mbakaya *et al*. (201) reported that effects of liming and inorganic fertilizers on maize yield. The study demonstrated integrated soil fertility management technologies (ISFM). Treatments included Lime, Diamonium phosphates, Mavuno, Lime + Diamonium phosphates, Lime + Mavuno and conventional farmers practice (FP) as control. The test crop to evaluate the technologies was several maize varieties (WS 505, Hybrid 516, Hybrid 6210, DK 8031 and KSTP94).The soil chemical analysis results showed most parts of Kakamega North and Ugunja were acidic with p^H ranging from 4.63 to 5.81. Overall, farmers rated DAP and Lime + DAP first, Mavono alone third, Mavuno + Lime fourth, lime alone fifth and farmers' practice last based on maize yields at harvesting. Liming was highly appreciated by all farmers due to appreciable maize yield increase realized compared to farmers' practice.

Khan *et al*.(2007) observed that effect of phosphorus application on wheat and rice yield under wheat- rice systema field experiment was conducted to study the response of wheat and rice to phosphorus during 2004-05 . The basal dose of N at 120 kg and K_2O at 60 kg ha^{-1} was applied with P levels (0, 45 and 90 kg P_2O_5 ha^{-1}) to both wheat and rice crops. Phosphorus application significantly increased the grain yield of wheat from 2920 kg ha^{-1} in control to 3560 kg ha^{-1} in the treatments receiving P at 90 kg P_2O_5 ha^{-1} giving an increase of 22 % over control. The number of tillers, spikes, spike length and plant height of wheat were also significantly increased by P application. The rice also showed positively response to P application and hence both yield and yield parameters were significantly greater in the P than in the check treatment. Paddy yield was increased significantly by P application up to 75% over control. Plant height and 1000 grain weight were also significantly increased with P application over control. The application of P significantly increase number of spike $plant^{-1}$ and spike length over control, however no statistical difference was recorded among the treatment. The cumulative application of 90 kg P_2O_5 ha^{-1}gave the highest increase of 75% while direct application of the same level gave an increase of 54% however 47% increase over control was recorded by the residual application of 90 kg P_2O_5 ha^{-1}.

Martini *et al.* (1974) studied the response of soybean to the direct and residual effect of liming in relation to soil acidity, Al and Mn toxicities and P availability in five Oxisols of Southern Brazil under successive wheat-soybean cropping. They observed that there was a significant increase in yield due to the high exchangeable Al and extractable Mn, the low p^H exchangeable Ca $^+$ Mg and available P found in these soils. Optimum yields were obtained when liming adjusted Al from 0.1 to 0.5 me per 100 g, soil p^H from 5.2 to 5.7 and Ca $^+$ Mg from 5.7 to 8.5me per 100 g.

Bheemaiah and Ananthanarayana (1984) reported that pod yield of groundnut increased with successive increments in calcium saturation levels (18.75 to 150.00%).

Mathur *et al.* (1985) in their studies on the methods of lime application (as amendment on surface and as fertilizer in furrows), observed the maximum yield at lime applied from 2 to 5.0 q per ha in furrows.

Sudhir *et al.* (1987) revealed that there was significant increase in the pod yield of groundnut with the application of 1875 kg calcium carbonate and with further increase in the dose of lime there was decrease in yield.

Vishwanath *et al.* (1990) observed that there was no significant variation in oil content due to increase in calcium saturation levels (35, 40, 45 and 50%). However, the increase in oil yield was observed with increase in calcium saturation up to 45 per cent and afterwards oil yield of sunflower declined. Panda *et al*. (1990) conducted a field experiment to study the effect of different sources of phosphorus and levels of lime on groundnut was studied by on a saline soil (p^H 5.0), applying 0, 1.25 and 2.50 tons per ha of lime as paper mill sludge, gave pod yield of 1.63, 1.92 and 2.17 t per ha, respectively. They also reported applying 60 kg P_2O_5 per ha as DAP, SSP, MRP or 50% as SSP + 50% as MRP gave yields of 1.81, 1.78, 1.91 and 2.11 tonnes per ha, respectively.

Nakagawa *et al.* (1990) reported that effects of some phosphorus sources and liming on groundnut seed quality. They observed the percentage of large seeds and 100- seed weight were not generally affected by P sources or liming. Germination of seed harvested from the wet season crop was greater with than without liming after nine months storage.

Rao *et al*. (1991) studied the effect of phosphorus and liming on lateritic soil (p^H 5.85) intercropped with pigeonpea and groundnut, given 1.25 t lime per ha or no lime and increasing P_2O_5 rates (0, 25, 50 and 75 kg/ha) increased pigeonpea seed yields in pure stands from 0.58 to 1.29 t per ha and groundnut yield in intercropped stands from 1.32 to 2.66 t per ha. They also observed groundnut pod yields in pure stands increased from 1.15 to 1.76 t per ha with 50 kg P_2O_5 kg per ha.

Savani *et al.* (1991) investigated the influence of sulfuric acid on the availability of applied phosphorus to groundnut in calcareous soils. They felt groundnuts cv. Gujarat-1 were grown in soil containing 13 or 33 per cent lime and given 0 or 11 ppm P and 0, 500 or 1000 ppm S as sulfuric acid. High lime content (33%) of soils reduced the pod and haulm yield but P and S uptake were unaffected. They also observed application of 500 ppm S significantly increased pod yield, but there was no further increase in yield with 1000 ppm S.

Mittra *et al.* (1992) obtained from the study conducted in which N (as urea), P (as rock phosphate or superphosphate), S (as gypsum), blue green algae and green manures or paper mill sludge (as liming material) were applied to a rice groundnut rotations. They concluded that on lateritic soils liming and application of S fertilizer gave the best results.

Sharma *et al*. (1994) carried out a field trail to study the effect of phosphorus, lime and farmyard manure on the yield and uptake of calcium and magnesium at different growth stages in late sown wheat in an acid Alfisol at Himalayan region was studied by and they reported an application of 8 tonnes FYM and

90.25 kg per ha P_2O_5 was optimum and gave 38.70 q per ha of grain yield with a profit of Rs. 4692 per ha.

Samanta *et al.* (1994) investigated the effect of lime and phosphorus on phosphate availability and yield of groundnut (cv. AK 12-24) in a field experiment on a sandy clay loam soil (p^H 5.3) amended with 0, 15 or 4.5 t lime per ha and 0, 30, 60 or 90 kg P_2O_5 per ha. They felt liming increased soil P availability and pod yield.

Dixit *et al.* (1995) studied the effect of lime and potassium on lime and phosphate potential and crop yield on an Alfisol and concluded that in a wheat-soybean-linseed cropping sequence, lime and potassium application increased the lime potential. Whereas, the effect was reverse in case of phosphate potential in the soil. The increase in lime potential and decrease in phosphate potential following lime and potassium addition significantly increased the grain yield of all the test crops.

Mandimba and Kils (1997) reported that Field experiments in Mfilou-Gamba district, Congo on short duration groundnut cv. Talon-Dame was conducted by on an acidic soil and given 80 kg P_2O_5 + 50 kg K_2O per ha alone or in combination with 2, 4, 6 or 8 t CaO per ha. He felt all treatments increased soil p^H (control soil p^H 4.74), nodule mass compared to control plot. Liming also increased shoot mass, shoot N accumulation, pod yield and seed yield especially at 6 or 8 t CaO per ha.

Mongia *et al.* (1998) studied the response of rice to liming and P application in acid soils of South Andaman. They felt application of lime alone did not influence markedly the grain and straw yield. But, both lime and P application showed significant positive effect of both grain and straw yield.

Kailash (2002) conducted a field experiment during the rainy season of 1994 and 1995 on maize succeeded by soybean during 1996 and 1997 to study the direct and residual effects of lime in an acid hill Ultisol of Manipur. They observed liming increased the base saturation and reduced the exchangeable aluminium, the maize yielded maximum (2.83, 2.70 t/ha during 1994 and 1995, respectively) with lime requirement level, beyond which its yield decreased significantly to 1.70 and 1.80 t per ha during 1994 and 1995, respectively with 0.75 lime requirement level.

Verma (1999) evaluated that the effect of phosphorus on crop yields in wheat-soybean cropping sequence in acid Alfisols amended with lime and gypsum was studied with three levels of lime (0, 1.5 and 3.0 t/ha), three levels of gypsum (0, 2.7 and 5.4 t/ha) and four levels of phosphorus (0, 30, 60 and 90 mg/kg soil). They felt the average increase in grain yield as a consequence of the application of 30, 60 and 90 mg per kg soil of P amounted to about 118, 193 and 227 per cent in wheat and 104, 170 and 213 per cent in soybean, respectively over the control.

Tanglina *et al.* (1999) laid out a field experiment with a view to find out the effects of different liming rates on photosynthesis, root growth, disease resistance, yield and leaf quality of tobacco were investigated by, they observed application of 750 kg lime per ha to soil (p^H 5.2) increased the proportion of high quality leaves, average price per kg and production value per ha.

Gogoi *et al.* (2000) studied the effect of levels of lime and nitrogen on production of groundnut with variety JL-24, involving three levels of lime and five level of nitrogen. They concluded that liming at 50 per cent lime requirement recorded the highest pod, haulm and oil yield during the growing season.

Deka *et al.* (2001) stated that an experiment was conducted by to study the response of groundnut cv. JL-24 to lime and nitrogen application through lime and urea, respectively. Three levels of lime (0,25 and 50% LR) and combinations of five levels of N (0, 20, 40, 60 and 80 kg/ha). They revealed that highest N, P and K uptake both in kernel and stover and total uptake were recorded under 50 per cent lime requirement. Application of nitrogen resulted in significantly higher N, P and K uptake with 40 kg N per ha giving the maximum increase.

Berman *et al.* (2001) studied that the effect of different levels of lime (0, 25 and 50% LR) and P (0, 25, 50, 75 and 100 kg/ha) on nutrient content and uptake of groundnut cv. AK 12- 24. They felt the lime requirement to raise the soil p^H upto 6.5 from the initial value was 1.2 t per ha. N, P and K contents in kernel and stover and their uptake were higher under 50 per cent lime requirement.

Raychaudhuri *et al.* (2002) investigated that the yield response of groundnut to dual inoculation and liming of an acid hill Ultisol of Manipur was studied by They conducted an experiment to study the efficiency of single as well as dual inoculation with *Rhizobium* and phosphate solubilizing microorganism (*Bacillus polymyxa*) in increasing the yield under limed and controlled condition. They observed *Rhizobium* alone did not increase the pod and haulm yields significantly, but when inoculated in combination with *B. polymyxa* increased the nodule weight per plant (0.23 g), pod (1520 kg/ha) and haulm yield (2250 kg/ha) and their respective N uptake (65.1 and 61.5 kg/ha), respectively and P uptake (4.98 and 4.63 kg/ha, respectively) significantly. *B. polymyxa* was effective in solubilizing the insouble phosphorus of the soil and increased the available P content in the soil by 13.5 per cent.

Nguyen-Cong-Vinh (2003) was studied the response of groundnut (cv. Senlai) to various P rates (0, 30, 60, 90, 120 and 150 kg/ha P_2O_5 as single super phosphate) and other sources (SSP, fused magnesium phosphate and farmyard manure). He observed that the highest increase in yield due to P application was 0.303 t per ha in 1997 and 0.271 t per ha in 1998. Application of P fertilizer increased pod yield by 26 to 66 per cent and seed yield by 24 to 102 per cent, SSP with lime (500 kg/ha) gave higher pod and seed yields than fused magnesium phosphate with lime.

Tran-thi-tha-ha (2003), studied the effects of phosphorus fertilizer on groundnut yield on poor alluvial and sandy soils of Thua Thien Hue was studied by P was applied at five rates (30, 60, 90, 120 and 150 kg P_2O_5/ha), based on 8 tonnes of FYM, 40 kg N, 60 kg K_2O and 500 kg lime per ha for poor alluvial soil and on 30 kg N, 60 kg K2O and 300 kg lime per ha for sandy soil, phosphorus was applied as SSP, N as urea, K as MOP and lime as calcium oxide. He observed P fertilizer significantly increased groundnut yield on both soils. Yields higher than those of the control were recorded for plants grown on poor alluvial soil treated with 60 kg P_2O_5 per ha and on sandy soil treated with 90 kg P_2O_5 per ha, respectively.

Dixit and Sharma (2003) studied the effect of phosphorus and lime on productivity and phosphorus uptake by onion in a Typic Haplustalf of Himachal Pradesh with three levels of lime *i.e.,* L_0 (1.54 t/ha) and L_1 (3.08 t/ha) and four levels of phosphorus *i.e.,* P_0, P_1, P_2 and P_3 as 0, 16.3, 32.6 and 48.9 kg per ha. They observed application of lime significantly increased the marketable bulb yield of onion upto 3.08 t per ha, the increase in the productivity of onion over no lime was 23 and 41 per cent owing to 1.54 and 3.08 t per ha lime application. Liming also increased the P uptake by onion significantly. There was 49 per cent increase in P uptake over no lime in the treatment where lime was applied @ 3.08 t per ha.

Dosai *et al.* (2003) carried out by to find the effect of lime application to groundnut on the change in soil acidity in Alfisols of Konkan. They concluded furrow application of lime at one-tenth, one-half and equal to lime requirement to groundnut increased pH, exchangeable calcium and decrease the different forms of acidity, exchangeable aluminium and iron and increased pod yield of different genotypes of groundnut.

Dixit and Sharma (2004) studied that the effect of lime and phosphorus on yield and phosphorus uptake by radish in mountainous acidic soil of Northwest Himalayas, India with three level of lime (0, 1.54 and 3.08 t/ha) and four levels of phosphorus (0, 11, 22 and 33 kg P/ha). They felt lime application with full lime requirement (3.08 t/ha) significantly upgraded the productivity and the uptake of P in radish *i.e.*, 32 and 41 per cent, respectively. Like-wise the application of phosphorus up to highest level *i.e.*, 33 kg per ha also improved the yield and P uptake to a significant level, the increase in productivity of radish was 25 per cent and increase in P uptake was 40 per cent when P was applied @ 33 kg per ha over no P.

Hossain *et al*. (2011) laid out a field experiment with a view to find out the Effect of Lime, Magnesium and Boron on Wheat and their residual effects on Mungbean the Experiment was laid out in Randomized Complete Block Design with three replications, both in wheat and mungbean. Treatments for wheat were (I) recommended fertilizer + Mg + B, (II) recommended fertilizer + lime + B + Mg, (III) recommended fertilizer + lime + Mg, (IV) recommended fertilizer + lime + B and (V) control (Only recommended fertilizer) and for mungbean were (I) recommended fertilizer + Mg + B, (II) 75% of recommended dose, (III) recommended fertilizer + B, (IV) recommended fertilizer + Mg and (V) control (without fertilizers). Results showed that the highest yield and yield components of wheat were recorded from recommended fertilizers + lime + B + Mg treated plot and the second highest were recorded from recommended fertilizers + lime + Mg treated plot. The lowest was recorded in control plot (only recommended fertilized). In case of mungbean the highest was found from recommended fertilizers + B treated plot, this treatment was limed in previously cultivated wheat crop and the lowest was recorded from control plot (without fertilizer).

Osundwa *et.al* (2013) studied that influence of agricultural lime on soil properties and wheat yield on acidic soils. The experiment was a split plot arrangement with two wheat varieties as the main plots and the lime treatments as the subplots. The two varieties compared were 'Njoro BW 2' and 'KS Mwamba' characterized as tolerant and moderate tolerant to soil acidity, respectively. Phosphorus and nitrogen were applied as a blanket treatment at the rates of 40 kg P_20_5 /ha and 46 kg N/ha respectively. Lime was applied at the rates of 0.0, 0.5, 1.0, 1.5 and 2.0 t/ha. Soil p^H and soil available P increased with the increase in the rate of lime addition. Wheat grain yield increased significantly (p=0.05) due to soil acidity amendment above the control. The most profitable treatment was 2 t/ha of lime in Njoro BW 2 at Kipsangui site. There was no viable treatment at Chepkoilel site. Higher wheat yields may probably be achieved from rates of lime above 2 t/ha.

Rahman *et al.* (2013) conducted a field experiment during 2009-10 and 2010-11, to determine adaptability of Wheat varieties in strongly acidic soils of Sylhet**,** 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 seeds were sown on 05 December 2009 and 30 November 2010 for the growing season of 2009-10 and 2010-11, respectively. The wheat varieties used in this study were Shatabdi, Sufi, Sourav, Bijoy, Prodip, BARI Gom-25 and BARI Gom-26. The index of relative performance of each variety in comparison to mean yield of all varieties under the contrast conditions of liming and non-liming was estimated to determine relative adaptability of wheat variety under experimental soil conditions. 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.

Khan *et al*. (2010) laid out a field experiment with a view to find out the effect of different phosphatic fertilizers on growth attributes of wheat Phosphorus was applied at the rate of 40 and 80 kg P ha^{-1} in the form of SSP, TSP, NP and DAP. A basal doze of 100 kg N and 60 kg K ha^{-1} was applied as urea and murate of potash (MOP) respectively. It was concluded from the study that phosphorus application at the rate of 80 kg P ha^{-1} as single super phosphate (SSP) showed better results as compared to triple super phosphate (TSP), nitrophos (NP) and diammonium phosphate (DAP) on phosphorus deficient soil Number of grains per spike is one of the easily determinable characters, which has a positive co-relation with the yield. The results showed that maximum numbers of grains per spike (39.67) were observed in treatment T_6 (80 kg P ha^{-1} as SSP) and minimum numbers of grains per spike (33.33) were observed in treatment T_1 (control). Different P sources showed significant effect on number of grains per spike. Number of grains per spike increased with the increased level of phosphorus application. At low P level applications, DAP increased more number of grains per spike while at high P level applications, SSP had produced maximum number of grains per spike as compared to TSP, NP and DAP.

Uzoho *et al*. (2010) reported that Maize (*Zea mays*) response to phosphorus and lime on gas flare affected soils. The experimental design was a 2 x 2 x 4 factorial of 2 sites (S_1 and S_2), 2 P rates (0 and 30 kg P_20_5 ha^{-1}) and 4 lime rates (0, 1, 1.5 and 2.0 t ha^{-1}) in a CRD and replicated 3 times. Plant height, leaf area, dry matter yield, nutrient uptake (N and P) and residual soil properties (pH, Ca, Mg and P) increased with treatments up to 30 kg P_20_5 ha^{-1} and 1.5 t ha^{-1} lime combined rates in both sites. Maize performance and residual soil properties were better in S_2 than S_1 due its higher fertility status and distance (400 m) from the gas flare pit. Performance of all measured parameters were best using 30 kg P_20_5 ha^{-1} and 1.5 t ha^{-1} lime combined rates

Kamaruzzaman *et al*. (2013) evaluated the effect of lime on yield contributing characters of wheat in barind tract of Bangladesh. There were six lime treatments viz.T_1: Control, T_2: 0.5 t lime ha^{-1}, T_3: 1.0 t lime ha-1, T_4: 1.5 t lime ha^{-1}, T_5 : 2.0 t lime ha^{-1}, and T_6 : 2.5 t lime ha^{-1}. Dolochun ($CaCO_3$) was used as the liming material. Grain yield of wheat (var. Prodip) was significantly responded due to application of different rates of lime. The highest grain yield was found in T_4 (4.73 t ha^{-1}) while the lowest was in T_1 treatment (2.71 t ha^{-1}). The rate of lime application 0.5 t ha^{-1} (T_2) significantly increased the grain yield of wheat compared to control treatment. Application of lime increased grain yield of wheat to a considerable extent but application of lime at the rate of 1.5 t ha^{-1} was optimum for desired yield of wheat in the study area. The application of 0.5, 1.0, 1.5, 2.0 and 2.5 t lime ha^{-1} recorded 3.41, 3.89, 4.73, 4.49 and 4.30 t ha^{-1} compared to lime control treatment. The grain yield of wheat was positively correlated with different plant characters like plant height. The grain yield of wheat was affected by changes in soil properties due to liming. It appeared that liming increased soil p^H and availability.

Caires *et al*. (2006) reported that surface liming caused increases up to 140% in the grain yield of wheat.

Kisic *et al*. (2002) found that besides mineral and organic fertilization, liming also rendered significantly higher yields compared to the control and relatively higher yields than treatments involving mineral fertilizers.

Jovanovic *et al*.(2006) found that liming considerably influenced the yields of the field crops and single application of high rates was the better choice compared with repeated use of low rates.

Poulsen *et al.* (2005) recommended that the phosphatic fertilizer application enhanced significantly higher number of grains per spike which ultimately increased the grain and straw yields. DAP and SSP had produced more number of grains per spike as compared to other P containing fertilizers.

Rasel *et al*. (2009) carried out a field experiment to study the effect of lime on yield contributing characters of wheat in barind tract of Bangladesh. There were six lime treatments viz.T_1: Control, T_2: 0.5 t lime ha^{-1}, T_3: 1.0 t lime ha^{-1}, T_4: 1.5 t lime ha^{-1}, T_5: 2.0 t lime ha^{-1}, and T_6: 2.5 t lime ha^{-1}. He found that the number of grains $spike^{-1}$ of wheat ranged from 28.33 to 41.33. The highest number of grains was found in T_4 treatment which is not statistically similar to all the treatments. The treatments T_2 and T_3 and T_5 and T_6 recorded identical number of grain $spike^{-1}$. Again the treatment T_3 recorded higher number grains $spike^{-1}$ over T_2 treatment but they were statistically alike. The grain yield of wheat was positively correlated with the number of grains $spike^{-1}$ characters.

Samia *et at*. (2007) found that liming effect of the number of grains $spike^{-1}$ was significantly influenced by the different treatments of lime.

2.2.4 Effect on straw yield

Asrat *et al*. (2014) studied the effect of integrated use of lime, manure and mineral P fertilizer on bread wheat yield. The aim of this study was to examine the effects of integrated use of lime, manure and mineral P fertilizer on acid soils for wheat production and status of residual soil P. The treatments were factorial combinations of lime, manure and P fertilizer which were laid down in a randomized complete block design with three replications. 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 yield at non-significant ($p > 0.05$) level. In these interactions lime rates were related in quadratic trend while manure and mineral P related linearly. The combined application of 5 t manure and 2.2 t ha^{-1} lime increased grain and straw yield by 279% and 187%. The present 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. It is resulted that the application 2.2 t ha^{-1} lime increased straw yield by 187% respectively.

Kaitibie *et al*. (2014) evaluated economics of lime and phosphorus application for dual-purpose winter wheat production in low-p^H soils .After decades of continuous cropping, the p^H of many soils used to produce continuous winter wheat (*Triticum aestivum* L.) in the southern plains of Oklahoma has declined to levels that limit wheat grain and forage yield. Data from a 3-yr study were used to determine the effect of lime and diammonium phosphate (DAP) application on fall–winter forage yield and grain yield of winter wheat grown in extremely acid soil and to determine the economically optimal strategy for dual-purpose (forage plus grain) wheat production. A split-split plot with sub-subplot treatments arranged in a randomized complete block design was used, with lime in the main plots, variety in the subplots, and DAP in the sub-subplots. Grain yield significantly increased (0.05) with lime at 2800 kg ha 1effective calcium carbonate equivalent (ECCE), DAP at 73 kg ha 1applied in seed furrows or DAP at 146 kg ha1 broadcast. Forage yields were greatest when DAP was applied at 146 kg ha^{-1} in seed furrows (0.05). When lime costs were fully assessed in the year of application, the strategy. of applying 73 kg ha^{-1} DAP in seed furrows and zero lime generated the greatest expected returns across all forage value estimates and grain prices. With lime costs amortized over a 5-yr period, the optimal strategy included both the application of lime before the initial season and 73 kg ha^{-1}DAP in seed furrows in each season.

Mamun *et al*. (2006) conducted a field experiment during rabi season, to determine the effect of phosphate rock on the growth and yield of wheat under old brahmaputra floodplain soils. The experiment was designed with four treatments and was laid out in a Randomized Complete Block Design (RCBD) with four replications. The treatments were: T_1: control (0 kg P ha^{-1}), T_2: PR (26 kg P ha^{-1}), T_3**:** TSP (26 kg P ha^{-1}), and T_4: PR (210 kg P ha^{-1} applied in previous crop to cover 6 succeeding crops). The highest grain yield (3.10 t ha^{-1}) and straw yield (5.54 t ha^{-1}) were found in T_3 treatment. Economic analysis demonstrated that the highest net benefit of Tk. 24,788 ha^{-1} was obtained in T_3 treatment which was followed by Tk. 22,964 ha^{-1} and Tk.12,292 ha^{-1} in T_4 and T_2, respectively. The highest net benefit was obtained from T_3 treatment due to higher grain and straw yields.

CHAPTER 3
MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, intercultural operations, data collection and statistical analysis.

3.1 Location

The field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2012 to March 2013. Geographically the experimental field is located at 23°46' N latitude and 90° 22' E longitude (Google maps, 2014) at an elevation of 8.2 m above the sea level belonging to the Agro-ecological Zone “AEZ-28” of Madhupur Tract (BBS, 2011). The location of the experimental site has been shown in Appendix I.

3.2 Soil

The soil of the research field is high acidic in reaction p^H 5.4 with low organic matter content. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done from Soil Resources Development Institute (SRDI), Dhaka. The experimental plot was also high land. The Physical characteristics and chemical composition of soil of the experimental plot are given in Appendix II.

3.3 Climate

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year (Biswas, 1987). The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991). The detailed meteorological data in respect of air temperature, relative humidity, total rainfall and soil temperature recorded by the Weather Station of SAU, Sher-e-Bangla Nagar, Dhaka during the period of study have been presented in Appendix III.

3.4 Plant materials and features

Wheat Research Centre, Bangladesh Agricultural Research Institute (BARI) so far released 28 wheat varieties of which BARI Gom 26 (Hashi) was released in 2010. BARI Gom 26 is one of the recommended varieties for commercial cultivation in Bangladesh. BARI Gom 26 was used as plant material for the present study. Seeds were collected from the Wheat Research Centre, BARI, Joydebpur, Gazipur. Germination test of seed was done in the laboratory before sowing and germination was found to be 95%. The characteristics of the variety used are as follows.

BARI Gom 26: The variety is semi-dwarf in height with high yield potential as released in 2010. The grain yield ranges from 4.0-5.0 t ha^{-1} under optimum management. It requires 60-65 days to heading and 104-110 days to mature. Spike is medium with 45-50 grains per spike. Grains are amber in color, bright and larger in size (1000-grain weight 48-52 g). The variety is tolerant to terminal heat stress giving 10-12% higher yield than BARI Gom 21 (Shatabdi) under late seeding. The variety is tolerant to bipolaris leaf blight and resistant to leaf rust diseases with moderate level of resistance to stem rust race, Ug 99. The variety is suitable for growing both in optimum and late seeding condition. It can also be grown successfully throughout the country except in areas with salinity level less than 6 dS/m. (BARI, 2012).

3.5 Treatments

The experiment consisted of two treatment factors as mentioned below.

Factor 1 : Lime

1. L_0=No Lime (control)
2. L_1= 1 t ha^{-1}
3. L_2= 2 t ha^{-1}

Factor 2: Phosphorus

1. P_0= No P_2O_5 ha^{-1}(control)
2. P_1= 48 kg P_2O_5 ha^{-1}
3. P_2= 77 kg P_2O_5 ha^{-1}
4. P_3=106 kg P_2O_5 ha^{-1}

3.6 Design and layout

The experiment was laid out in a split plot design with three replications. The size of the individual plot was 5m × 2m and total numbers of plots were 36. There were 12 treatments combinations. Lime treatments were placed along the main plot and phosphorus treatments were placed in the sub plot. Layout of the experiment was done on November 14, 2012 with interplot spacing of 0.50 m and inter block spacing of 1 m.

3.7 Land preparation

The land of the experimental field was first opened on November 5, 2012 with a power tiller. Then it was exposed to the sunshine for 7 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. Deep ploughing was done to produce a good tilth, which was necessary to get better yield of the crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the experimental field. The soil was treated with insecticides at the time of final ploughing . Insecticides, Furadan 5G was used @ 8 kg ha^{-1} to protect young plants from the attack of mole cricket, ants, and cutworms.

3.8 Fertilizer application

The following doses of manure and fertilizers were used:

Cowdung	:	10 t ha^{-1}
Urea	:	220 kg ha^{-1}
MoP	:	50 kg ha^{-1}
Zypsum	:	110 kg ha^{-1}
Zinc oxide	:	4 kg ha^{-1}
Boric acid	:	5 kg ha^{-1}

The total amount of cowdung, M0P, gypsum, zinc oxide and boric acid were applied during final land preparation. Lime and phosphorus fertilizers were applied as per treatments in each plot. Urea was applied in three equal splits, during final land preparation, crown root initiation stage (21 DAS) and panicle initiation stage (53 DAS). The fertilizers were incorporated to soil by spading one day before sowing.

3.9 Seed treatment

Seeds were treated with Vitavex-200 @ 0.25% before sowing to prevent seeds from the attack of soil borne disease.

3.10 Seed sowing

Seeds were sown on November 15, 2012 continuously in 20 cm apart rows opened by specially made iron hand tine. The seed rate was 120 kg ha^{-1}. After sowing, the seeds were covered with soil and slightly pressed by hands.

3.10.1 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.10.2 Thinning

Emergence of seedling was completed within 10 days after sowing. Overcrowded seedlings were thinned out for two times. First thinning was done after 15 days of sowing which was done to remove unhealthy and lineless seedlings. The second thinning was done 10 days after first thinning keeping one or two or three healthy seedlings in each hill according to the treatment.

3.10.3 Weeding

Weeding was done twice during the whole growing period, the first weeding after 20 days of sowing and the second other after 40 days of sowing. During the irrigation care was taken so that water could not flow from one plot to another or overflow the boundary of the plot.

3.10.4 Irrigation

The first irrigation was done at 21 DAS, crown root initiation stage. Second irrigation was provided at 55 DAS which is the maximum tillering stage of wheat and the last irrigation was done at 75 DAS, grain filling stage.

3.10.5 Insect and pest control

The crop was attacked by different kinds of insects (cereal aphid and grass hopper) during the growing period. The experimental plots were sprayed at 35 days with appropriate insecticides to control the insects. Insecticide was applied to the plots after irrigation at afternoon. Two guards were appointed to protect the wheat grain from birds especially pigeons from mid February to harvest.

3.11 General observations of the experimental field

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants which were vigorous and luxuriant in the treatment plots than that of control plots.

3.12 Sampling

Ten plants were collected randomly from each plot. These 10 plants were used for taking yield component data.

3.13 Harvest and post-harvest operation

The crop was harvested on March 2, 2013. At maturity, when leaves, stems and pods became yellowish in colors, then the plants were harvested. One meter area was harvested for yield data and it was converted to t ha^{-1}. The harvested plants were tied into bundles and carried to the threshing floor. The crops were sun dried by spreading on the threshing floor. The seeds were separated from the plants by paddle thresher and there after were cleaned, dried and weighed. The weights of the dry straw were also taken from the same demarcated area and were also converted to t ha^{-1}.

3.14 Collection of data

3.14.1 Relative water content (%): To determine RWC the flag leaves were sampled (Baque *et al*,2002) .The leaves were placed in polythene bags and transported to the laboratory as quickly as possible in order to minimize water losses due to evaporation (Baque *et al*,2002) .The leaves were also weighed immediately as fresh weight (FW), then leaves were immersed in distilled water for 24 hours at room temperature in the dark. These leaves were weighed after removing excess water by gently wiping with paper towel to determine their turgid weight (Baque *et al*,2002) .The leaves were then dried in an oven for 72 h at 70^0c to determine their dry weights (Baque *et al*,2002) .The fresh, turgid weight (TW) and dry weights (DW) of the leaves were used to calculate the following:

Relative water content (RWC) % $= \frac{\text{fresh weight} - \text{dry weight}}{\text{turgid weight} - \text{dry weight}} \times 100$

3.14.2 Water saturation deficit (%) =(100-RWC)

3.14.3 Water retention capacity (%) $= \frac{\text{Turgid weight}}{\text{Dry weight}}$

3.14.4 Crop growth parameters

- Total dry matter weight of plant at 45 DAS after that 10 days interval up to harvest.
- Plant height (cm) after harvesting.

3.14.5 Yield Contributing Characters

- Effective tillers m^{-2}
- Spike length (cm)
- Number of spikelets $spike^{-1}$
- Weight of 1000 grains (g)

3.14.6 Yield and harvest index

- Grain yield (t ha^{-1})
- Straw yield (t ha^{-1})
- Biological yield (t ha^{-1})
- Harvest index (%)

3.15 Procedure of sampling for growth study during the crop growth period

Dry weight plant^{-1}

With the help of hand weeder (nirani) 10 plants were uprooted and cleaned with water. Plants were oven dried at 80ºC for 72 hours until a constant weight was obtained. The dry weight of plants were recorded in gram and converted into dry weight plant^{-1}. The data were collected at 45,55,65,75 and 85 DAS.

3.16 Procedure of data collection for yield and yield components

For assessing yield parameters except the grain and straw yields data were collected from 10 randomly selected hills from each of the plots. For yield measurement, an area of 1.0 m^2 from center of each plot was harvested.

Effective tillers m^{-2}

The average number of effective tillers of one linear meter was counted and then multiplied with wheat row per meter.

Spike length (cm)

The length of spike was measured by using a meter scale. The measurement was taken from the base to tip of the spike. Average length of spike was taken from 10 randomly selected spikes from inner row plants of each plot. Data was recorded at harvest time. Mean data was expressed in centimeter (cm).

Spikelet's spike^{-1}

Data on the number of spikelet's spike^{-1} was counted. Ten spike bearing plants were randomly selected and the average data were collected from inner rows of each plot except harvest area during the time of harvesting.

Grains spike^{-1}

The total number of filled grains from randomly selected ten spikes were counted and average of which gave the number of filled grains spike^{-1}. Presence of any food material in the grains was considered as filled grain.

Weight of 1000 grains (g)

One thousand cleaned dried grains were randomly collected from the seed stock of each plot and were sun dried properly at 14% moisture content and weight by using an electric balance.

Grain and straw yield (t ha^{-1})

An area of 1.0 m^2 harvested for yield measurement. The crop of each plot was bundled separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in sun.

Biological yield

Biological yield was calculated by using the following formula:

Biological yield= Grain yield + straw yield

Harvest index (%)

Harvest index is the relationship between grain yield and biological yield (Gardner *et al.*, 1985). It was calculated by using the following formula:

$$\text{Harvest index} = \frac{\text{Grain yield (t ha} - 1)}{\text{Biological yield (t ha} - 1)} \times 100$$

3.17 Statistical analysis

The recorded data were subjected to statistical analysis. Analysis of variance was done following two factor split plot design with the help of computer package MSTAT-C. The mean differences among the treatments were adjusted by Duncan's Multiple Range Test (DMRT) at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

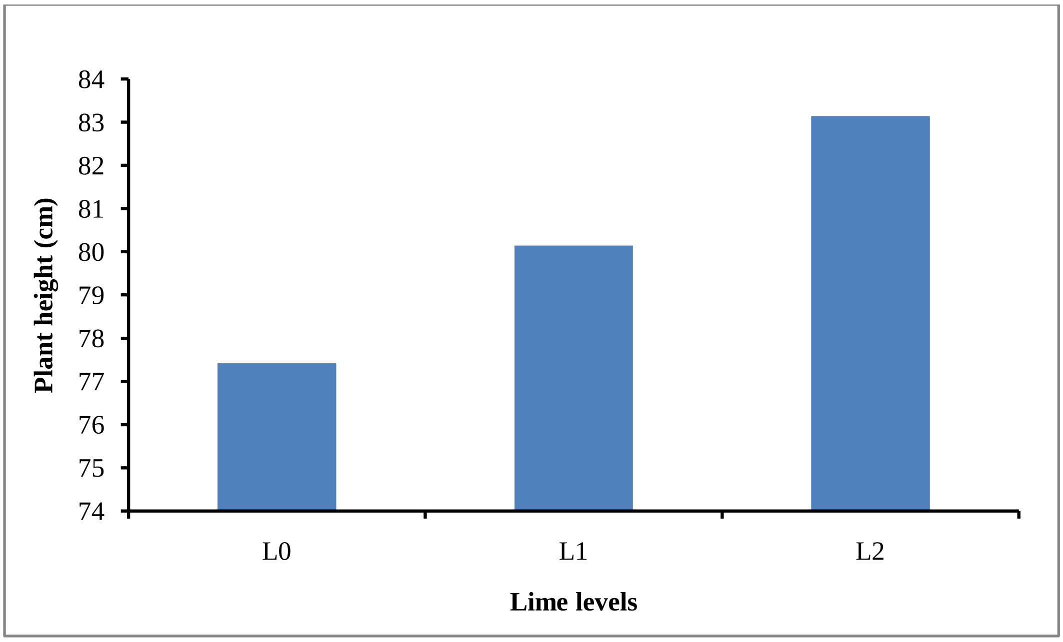
The present experiment was conducted to study the growth and yield response of wheat to the application of lime and phosphorus level. Data on different growth and yield of wheat were recorded. The analysis of variance data on different growth and yield contributing characters as well as yield of wheat as influenced by different levels of lime and phosphorus has been presented in Appendix III-XVI. The results have been presented and discussed with the help of table and graphs and possible interpretations are given under the following headings.

4.1 Growth parameters

4.1.1 Plant height (cm):

4.1.1.1 Effect of lime

Plant height of wheat was found statistically significantly affected by different levels of lime. The external application of different rates of lime significantly increased the plant height of wheat (Fig.1). Plant height of wheat progressively increased with increasing in lime rates. After harvest, the plant height ranged from 77.42 cm in L_0 (control) treatment to 83.14 cm in L_2 treatment. The highest plant height recorded in L_2 (83.14) which was statistically similar with L_1 (80.14) .The lowest plant height L_0 (77.42) which was statistically similar with L_1 (80.14). Results obtained from the present study were similar to the findings of Rhaman *et al*. (2002), who reported that application of the highest level of lime application in a soil increased soil p^H resulting increase in nutrient availability and thereby favoured plant growth and tillering of wheat .Thus the lime induced higher plant height and more tiller formation might contribute to higher spikes m^{-2} compared to non-limed plots.

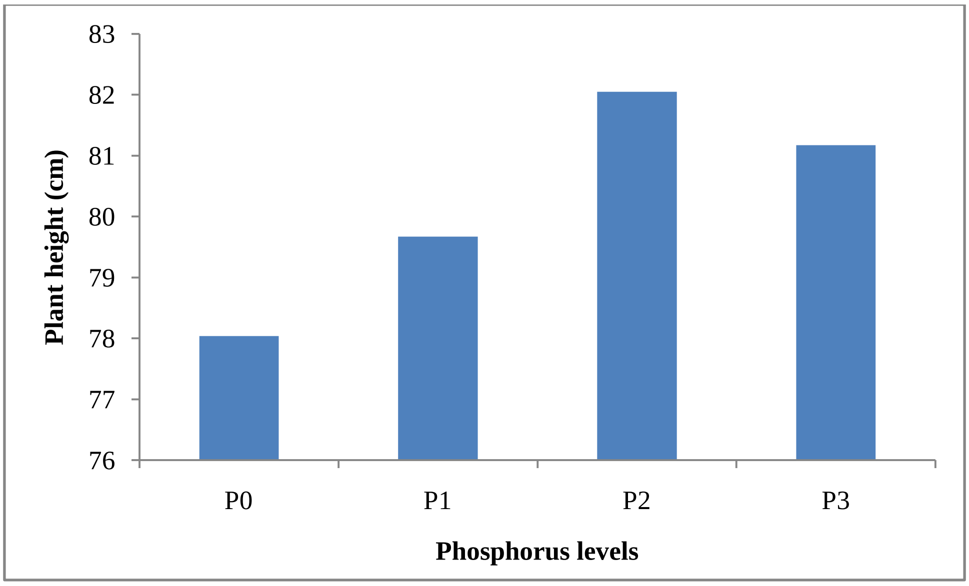


L_0= No lime (control), L_1= 1t ha^{-1}, L_2= 2 t ha^{-1}

Fig. 1: Effect of lime levels on plant height of BARI Gom 26. (SE value:1.129).

4.1.1.2 Effect of Phosphorus:

Statistically no significant variation was observed on plant height by different phosphorus rate (Fig. 2). After harvest, the highest Plant height of wheat (82.05cm) was recorded with P_2 and lowest plant height of wheat was (78.05cm) with P_0 treatment. Similar findings also reported by several authors of Khan *et al*. (2010), ; Holoway *et al*. (2001). In addition to them, plant height also contributed a significant impact on enhancing the straw yield.



P_0 = No phosphorus (control)**, P_1 =** 48 kg $P_2 0_5$ ha^{-1}**, P_2 =** 77 kg $P_2 0_5$ ha^{-1}, **P_3=** 106 kg $P_2 0_5$ ha^{-1}.

Fig. 2: Effect phosphorus levels on plant height of BARI Gom 26. (SE value:1.304).

4.1.1.3 Interaction effect of lime and phosphorus

From the value of plant height it was found that interaction effect of different levels of lime and phosphorus showed significant differences (Fig. 3). After harvest, the highest plant height (85.20cm) observed from the combination of L_2P_2 treatment which was statistically similar with L_0P_2, L_0P_3, L_1P_0, L_1P_1, L_1P_2, L_1P_3, L_2P_0, L_2P_0, L_2P_1 and L_2 P_3. The lowest plant height (76.00 cm) observed in L_0P_0 treatment which was statistically similar with L_0P_1, L_0P_2, L_0P_3, L_1P_0, L_1P_1, L_1P_2, L_1P_3, L_2P_0, L_2P_0 and L_2P_1 treatment. Therefore, these results are in consistent with the findings of Kamaruzzaman *et al.* (2013) who reported that application of the recommended dose of available K, P, Ca and Mg were significantly increased due to application of lime which was mainly associated with increased wheat yields.

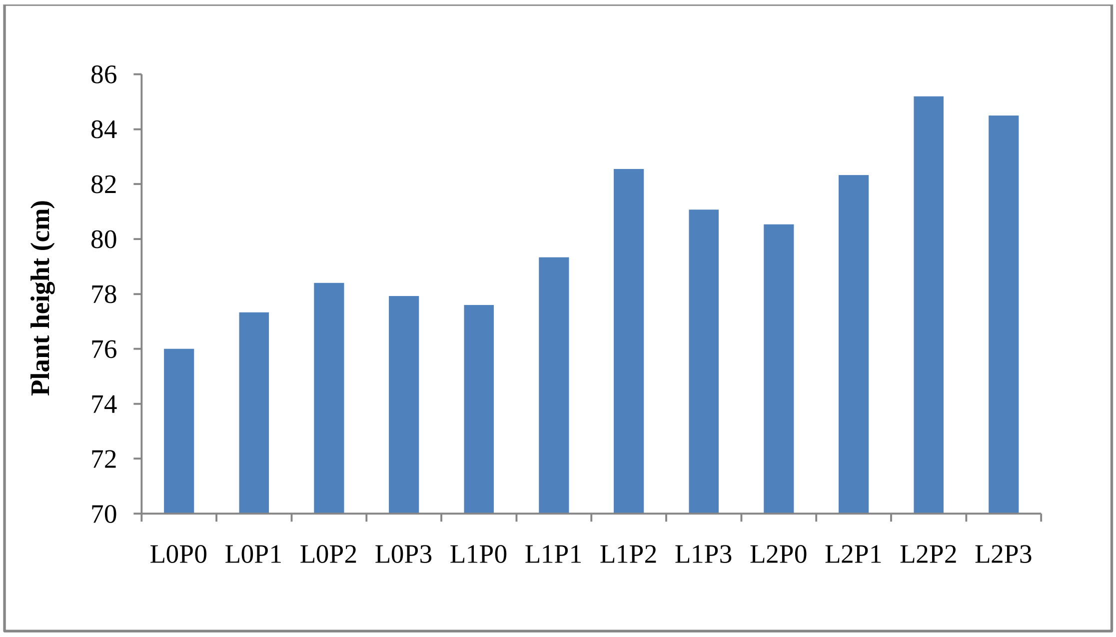


Fig. 3: Interaction effect of lime and phosphorus on plant height of BARI Gom 26. (SE value:2.259)

4.1.2 Dry matter content plant^{-1}

4.1.2.1 Effect of lime

Dry matter content plant^{-1} of wheat showed statistically significant variation due to different levels of lime at 45,55,65,75 and 85 DAS (Figure 4). At 45 DAS, the highest dry matter content plant^{-1} was recorded from treatment L_2 (0.6917g) and the corresponding lowest quantity of 0.48 g was found in treatment L_0 which was statistically similar to L_1 (0.52 g).

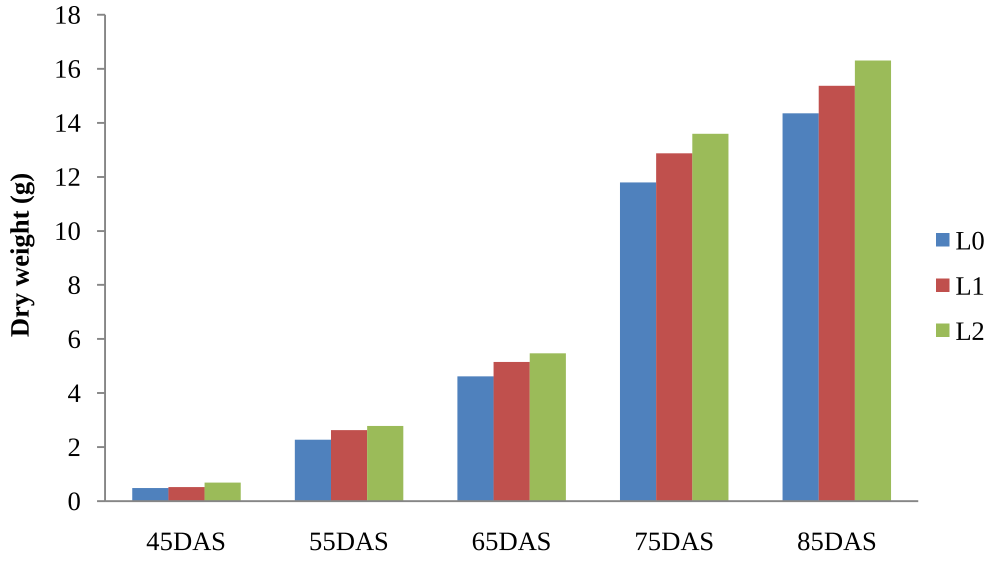
At 55 DAS, the highest dry weight plant^{-1} was found in L_2 treatment (2.78) which was statistically similar with L_1 (2.62). The lowest dry weight plant^{-1}was found in L_0 (2.270) treatment**.**

At 65 DAS, the highest dry weight plant^{-1} was found in L_2 treatment (5.46) which was statistically similar with L_1 (5.15). The lowest dry weight plant^{-1}was found in L_0 (4.61) treatment**.**

At 75 DAS, the highest dry weight plant^{-1} was found in L_2 treatment (13.59) which was statistically similar with L_1 (12.87). The lowest dry weight plant^{-1} was found in L_0 (11.79) treatment.

At 85 DAS, the highest dry weight plant^{-1} was found in L_2 treatment (16.31) which was statistically similar with L_1 (15.37). The lowest dry weight plant^{-1} was found in L_0 (14.35) treatment.

In consistent with the present study it has been reported that total dry weight production gradually increased with the increasing of lime level and the highest yield was obtained by the application of lime at the rate of 2 t ha^{-1} compared to no lime (Rahman, 2000; Dixit *et al*., 1988; Detta *et al*., 1983). These findings indicate that increased dry matter yield of wheat due to liming is attributed to the beneficial effect of ameliorating the soil, which increased Ca-saturation and availability of major nutrients. Higher vegetative growth in wheat must have caused efficient extraction of nutrients resulting in higher dry matter production and a maximum yield in the study was obtained at the application of 2 t ha^{-1} lime.



L_0 = Control (No lime), **L_1** = 1 t ha^{-1}, **L_2** = 2 t ha^{-1}

Fig. 4 : Effect of lime on dry weight plant^{-1} of BARI Gom 26 at different days after sowing (DAS) (SE value = 0.02,0.10,0.21,0.48 and 0.66 at 45, 55, 65 ,75 and 85 DAS, respectively).

4.1.2.2 Effect of Phosphorus:

Significant variations for dry matter content plant^{-1} of wheat due to different phosphorus level were evident at 45,55, 65,75 and 85 DAS (Fig. 5).At 45 DAS, the highest dry matter content plant^{-1} was recorded from treatment P_2 (0.64g) which was statistically similar with P_3 (0.59g) and the corresponding lowest quantity of 0.47 g was found in treatment P_0 .

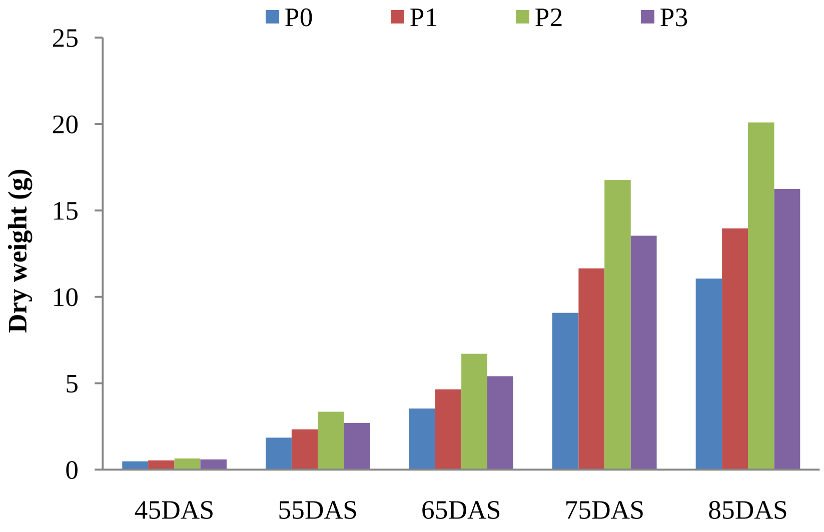
At 55 DAS, the highest dry weight plant^{-1} was found in P_2 treatment (3.35g).The lowest dry weight plant^{-1}was found in P_0 (1.85g) treatment**.**

At 65 DAS, the highest dry weight plant^{-1} was found in P_2 treatment (6.70). The lowest dry weight plant^{-1}was found in P_0 (3.54) treatment**.**

At 75 DAS, the highest dry weight plant^{-1} was found in P_2 treatment (16.75). The lowest dry weight plant^{-1}was found in P_0 (9.07) treatment**.**

At 85 DAS, the highest dry weight plant^{-1} was found in P_2 treatment (20.10). The lowest dry weight plant^{-1}was found in P_0 (11.06) treatment**.**

The results obtained from the present study were similar to the findings of several authors (Khan *et al.*, 2010; Kaleem *et al.*, 2009). Khan *et al.(*2010) reported that application of the highest dose of phosphorus contributed maximum to translocate dry matter towards the yield attributes in wheat variety (BARI Gom 26) and therefore maximum phosphorus dose helped in achieving the highest number of grains spike^{-1}, 1000 grain weight and ultimately wheat yield.



$\mathbf{P_0}$ = No phosphorus (control), $\mathbf{P_1}$ = 48 kg P_20_5 ha^{-1}, $\mathbf{P_2}$ = 77 kg P_20_5 ha^{-1}, $\mathbf{P_3}$= 106 kg P_20_5 ha^{-1}.

Fig. 5: Effect of phosphorus on dry weight $plant^{-1}$ of BARI Gom 26 at different days after sowing (DAS) with (SE value = 0.02, 0.12, 0.24, 0.56 and 0.76 at 45, 55, 65 ,75 and 85 DAS, respectively).

4.1.2.3 Interaction effect of lime and phosphorus:

Dry weight $plant^{-1}$ was significantly influenced by interaction of lime and phosphorus at different days after sowing DAS (Table 1). At 45 DAS, the highest dry weight $plant^{-1}$ was found in L_2P_2 treatment (0.76) which was statistically similar with L_2P_3 (0.71). The lowest dry weight $plant^{-1}$was found in L_0P_0 (0.39) which was statistically similar with L_0P_1 (0.45), L_1P_0 (0.42) treatment.

At 55 DAS, the highest dry weight $plant^{-1}$ was found in L_2P_2 treatment (3.88). On the other hand the lowest dry weight $plant^{-1}$was found in L_0P_0 (1.26) treatment.

At 65 DAS, the highest dry weight $plant^{-1}$ was found in L_2P_2 treatment (7.76) The lowest dry weight $plant^{-1}$was found in L_0P_0 (2.83) which was statistically similar with L_1P_0 (4.00), L_2P_0 (3.78) treatment.

At 75 DAS, the highest dry weight plant^{-1} was found in L_2P_2 treatment (19.40). The lowest dry weight plant^{-1}was found in L_0P_0 (8.08) which was statistically similar with L_0P_1 (10.75), L_1P_0 (9.99), L_2P_0 (9.15) treatment**.**

At 85 DAS, the highest dry weight plant^{-1} was found in L_2P_2 treatment (23.28). The lowest dry weight plant^{-1}was found in L_0P_0 (10.50) which was statistically similar with L_0P_1 (12.90) , L_1P_0 (11.67), L_1P_1 (14.42), L_2P_0(11.00) , L_2P_1 (14.58) treatment.

In consistent with the present study it has been reported that the maximum yield was obtained at the application of 2 ton ha^{-1}lime with 150-160 kg P indicating that the soil was effectively neutralized and calcium ions retained on exchange complex (Sarker *et al*. 2014).

Table 1: Interaction effect of lime and phosphorus on dry weight of BARI Gom 26

Treatments	**Dry weight (g)**				
	45 DAS	**55 DAS**	**65 DAS**	**75 DAS**	**85 DAS**
L_0P_0	0.3933 f	1.267 f	2.833 f	8.083 h	10.50e
L_0P_1	0.4500ef	2.150 de	4.300 de	10.75efgh	12.90c-e
L_0P_2	0.5700cd	3.110 b	6.220 b	15.55 b	18.66 b
L_0P_3	0.5167 de	2.553 b-e	5.107 b-e	12.77 b-f	15.32 b-d
L_1P_0	0.4267ef	2.207 de	4.000ef	9.997 f-h	11.67 de
L_1P_1	0.5167 de	2.403c-e	4.807c-e	12.02 d-g	14.42 b-e
L_1P_2	0.5967cd	3.060 bc	6.120 bc	15.30 bc	18.36 b
L_1P_3	0.5600 d	2.837 b-d	5.673 b-d	14.18 b-d	17.02 bc
L_2P_0	0.6167cd	2.100e	3.787ef	9.150gh	11.00 de
L_2P_1	0.6667 bc	2.430 b-e	4.860 b-e	12.15c-fg	14.58 b-e
L_2P_2	0.7667a	3.880a	7.760a	19.40a	23.28a
L_2P_3	0.7167ab	2.730 b-e	5.460 b-d	13.65 b-e	16.38 bc
SE	0.03	0.21	0.41	0.97	1.31
CV (%)	10.32	13.95	14.13	13.16	14.83

Here: L_0 = Control (No lime**), L_1 =** 1 t ha^{-1}**, L_2 =** 2 t ha^{-1},
P_0 = No phosphorus (control)**, P_1 =** 48 kg P_20_5 ha^{-1}**, P_2 =** 77 kg P_20_5 ha^{-1}, **P_3=** 106 kg P_20_5 ha^{-1}.

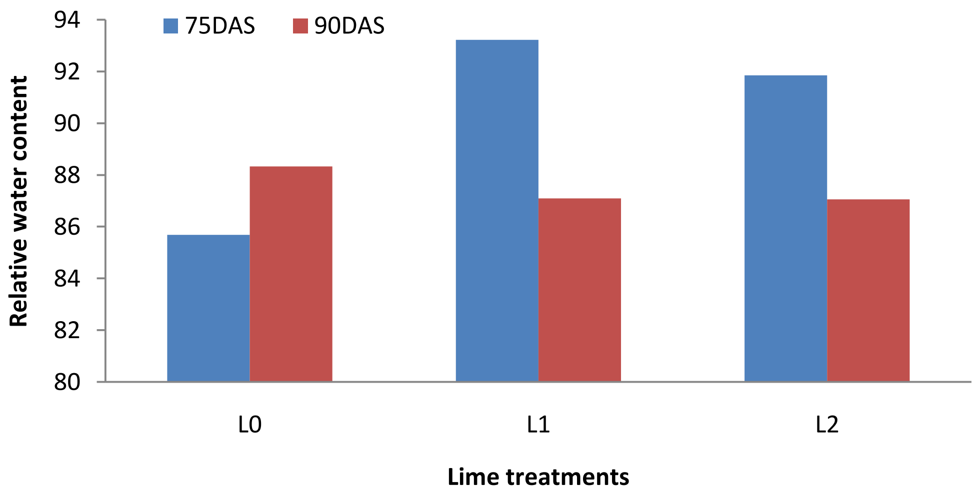
4.1.3 Relative water content

4.1.3.1 Effect of lime

Relative water content plant^{-1} of wheat leaf showed statistically significant variation due to different levels of lime at 75 and 90 DAS (Figure 6). At 75 DAS the highest relative water content (RWC) plant^{-1} was obtained from L_1 (93.22 %) treatment which was statistically similar with L_2 treatment at 75 DAS (91.85%). On the other hand the lowest RWC (85.69%) was observed at 75 DAS with L_0 treatment.

At 90 DAS the highest relative water content (RWC) plant^{-1} was obtained from L_0 (88.33) treatment. On the other hand the lowest RWC (87.05%) was observed at 90 DAS with L_2 treatment which was statistically similar with L_1 treatment.

In consistent with the present study it has been reported that RWC were significantly reduced by creating water stress and more reduced RWC were recorded when crop faced deficit water at flower initiation stage. Water deficit lowered the leaf turgor, thus causing reduction in leaf expansion rate. This led to the reduced assimilatory surface of the crop which ultimately adversely affected yield and yield contributing factors (Raza *et al.*, 2013) .



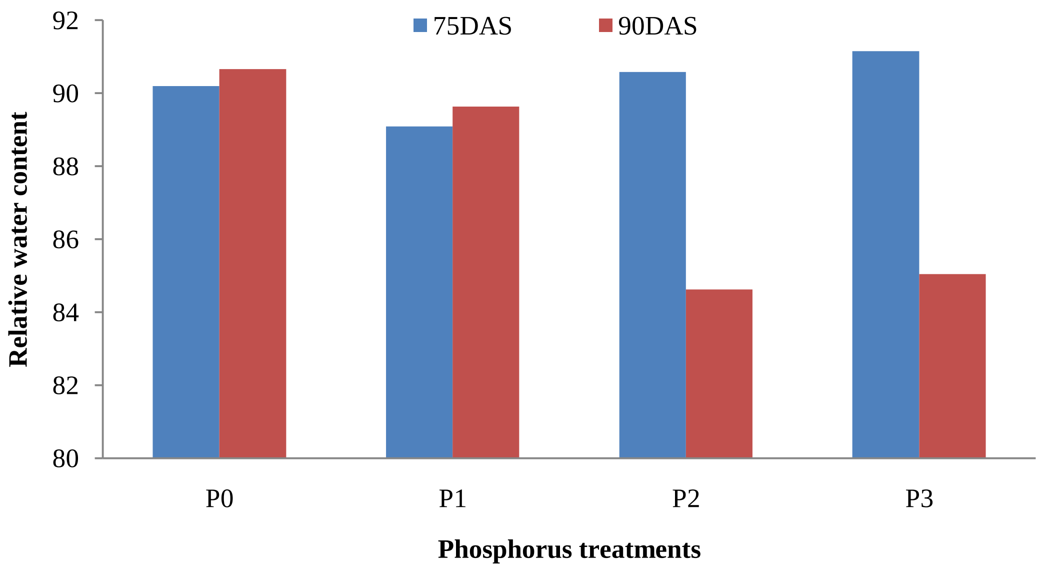
Here: L_0 = Control (No lime**), L_1** = 1 t ha^{-1}**, L_2** = 2 t ha^{-1}

Fig 6 : Effect of lime on dry weight plant^{-1} of BARI Gom 26 at different days after sowing (DAS) (SE value = 1.75 and 1.33 at 75 and 90 DAS respectively).

4.1.3.2 Effect of Phosphorus:

Significant variation for relative water content of wheat at 75 and 90 DAS were due to different Phosphorus rate (Figure 7). At 75 DAS the highest relative water content (RWC) plant^{-1} was obtained from P_3 (91.15 %) treatment which was statistically similar with P_2 treatment at 75 DAS (90.58%) and P_0(90.19%) .On the other hand the lowest RWC (89.09%) was observed at 75 DAS with P_1treatment.

At 90 DAS the highest relative water content (RWC) plant^{-1} was obtained from P_0 (90.66) treatment. On the other hand the lowest RWC (85.04%) was observed at 90 DAS with P_3 treatment.



Here: P_0 = No phosphorus (control)**, P_1 =** 48 kg P_20_5 ha^{-1}**, P_2 =** 77 kg P_20_5 ha^{-1}, **P_3=** 106 kg P_20_5 ha^{-1}.

Fig. 7: Effect of lime on relative water content of BARI Gom 26 at different days after sowing (DAS) sowing (SE value = 2.02and 1.54 at 75 and 90 DAS respectively).

4.1.3.3 Interaction effect of lime and phosphorus:

Relative water content was significantly influenced by interaction effect of lime and phosphorus at different 75DAS (Table 2) but no difference at 90DAS. At 75 DAS, the highest dry weight plant^{-1} was found in L_2P_2 treatment (93.18). The lowest dry weight plant^{-1}was found in L_0P_1 (78.58) which was statistically similar with $L_0P_{2,}$ $L_0P_{3,}$ L_2P_0 treatment**.**

At 90 DAS, the highest relative water content plant^{-1} was found in L_0P_0 treatment (91.28 %) which was statistically similar with other treatments. The lowest dry weight plant^{-1}was found in L_1P_2 (83.27 %) treatment**.**

Table 2: Interaction effect of lime and phosphorus on relative water content of BARI Gom 26

Treatments	Relative water content (%)	
	75 DAS	**90 DAS**
$\mathbf{L_0P_0}$	90.45a	91.28
$\mathbf{L_0P_1}$	78.58 b	88.68
$\mathbf{L_0P_2}$	85.36ab	86.89
$\mathbf{L_0P_3}$	88.39ab	86.49
$\mathbf{L_1P_0}$	92.74a	90.89
$\mathbf{L_1P_1}$	95.15a	90.49
$\mathbf{L_1P_2}$	93.21a	83.27
$\mathbf{L_1P_3}$	91.78a	83.69
$\mathbf{L_2P_0}$	87.40ab	89.83
$\mathbf{L_2P_1}$	93.56a	89.72
$\mathbf{L_2P_2}$	93.18a	83.70
$\mathbf{L_2P_3}$	93.27a	84.95
SE	3.51	NS
CV (%)	6.73	5.28

Here: $\mathbf{L_0}$ **=** Control (No lime**),** $\mathbf{L_1}$ **=** 1 t ha^{-1}**,** $\mathbf{L_2}$ **=** 2 t ha^{-1}, **:**

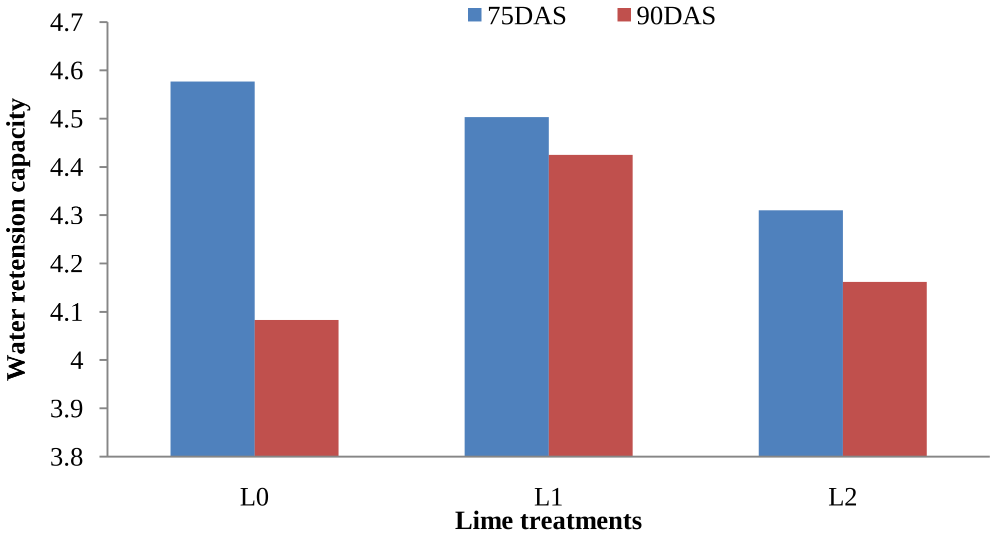
$\mathbf{P_0}$ **=** No phosphorus (control)**,** $\mathbf{P_1}$ **=** 48 kg P_20_5 ha^{-1}**,** $\mathbf{P_2}$ **=** 77 kg P_20_5 ha^{-1}, $\mathbf{P_3}$**=** 106 kg P_20_5 ha^{-1}.

4.1.4 Water retension capacity

4.1.4.1 Effect of lime

Water retension capacity of wheat showed statistically significant variation due to different levels of lime at 75 and 90 DAS (Figure 8). At 75 DAS, the highest water retention capacity was found in L_0 (4.57%) treatment. The lowest water retention capacity was found in L_2 (4.31 %) treatment.

At 90 DAS, the highest water retention capacity was found in L_1 (4.42 %) treatment. The lowest water retention capacity was found in L_0 (4.08 %) treatment.



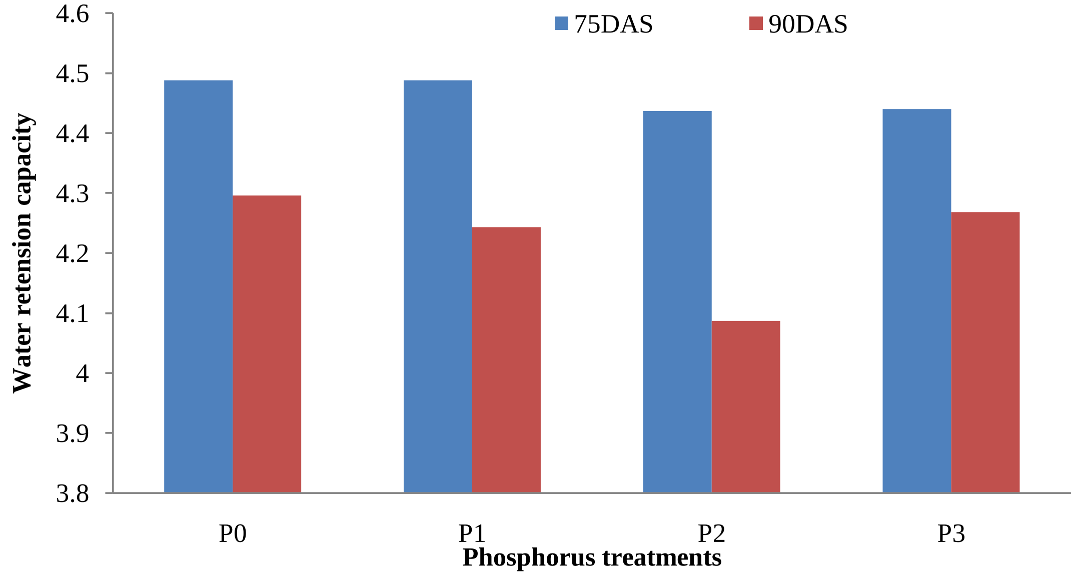
Here: L_0 = Control (No lime), **L_1** = 1 t ha^{-1}, **L_2** = 2 t ha^{-1}

Fig. 8 : Effect of lime on water retention capacity of BARI Gom 26 at different days after sowing (DAS) (SE value = 0.39 and 0.70 at 75 and 90 DAS respectively).

4.1.4.2 Effect of Phosphorus:

Significant variation for water retension capacity of BARI Gom 26 at 75 and 90 DAS were due to different phosphorus rate (Figure 9). At 75 DAS, the highest water retention capacity was found in P_0 (4.48 %) treatment. The lowest water retention capacity was found in P_2 (4.43 %) treatment.

At 90 DAS, the highest water retention capacity was found in P_0 (4.29%) treatment. The lowest water retention capacity was found in P_2 (4.08 %) treatment.



P_0 = No phosphorus (control)**, P_1 =** 48 kg P_20_5 ha^{-1}**, P_2 =** 77 kg P_20_5 ha^{-1}, **P_3=** 106 kg ha^{-1}.

Fig. 9: Effect of phosphorus on water retention capacity of BARI Gom 26 at different days after sowing (DAS) (SE value = 0.45 and 0.81 at 75 and 90 DAS respectively).

4.1.4.3 Interaction effect of lime and phosphorus:

Water retension capacity was not significantly influenced by interaction of lime and phosphorus at different days after sowing (DAS) (Table 3). At 75 DAS, the highest water retention capacity was found in L_0P_1 (4.66%) treatment. The lowest water retention capacity was found in L_2P_2 (4.09 %) treatment.

At 90 DAS, the highest water retention capacity was found in L_1P_3 (4.66%) treatment. The lowest water retention capacity was found in L_0P_2 (3.83 %) treatment.

Table 3: Interaction effect of lime and phosphorus on water retension capacity of BARI Gom 26

Treatments	Water retension capacity (%)	
	75 DAS	90 DAS
L_0P_0	4.553	4.267
L_0P_1	4.663	4.167
L_0P_2	4.627	3.830
L_0P_3	4.463	4.070
L_1P_0	4.563	4.367
L_1P_1	4.493	4.617
L_1P_2	4.587	4.053
L_1P_3	4.367	4.663
L_2P_0	4.347	4.253
L_2P_1	4.307	3.947
L_2P_2	4.097	4.377
L_2P_3	4.490	4.070
SE	NS	NS
CV (%)	9.03	10.10

Here: L_0 = Control (No lime), L_1 = 1 t ha^{-1}, L_2 = 2 t ha^{-1},

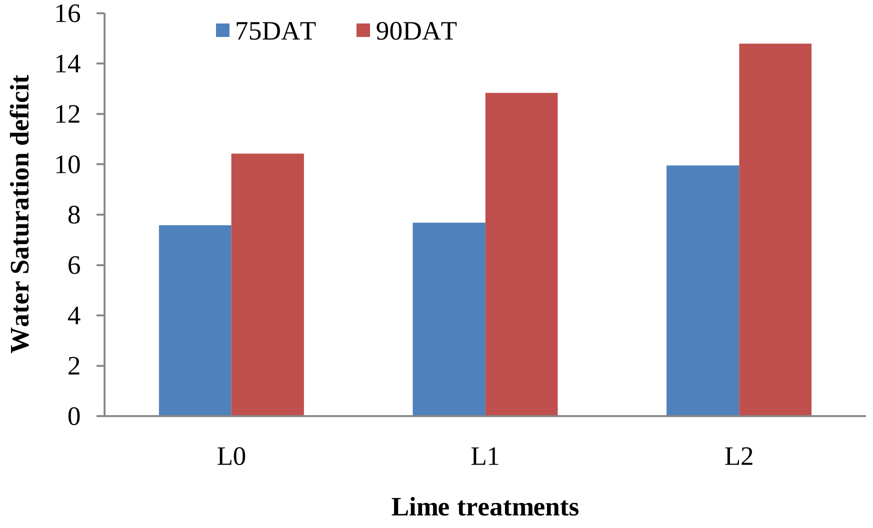
P_0 = No phosphorus (control), P_1 = 48 kg P_20_5 ha^{-1}, P_2 = 77 kg P_20_5 ha^{-1}, P_3= 106 kg P_20_5 ha^{-1}.

4.1.5 Water Saturation deficit

4.1.5.1 Effect of lime

Water saturation deficit of wheat leaf showed statistically significant variation due to different levels of lime at 75 and 90 DAS (Figure 10). At 75 DAS, the highest water saturation deficit was found in L_2 (9.95%) treatment. The lowest water saturation deficit was found in L_0 (7.58 %) treatment.

At 90 DAS, the highest water saturation deficit was found in L_2 (14.80 %) treatment. The lowest water saturation deficit was found in L_0 (10.42 %) treatment.



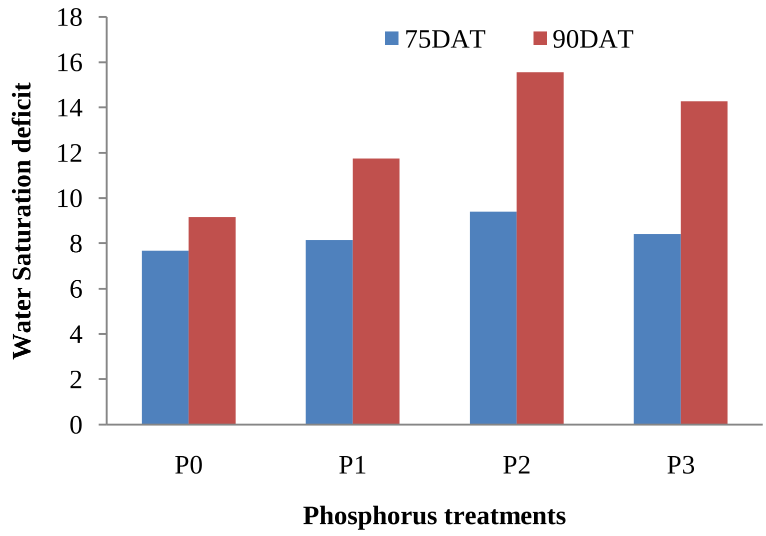
Here: L_0 = Control (No lime**), L_1** = 1 t ha^{-1}**, L_2** = 2 t ha^{-1}

Fig. 10 : Effect of lime on water saturation defecit of BARI Gom 26 at different days after sowing (DAS) (SE value = 0.12 and 0.12at 75 and 90 DAS respectively).

4.1.5.2 Effect of Phosphorus:

Significant variation for water saturation deficit of BARI Gom 26 was observed at 75 and 90 DAS were due to different phosphorus rate (Figure 11). At 75 DAS, the highest water saturation deficit was found in P_2 (9.40%) treatment. The lowest water retention capacity was found in P_0 (7.67 %) treatment.

At 90 DAS, the highest water saturation deficit was found in P_2 (15.56 %) treatment. The lowest water saturation deficit was found in P_0 (9.163%) treatment.



P_0 = No phosphorus (control)**, P_1 =** 48 kg P_20_5 ha^{-1}**, P_2 =** 77 kg P_20_5 ha^{-1}, **P_3=** 106 kg ha^{-1}.

Fig. 11: Effect of phosphorus on water saturation defecit BARI Gom 26 at different days after sowing (DAS) (SE value = 0.13 and 0.14 at 75 and 90 DAS respectively)

.

4.1.5.3 Interaction effect of lime and phosphorus:

Water saturation deficit was significantly influenced by interaction of lime and phosphorus at different days after sowing (Table 4). At 75 DAS, the highest water saturation deficit was found in L_2P_2 treatment (10.87%) which was statistically similar with L_2P_3, L_2P_1, L_2P_0, L_1P_2, L_0P_2. The lowest water saturation deficit was found in L_1P_0 (6.84%) which was statistically similar with L_0P_0, L_0P_1, L_0P_2, L_0P_3, L_1P_1, L_1P_2, L_1P_3 treatment**.**

At 90 DAS, the highest water saturation deficit was found in L_2P_2 treatment (16.29%) which was statistically similar with L_2P_3, L_2P_1, L_2P_0, L_1P_3, L_1P_2 treatments. The lowest water saturation deficit was found in L_0P_0 (7.00 %) treatment which was statistically similar with L_0P_1, L_0P_2, L_1P_0, L_1P_1 treatments**.**

Table 4: Interaction effect of lime and phosphorus on water saturation deficit of BARI Gom 26

Treatments	Water Saturation deficit (%)	
	75 DAS	90 DAS
L_0P_0	6.647e	7.000e
L_0P_1	7.033c-e	9.287 de
L_0P_2	8.443a-e	13.67a-e
L_0P_3	8.207 b-e	11.72 b-d
L_1P_0	6.840 de	9.103 de
L_1P_1	7.333c-e	10.13 de
L_1P_2	8.887a-e	16.72a
L_1P_3	7.687 b-e	15.40a-c
L_2P_0	9.543ac	11.39c-e
L_2P_1	10.06ab	15.79a-c
L_2P_2	10.87a	16.29ab
L_2P_3	9.333a-d	15.72a-c
LSD	2.33	4.17
SE	0.78	1.41
CV (%)	16.15	19.19

Here: L_0 = Control (No lime), L_1 = 1 t ha^{-1}, L_2 = 2 t ha^{-1},

P_0 = No phosphorus (control), P_1 = 48 kg P_20_5 ha^{-1}, P_2 = 77 kg P_20_5 ha^{-1}, P_3= 106 kg P_20_5 ha^{-1}.

4.1.6 Effective tillers per m^2

4.1.6.1 Effect of lime

Effective tillers per m^2 was significantly influenced by different levels of lime (Table 5). Results showed that the highest effective tillers (209.20) per m^2 is L_2 and the lowest effective tillers per m^2 (105.70) with L_0 treatment. This result is in agreement with Sharma et al. (2000), they reported that lime application significantly increased yield of mungbean. Samia (2007) also agreed with this result, she found that liming effect on number of tillers plant-1 was significantly influenced by the different treatments of lime. The number of tillers per plant by different treatments varied from 2.09 to 4.03.

Table 5: Effect of lime on the yield contributing characters of BARI Gom 26

Treatments	Effective tiller per m^2	No. of spikelet per spike	No. of grain per spike	spike length (cm)	1000 - Seed weight (g)
L_0	105.70 c	15.82 b	55.75 b	15.46 b	37.35
L_1	195.50 b	17.58 a	57.17 ab	16.30 b	38.30
L_2	209.20 a	18.83 a	61.67 a	17.38 a	39.72
SE	3.42	0.5533	1.686	0.3037	NS
CV %	6.95	15.01	10.03	6.42	10.79

Here: L_0 = Control (No lime**), L_1 =** 1 t ha^{-1}**, L_2 =** 2 t ha^{-1},

4.1.6.2 Effect of phosphorus

Significant variations in number of effective tillers per m^2 was observed by the application of different rates of phosphorus (Table 6). Results showed that the highest effective tillers per m^2 is P_2 (185.20) was recorded which was significiently similier to $P_{3.}$ The lowest effective tillers per m^2 (153.80) was observed with P_0 which was significiently similier to P_1 .The results are in line with the findings of Jamwal and Bhagat (2004) who reported that basal application of the recommended doses of phosphorus produced significantly higher number of effective tillers m^2 row length which ultimately increased the grain and straw yields. Renu *et al.* (2005) also found that the number of tillers per plant was less where no fertilizer was applied as compared to phosphorus fertilizer application in case of wheat. Various other scientists also reported similar results (Baon *et al.*,1992).

Table 6: Effect of phosphorus on yield contributing characters of BARI Gom 26

Treatments	Effective tiller per m^2	No. of spikelet per spike	No. of grain per spike	spike length (cm)	1000 - Seed weight (g)
P_0	153.80 b	16.47 b	56.67	16.11	36.60
P_1	164.10 b	16.84 ab	56.78	16.25	37.33
P_2	185.20 a	18.67 a	60.44	16.76	40.72
P_3	177.40 a	17.67 ab	58.89	16.40	39.17
SE	3.94	0.6389	NS	NS	NS
CV %	6.95	15.01	10.03	6.42	10.79

P_0 = No phosphorus (control)**, P_1 =** 48 kg P_20_5 ha^{-1}**, P_2 =** 77 kg P_20_5 ha^{-1}, **P_3=** 106 kg ha^{-1}.

4.1.6.3 Interaction effect of lime and phosphorus

Effective tiller per m^2 was significantly influenced by interaction effect of lime and phosphorus (Table 7). Results showed that no of highest effective tillers (223.30) were found with the treatment combination of L_2P_2 which was significiently similier with L_1P_2, L_1P_3, L_2P_1 and L_2P_3(212.40,207.50,203.50 and 217.00 respectively) .On the other hand the lowest effective tiller per m^2 was observed with L_0P_0 (92.33) which was statistically similar with L_0P_1 and L_0P_3. The results obtained from the present study were conformity with the findings of Chaudhury *et al.* (1999). Application of 25 percent lime sludge at seven days before sowing significantly enhanced the availability of N, P, K,Ca and Mg in the soil compared to ten days and three days before sowing. Lime enhancing p^H, CEC, base saturation and in reducing total acidity, exchange acidity, exchangeable Al^{3+} at maximum tillering stage and harvesting stage of wheat.

Table 7: Yield contributing parameters of BARI Gom 26 as influenced by interaction effect of lime and phosphorus

Treatments	Effective tiller per m^2	No. of spikelet per spike	No. of grain per spike	spike length (cm)	1000 - Seed weight (g)
L_0P_0	92.33 f	15.07 c	54.67	15.17 c	36.17
L_0P_1	102.70 ef	15.53 bc	53.67	15.37 c	36.33
L_0P_2	120.00 e	16.67 bc	58.00	15.89 a-c	38.67
L_0P_3	107.70 ef	16.00 bc	56.67	15.43 bc	38.23
L_1P_0	176.10 d	16.67 bc	55.67	16.07 a-c	36.40
L_1P_1	186.00 cd	17.00 a-c	56.00	16.16 a-c	36.80
L_1P_2	212.40 ab	18.67 a-c	59.00	16.67 a-c	41.00
L_1P_3	207.50 a-c	18.00 a-c	58.00	16.31 a-c	39.00
L_2P_0	193.00 b-d	17.67 a-c	59.67	17.09 a-c	37.23
L_2P_1	203.50 a-c	18.00 a-c	60.67	17.21 a-c	38.87
L_2P_2	223.30 a	20.67 a	64.33	17.73 a	42.50
L_2P_3	217.00 a	19.00 ab	62.00	17.47 ab	40.27
SE	6.83	1.107	NS	0.6075	NS
CV %	6.95	15.01	10.03	6.42	10.79

Here: L_0 = Control (No lime)**, L_1 =** 1 t ha^{-1}**, L_2 =** 2 t ha^{-1},

P_0 = No phosphorus (control)**, P_1 =** 48 kg $P_2 0_5$ ha^{-1}**, P_2 =** 77 kg $P_2 0_5$ ha^{-1}, **P_3=** 106 kg ha^{-1}.

4.1.7 Spike length

4.1.7.1 Effect of Lime:

Spike length of wheat was found significantly different due to the increasing amount of lime application (Table 5). Spike length of wheat ranged from 6.42 to 17.38 cm, tallest spike was found in L_2 treatment which is not statistically similar to others treatment ($L_{0,}$ L_1). The treatment L_0 recorded the spike length of 15.46 cm which was comparable to those found in L_1 treatment (16.30 cm). The treatment L_2 was statistically superior to $L_{0,}$ L_1 treatments in terms of spike length. The grain yield of wheat was positively correlated with spike length characters. The results obtained from the present study were similar to the findings of Kamaruzzaman *et al*. (2013). They said application of 1.5 t lime ha^{-1} spike length of wheat ranged from 6.35 to 11.82 cm. These findings indicate that application of 2 t lime ha^{-1} gives heighest spike length which containss heighest grain yield.

4.1.7.2 Effect of Phosphorus:

Non significant variation was recorded for biological yield of wheat due to different phosphorus level in (Table-6).The heighest spike length was recorded maximum (16.76 cm) in 77 kg P_20_5 ha^{-1} and was noted minimum (16.11 cm) was found in control treatment. Some other scientists (Mcbeath *et al.,* 2005; Mohammad *et al*., 2004) showed the similar trend for phosphorous application to various crops. They also found that spike length of the cereal crops are the major factor to feed the livestock for the sustainability of the food web. They observed that basal application of the recommended dose of P produced significantly heigher spike length that ultimately increased the grain and straw yield.

4.1.7.3 Interaction effect of lime and phosphorus

From the value of spike length it was found that interaction effect of different levels of lime and phosphorus showed significant differences (Table 7). The highest spike length (17.73cm) was observed for the combination of L_2P_2 treatment which was statistically similar with $L_0P_{2,}$ $L_1P_{0,}$ $L_1P_{1,}$ $L_1P_{2,}$ $L_1P_{3,}$ L_2P_0 L_2P_1 and $L_2P_{3.}$ The lowest spike length (15.17 cm) was observed in L_0P_0 treatment combination which was statistically similar with $L_0P_{1,}$ L_0P_2, L_0P_3 L_1P_0 ,L_1P_1 , L_1P_2 , L_1P_3 , L_2P_0 ,L_2P_1 treatments .

4.2 Yield and yield contributing parameters

4.2.1 Number of spikelets spike^{-1}

4.2.1.1 Effect of lime

Number of spikelets spike^{-1} was significantly influenced by different levels of lime used in the present study (Table 5). Results showed that the highest number of spikelets spike^{-1}(18.83) was recorded with L_2 which was statiscally simileir with L_1 but the lowest number of spikelets spike^{-1} (15.82) with treatment.

4.2.1.2 Effect of phosphorus

Nonsignificant variation was observed on number of spikelets spike^{-1} in case of different levels of phosphorus (Table 6).The highest number of spikelets spike^{-1} was observed at P_2 treatment (18.67) which was statiscally simileir with P_1 and P_3 and The lowest number of spikelets spike^{-1} was observed at P_0 treatment (16.47) which was statiscally simileir with P_1 and $P_{3.}$

4.2.1.3 Interaction effect of lime and phosphorus

Number of spikelets spike^{-1} was significantly influenced by interaction effect of lime and phosphorus (Table 7). Results showed that the highest number of spikelets spike^{-1} and (20.67) was found with the treatment combination of L_2P_2 which was significiently similier $L_1P_{1,}$ $L_1P_{3,}$ $L_1P_{2,}$ $L_2P_{0,}$ L_2P_1 and L_2P_3 (17.00, 18.67, 18.67 ,17.67 , 18.00 and 19.00 respectively) .On the other hand the lowest number of spikelets spike^{-1} (15.07) were observed with L_0P_0 which was statistically similar with $L_0P_{1,}$ $L_0P_{2,}$ $L_0P_{3,}$ $L_1P_{0,}$ $L_1P_{1,}$ $L_1P_{2,}$ $L_1P_{3,}$ $L_2P_{0,}$ L_2P_1 .Islam (1999) said number of spikelet spike-1 depends on the length of spike and it is determined by genetic make up and growth factors prevailing during the growth period.The longest spike and highest number of spikelets $spike^{-1}$ were obtained from recommended P fertilizer with lime .

4.2.2 Number of Grains per Spike

4.2.2.1 Effect of Lime:

The number of grains $spike^{-1}$ was also shown significantly variation due to different liming treatments (Table 5). The number of grains $spike^{-1}$ of wheat ranged from 61.67 to 55.75. The highest number of grains was found in L_2 (61.67) treatment which is statistically similar with L_1 treatment and the lowest number of grains was recorded with L_0 treatment (55.75). The grain yield of wheat was positively correlated with the number of grains $spike^{-1}$ characters. Samia (2007) also agreed with this result, she found that liming effect of the number of grains $spike^{-1}$ was significantly influenced by the different of lime treatment.

4.2.2.2 Effect of Phosphorus:

Statistically non significant variations in number of grains $spike^{-1}$ was observed at different levels of phosphorus .The maximum number of grain per spike (60.44) was found at P_2 treatment and the minimum number of grains per spike (56.67) at P_0 treatment (Table 6).

4.2.2.3 Interaction effect of lime and phosphorus

The interaction effect of lime and phosphorus showed statistically insignificant variation for grains spike^{-1}(Table 7). The highest grains spike^{-1} was observed for the treatment combination of L_2P_2 (64.33) and the lowest grains spike^{-1} (53.67) observed in L_0P_1 treatment.

4.2.3 1000-grain weight

4.2.3.1 Effect of lime

Non significant variations in number of 1000-grain of BARI Gom 26 was observed at different levels of lime levels in (Table 5). The treatment L_2 produced the highest 1000-grain weight of 39.72g and the treatment L_0 produced the lowest 1000-grain weight of 37.35g. The 1000 seeds weight and grain yield of wheat was affected due to changes in soil properties due to liming. This result is agreed with Samia (2007) and Basak (2010), they reported that liming increased soil p^H and availability of nutrients which increased the yield components of wheat and mungbean finally higher yields of wheat and mungbean

4.2.3.2 Effect of phosphorus

Non significant variation was recorded for weight of 1000-grain of wheat due to different phosphorus levels (Table 6). The treatment P_2 produced significantly the highest 1000 grain weight of 40.72g while P_0 produced significantly the lowest 1000-grain weight of 36.60g.

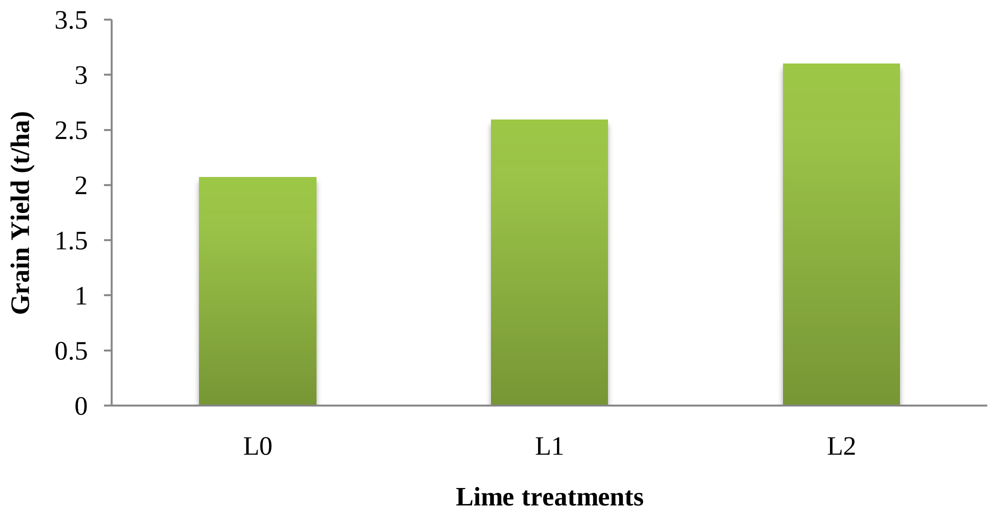
4.2.3.3 Interaction effect of lime and phosphorus

Interaction effect of different levels of lime and phosphorus rate varied nonsignificantly on weight of 1000-grain of wheat (Table 7). The highest weight of 1000 grain (42.50 g) was observed from, L_2P_2 while the lowest weight of 1000-grain (36.17 g) was recorded from L_0P_0.

4.2.4 Grain yield

4.2.4.1 Effect of lime

Grain yield was significantly influenced by different levels of lime used in the present study (figure 12). Results showed that the highest grain yield (3.099 t ha^{-1}) was found in L_2 (2 ton ha^{-1}) On the other hand the lowest grain yield (2.071 t ha^{-1}) was found in L_0 (0 ton ha^{-1}) . The grain yield of wheat was affected by changes in soil properties due to liming. It appeared that liming increased soil p^H and availability of nutrients which increased the yield components as well as yields of wheat. Caires *et al*. (2006) reported that surface liming caused increases up to 140% in the grain yield of wheat. Kisic *et al*. (2002) found that besides mineral and organic fertilization, liming also rendered significantly higher yields compared to the control and relatively higher yields than treatments involving mineral fertilizers. Jovanovic *et al.* (2006) found that liming considerably influenced the yields of the field crops and single application of high rates was the better choice compared with repeated use of low rates. Similar observations were also reported by several authors (Samia 2007 and Basak 2010).



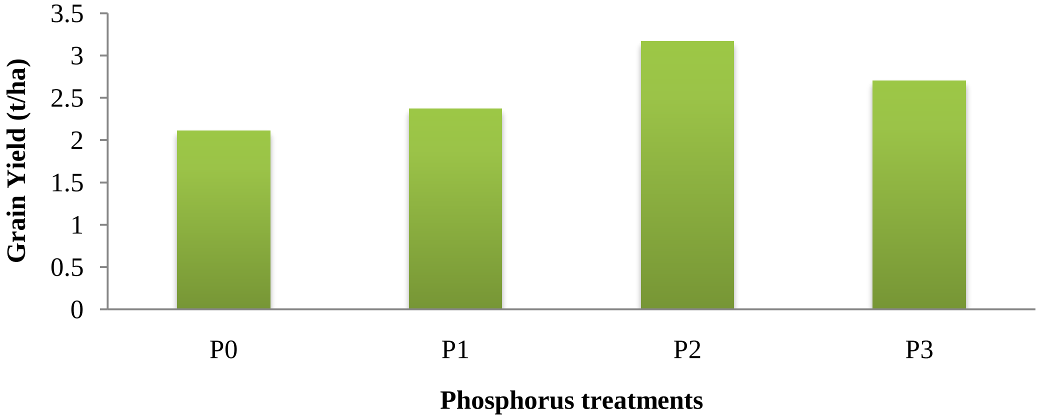
Here: $\mathbf{L_0}$ = Control (No lime**),** $\mathbf{L_1}$ = 1 t ha^{-1}**,** $\mathbf{L_2}$ = 2 t ha^{-1}

Fig. 12: Effect of lime grain yield of BARI Gom 26 (SE value = 0.1294)

.

4.2.4.2 Effect of phosphorus

Significant variation was observed on grain yield in case of different levels of Phosphorus application in the field (Fig. 13). It was found that the highest grain yield (3.166 t ha^{-1}) was achieved from P_2 (77 kg ha^{-1}) .On the other hand, the lowest grain yield (2.111 t ha^{-1}) was found in P_0 (control) which was also significantly similier with P_1 (2.368 t). The results obtained from all other treatments gave intermediate results.



Here: $\mathbf{P_0}$ **=** No phosphorus (control)**,** $\mathbf{P_1}$ **=** 48 kg P_20_5 ha^{-1}**,** $\mathbf{P_2}$ **=** 77 kg P_20_5 ha^{-1}, $\mathbf{P_3}$**=** 106 kg ha^{-1}.

Fig. 13: Effect of phosphorus on grain yield of BARI Gom 26. (SE value = 0.1494)

4.2.4.3 Interaction effect of lime and phosphorus

Grain yield was significantly influenced by interaction effect of lime and phosphorus rate (Table 8). Results showed that the highest grain yield (3.870 t ha^{-1}) was found with the treatment combination of L_2P_2 which was statistically similar with L_2P_3 and L_1P_2 .On the other hand the lowest grain yield (1.753 t ha^{-1}) was observed with L_0P_0 which was statistically similar with L_0P_1, L_0P_2 ,L_0P_3 , L_1P_0 ,L_1P_1 ,L_1P_3 and L_2P_0 treatment combinations.

Table 8: Interaction effect of lime and phosphorus on yield and harvest index of BARI Gom 26

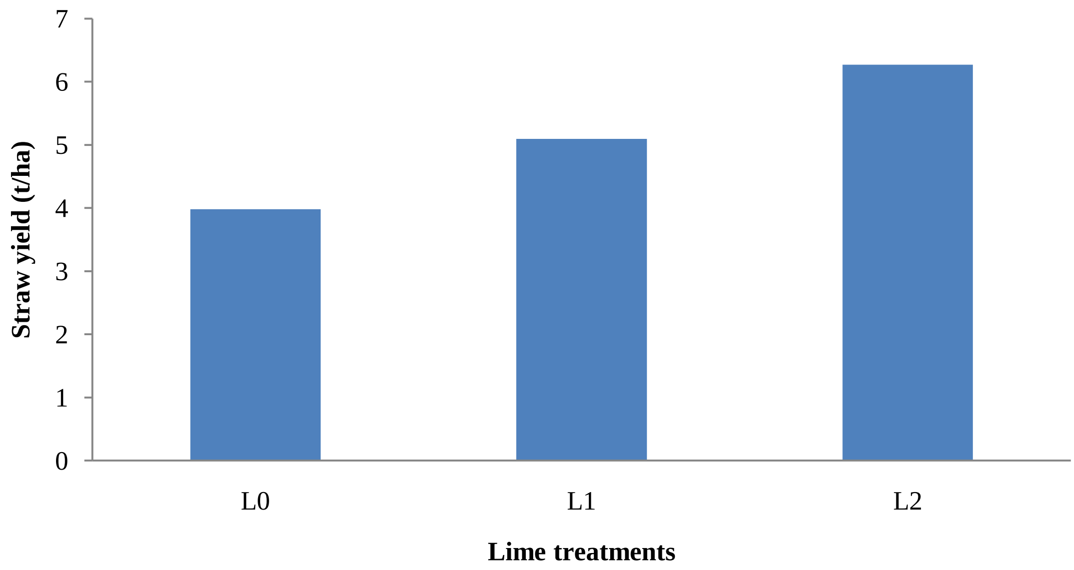
Treatments	Grain Yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
L_0P_0	1.753 e	3.683 b	5.437 f	32.15
L_0P_1	1.977 de	3.973 b	5.950 ef	34.12
L_0P_2	2.387 c-e	4.387 b	6.773 c-f	36.82
L_0P_3	2.167 de	3.887 b	6.773 d-f	36.08
L_1P_0	2.133 de	4.870 ab	7.003 c-f	30.38
L_1P_1	2.393 c-e	5.133 ab	7.527 b-e	31.87
L_1P_2	3.240 a-c	5.140 ab	8.380 a-c	38.56
L_1P_3	2.590 b-e	5.247 ab	7.837 b-d	33.43
L_2P_0	2.447 c-e	6.130 a	8.577 a-c	28.43
L_2P_1	2.733 b-d	6.257 a	8.990 ab	30.34
L_2P_2	3.870 a	6.253 a	10.12 a	38.29
L_2P_3	3.347 ab	6.437 a	9.783 a	34.05
LSD	0.7691	1.395	1.634	9.219
SE	0.2588	0.4694	0.5498	NS
CV %	17.33	15.9	12.37	15.24

Here: L_0 = Control (No lime)**, L_1 =** 1 t ha^{-1}**, L_2 =** 2 t ha^{-1},

4.2.5 Straw yield (t ha^{-1})

4.2.5.1 Effect of lime

Straw yield of wheat showed statistically significant variation due to different levels of lime (Fig. 14). The highest straw yield of 6.269 t ha^{-1} was recorded from L_2 treatment. On the other hand, the lowest straw yield 3.983 t ha^{-1} was observed from L_0 treatment.

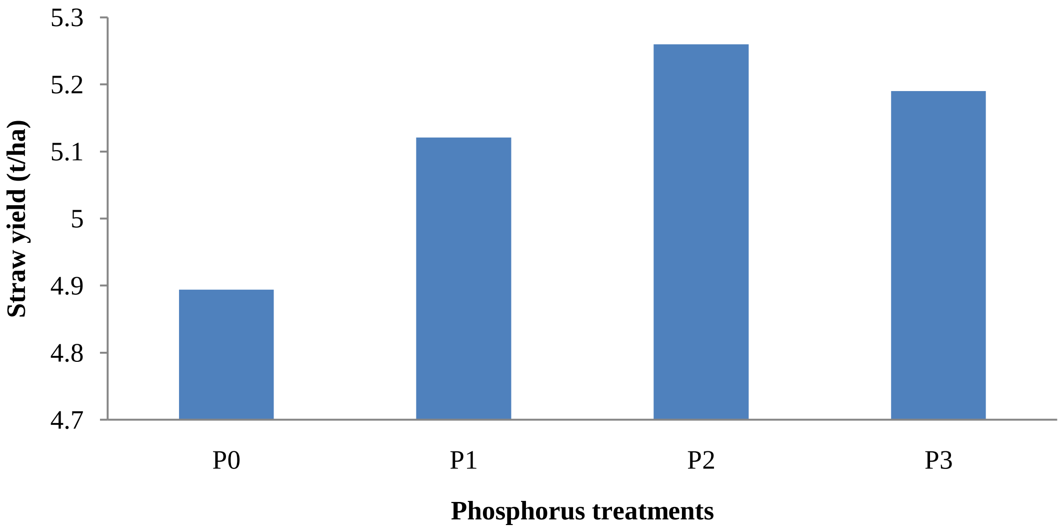


Here: $\mathbf{L_0}$ **=** Control (No lime**),** $\mathbf{L_1}$ **=** 1 t ha^{-1}**,** $\mathbf{L_2}$ **=** 2 t ha^{-1}

Fig. 14: Effect of lime on straw yield of BARI Gom 26(SE value = 0.2347)**.**

4.2.5.2 Effect of phosphorus

No Significant variation was recorded for straw yield of wheat due to different phosphorus levels under the present trial (Fig. 15). The highest straw yield as 5.260 t ha^{-1} was observed from P_2 treatment and the lowest straw yield 4.894 t ha^{-1} was recorded from P_0 treatment.



P_0 = No phosphorus (control)**, P_1 =** 48 kg P_20_5 ha^{-1}**, P_2 =** 77 kg P_20_5 ha^{-1}, **P_3=** 106 kg ha^{-1}.

Fig. 15: Effect of phosphorus on straw yield of BARI Gom 26 (SE value = 0.2710).

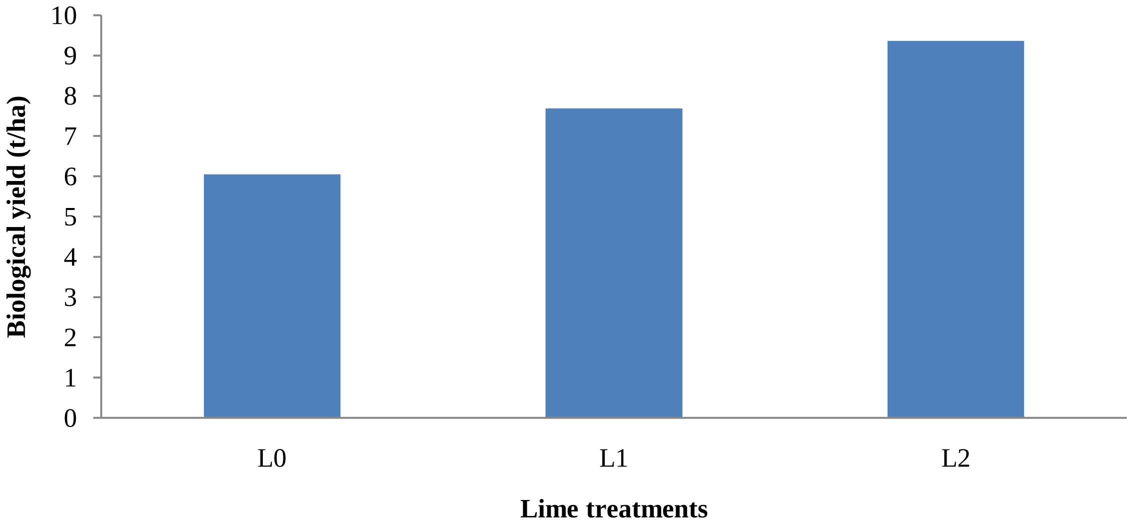
4.2.5.3 Interaction effect of lime and phosphorus

Interaction effect of different levels of lime and phosphorus showed significant differences on straw yield of wheat (Table 8). The highest straw yield (6.26 t ha^{-1}) was observed from L_2P_1 which was statiscally similier with L_2P_2, L_2P_0, L_2P_3, L_1P_0, L_1P_1, L_1P_2,L_1P_3 while the lowest straw yield (3.683 t ha^{-1}) was recorded from L_0P_0 which was statically similier with L_0P_1, L_0P_2, L_0P_3, L_1P_0, L_1P_1, L_1P_2, L_1P_3 treatments. The results obtained from the present study were conformity with the findings of Mongia *et al.* (1998). These findings indicate that the response of wheat to liming and P application is pronounced in acid soils. Application of lime alone did not influence markedly the grain and straw yield. But, both lime and P application showed significant positive effect of both grain and straw yield.

4.2.6 Biological yield (t ha^{-1})

4.2.6.1 Effect of lime

It was revealed from the experiment that biological yield of wheat showed statistically significant variation due to different rates of lime under the present trial (Fig. 16).The highest biological yield (9.368 t ha^{-1}) was observed from L_2 treatment. On the other hand, the lowest biological yield (6.053 t ha^{-1}) was observed from L_0 treatment.



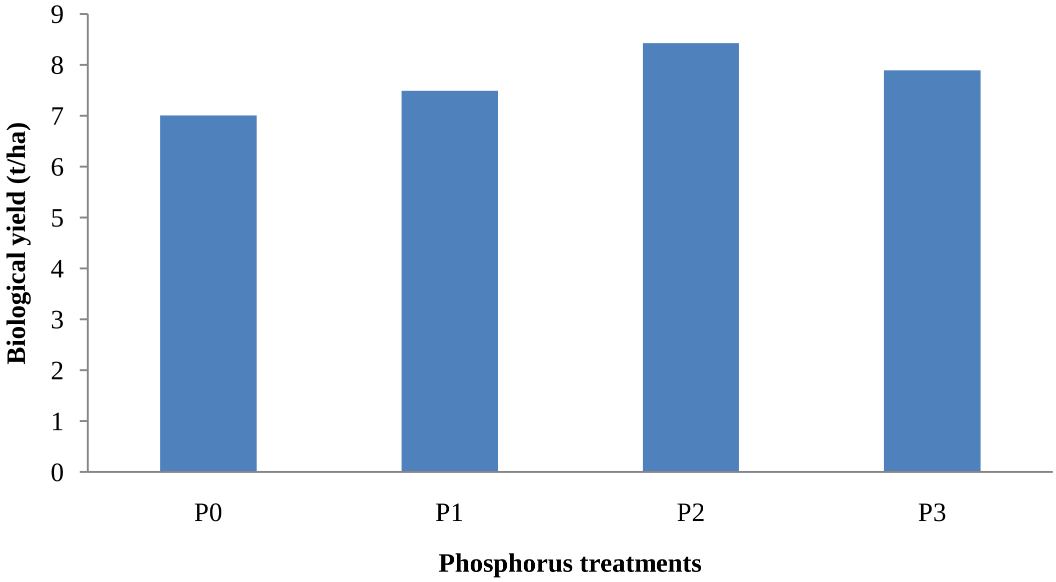
Here: L_0 = Control (No lime**), L_1** = 1 t ha^{-1}**, L_2** = 2 t ha^{-1}

Fig. 16: Effect of lime on biological yield of BARI Gom 26**.** (SE value = 0.2749)

4.2.6.2 Effect of phosphorus

Statistically significant variation was recorded for biological yield of wheat due to different phosphorus level (Fig. 17). The highest biological yield (8.426 t ha^{-1}) was observed from P_2 treatment which was statistically similar with P_1 treatment (7.489 t ha^{-1}) and P_3 treatment (7.891 t ha^{-1}) while the lowest biological yield (7.006 t ha^{-1}) was recorded from P_0 treatment which was statistically similar with P_1 treatment (7.489 t ha^{-1}) and P_3 treatment (7.891 t

ha^{-1}). The results obtained from the present study were conformity with the findings of Hussain (2011). P application enhanced biological yield by an average of 9.5 and 13.5% when its levels were increased to 90 and 120 kg ha^{-1} respectively as against lower level of P application. Variable response of wheat in terms of biological yield has been reported elsewhere Hussain,(2004). He reported that an increase in yield attributes with combined application of P, S and Zn is contrary to these findings.



P_0 = No phosphorus (control)**, P_1 =** 48 kg P_20_5 ha^{-1}**, P_2 =** 77 kg P_20_5 ha^{-1}, **P_3=** 106 kg ha^{-1}.

Fig. 17: Effect of phosphorus on biological yield of BARI Gom 26. (SE value = 0.3175)

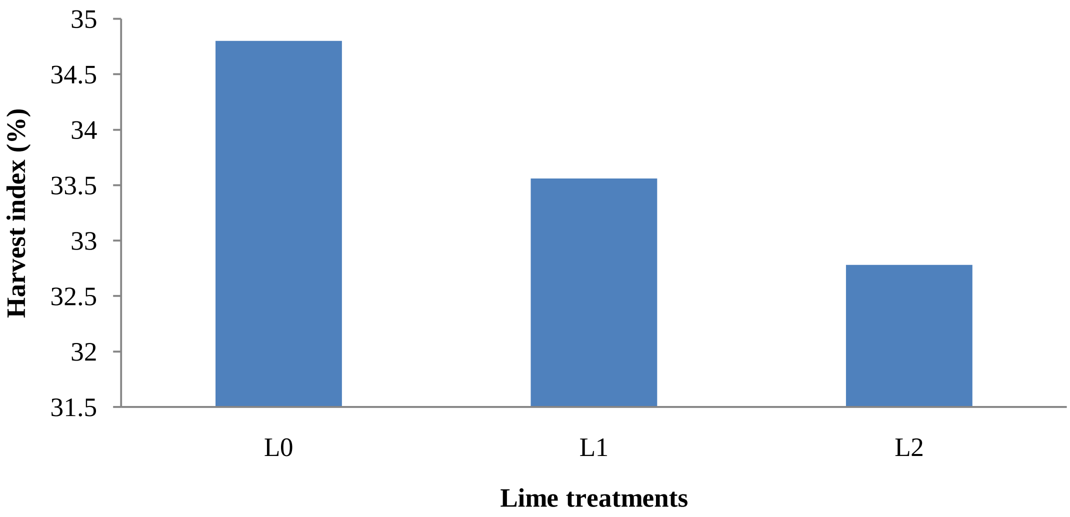
4.2.6.3 Interaction effect of lime and phosphorus

Different levels of lime and phosphorus rate showed significant differences on biological yield of wheat due to interaction effect (Table 8). The highest biological yield (10.12 t ha^{-1}) was observed from L_2P_2 treatment which was statistically similar with L_2P_0(8.577 t) ,L_2P_1(8.990t) ,L_2P_3 (9.783 t ha^{-1}) and L_1P_2 (8.380 t ha^{-1}) and the lowest biological yield (5.437t ha^{-1}) was recorded from L_0P_0 which was statistically similar with L_0P_1(5.950t ha^{-1}), L_0P_2 treatment (6.773 t ha^{-1}), L_0P_3 treatment (6.773 t ha^{-1}), L_0P_2 treatment (6.773 t ha^{-1}).

4.2.7 Harvest index (%)

4.2.7.1 Effect of lime

Harvest index of wheat showed statistically non significant variation due to different levels of lime under the present trial (Fig. 18). Numerically, the highest harvest index (32.78%) was recorded from L_2 treatment and the lowest harvest index (34.80%) was obtained from L_0 treatment.

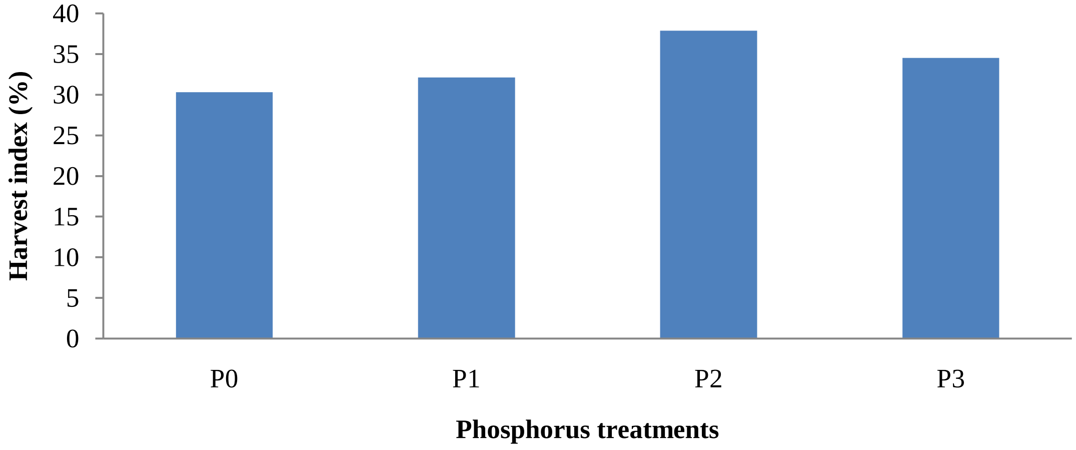


Here: L_0 = Control (No lime**), L_1 =** 1 t ha^{-1}**, L_2 =** 2 t ha^{-1}

Fig. 18: Effect of lime on harvest index of BARI Gom 26 with (SE value=1.551).

4.2.7.2 Effect of phosphorus

Data revealed that there was significant variation for harvest index of wheat due to different phosphorus rate (Fig. 19). Numerically, the highest harvest index (37.89%) was observed from P_2 treatment which was statistically similar with P_3 and the lowest 30.32% was from P_0 treatment which was statistically similar with P_1 and P_3.



Here: **P_0 =** No phosphorus (control)**, P_1 =** 48 kg P_20_5 ha^{-1}**, P_2 =** 77 kg P_20_5 ha^{-1}, **P_3=** 106 kg ha^{-1}.

Fig. 19: Effect of phosphorus on harvest index of BARI Gom 26 with (SE value=1.791)

4.2.7.3 Interaction effect of lime and phosphorus

Interaction effect of different levels of lime and phosphorus showed non significant differences on harvest index of wheat (Table 8). The highest harvest index (38.29%) was observed from L_2P_2 treatment, while the lowest harvest index (32.15%) was recorded from L_0P_0 treatment. The results obtained from the present study were conformity with the findings of Hussain (2011). Harvest index of crop fully depends on grain yield and biological yield of crop. Harvest index of wheat was also significantly affected by treatment effect. The highest harvest was obtained when the crops grown with recommended phosphorus fertilizer with lime treatment.

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was carried out at the Agronomy Field of Sher-e-Bangla Agricultural University, Dhaka-1207 during November 14, 2012 to March 2013 to evaluate growth and yield response of wheat to the application of lime and phosphorous levels. The experiment comprised of three lime levels *viz.* (i) L_0 = no lime (control), (ii) L_1 =1ton ha^{-1}, and (iii) L_2 = 2 ton ha^{-1} and four phosphorus levels viz. (i) P_0 = no P_2O_5 (control), (ii) P_1 = 48 kg P_2O_5 ha^{-1},(iii) P_2 = 77 kg P_2O_5 ha^{-1} and (iv) P_3 = 106 kg P_2O_5 ha^{-1}.

The experiment was laid out in a split-plot design with three replications. The experimental unit was divided into three blocks each of which representing a replication.

Collected data were complied and analyzed by split-plot design to find out the statistical significance of experimental results. The means for all recorded data were calculated and the analyses of variance for all characters were performed. The mean differences among the treatments were adjusted by Duncan's Multiple Range Test (DMRT) at 5% level of significance. Different lime and phosphorous levels showed significant variations on all the growth stages, yield and yield contributing parameters.

In case of lime, at 45,55, 65 ,75 and 85 DAS, the highest dry matter content plant^{-1} viz., 0.6917 g, 2.785g, 5.467 g ,13.59g and 16.31 g were attained from treatment L_2 (2 t ha^{-1}), which were statistically similar to corresponding values of 2.627g, 5.150g, 12.87g, 15.37 g obtained from treatment L_1 . Highest relative water content (RWC) was obtained from L_1 treatment at 75 and 90 DAS (93.22 % and 87.09 %) which was statistically similar with L_2 treatment at 75 DAS and 90 DAS (91.85 and 87.05) .The highest Water Saturation deficit (WSD) was obtained from L_2 treatment at 75 and 90 DAS (9.953% and 14.80%) . The highest (3.09 t ha^{-1}) grain yield was recorded from application of lime 2 ton ha^{-1} (L_2) and the lowest (2.07 t ha^{-1}) was recorded from control (L_0).

L_2 treatment (2 ton ha^{-1}) produced highest plant height (83.14 cm), maximum number of effective tillers m^{-2} (209.20), highest number of spikelet $spike^{-1}$ (18.83), longest spike length (17.38 cm), highest number of total grain $spike^{-1}$ (61.67), highest weight of 1000-grain (39.72 g), highest straw yield per hectare (6.269 ton ha^{-1}), highest biological yield per hectare (9.368 ton ha^{-1}).

For phosphorus, at 45,55, 65,75 and 85 DAS, the highest dry matter content $plant^{-1}$ as 0.6444 g, 3.350 g, 6.670 g,16.75g and 20.10 g were observed from treatment P_2 (77 kg P_2O_5 ha^{-1}), which were statistically similar to corresponding value of 0.5978 g obtained from treatment P_3(106 kg P_2O_5 ha^{-1}) . The highest relative water content was obtained from P_3 treatment at 75 DAS (91.15) which was statistically similar with P_0 ,P_1, P_2 at 75 DAS (90.19%, 89.09%, 90.58% respectively). The highest water saturation deficit was obtained from P_2 treatment at 90 DAS (15.56%) which was statistically similar with P_1, P_2 treatment at 75 DAS (8.409% and 8.142%). The highest (3.16 ton t ha^{-1}) grain yield was recorded from application of phosphorus 77 kg P_2O_5 ha^{-1} (P_2) and the lowest (2.11 t ha^{-1}) was recorded from control (P_0). P_2 treatment (77 P_2O_5 kg ha^{-1}) produced highest plant height (82.05 cm), maximum number of effective tillers/m^2 (185.20), longest spike length (16.76 cm), highest number of spikelet $spike^{-1}$ (18.67), highest number of total grain $spike^{-1}$ (60.44), highest straw yield (5.260 ton ha^{-1}), highest biological yield (8.426 ton ha^{-1}), maximum harvest index (38.29%).

Due to interaction effect of level of lime and phosphorus, the highest dry weight $plant^{-1}$ was obtained from L_2P_2 treatment at 45,55, 65,75 and 85 DAS (0.7667g, 3.880g, 7.760g ,19.40g and 23.28g respectively) which was statistically similar with L_2P_3 treatment at 45 DAS . The highest water saturation deficit (16.72%) was obtained from L_1P_2 treatment at 90 DAS which was statistically similar with L_1P_2, L_2P_3, L_2P_2 treatment at 75 DAS (8.887%, 9.333% and 10.87%). The highest plant height (85.20 cm), maximum number of effective tillers/m^2 (223.30), longest spike length (17.73 cm), highest number of spikelet $spike^{-1}$ (20.67), highest number of total grain $spike^{-1}$ (64.33), The highest weight of 1000-grain (42.50 g), highest grain yield (3.870 ton ha^{-1}), highest straw yield (6.253 ton ha^{-1}), highest biological yield per hectare (10.12ton ha^{-1}), maximum harvest index (38.29%) was observed from L_2P_2 .

From this study it can be concluded that application of lime and phosphorus offers a large scope for better performance of BARI Gom 26. Application of lime at 2 ton ha^{-1} along with phosphatic fertilizer at 77 kg P_2O_5 ha^{-1} favored the uptake of N, K and Ca under acidic soil condition.Most of the growth and yield contributing parameters were observed highest at higher level of lime and P.

Recommendations

If higher levels of lime and P were taken, the results of variation could be different and it would have been convenient to estimate the optimum requirement of lime and P.Further research may be carried out with higher levels of lime on crops in different cropping patterns for enhancing a sustainable wheat production.

REFERENCES

Asrat, M., Gebrekidan, and Negassa, W. (2014).Effect of integrated use of lime, manure and mineral P fertilizer on bread wheat (*Triticum aestivum* L.) yield, uptake and status of residual soil P on acidic soils of Gozamin District, north-western Ethiopia. *Agric. Fores. and Fisher.* **3**(2): 76-85.

Ataurrahman, M., Barma, N. C. D., Sarker, M. H. and Sarker, M. M. R. (2013). Adaptability of wheat varieties in strongly acidic soils of sylhet. *Bangladesh J. Agril. Res***.** **38**(1): 97-104.

Armando J. R.., and Ramos V. J. (2010).Response of four wheat genotypes to lime and phosphorus application. Caixa Postal 28, 13001-970 Campinas, SP, Brazil, E-mail:jfreitas@cec.iac.br

Berman, P., Gogoi, P. K. and Dutta, R.. (2001). Effects of levels of lime and phosphorus on nutrient content and uptake of groundnut. *Annals Agric. Resea.* **22**(4) : 503-507.

Basak, V. (2010). Nutrient Dynamics and Chemical Properties of Acid soil under different liming conditions in Mungbean field followed by Transplanted aman. MS Thesis Student No. 0905046, HSTU, Dinajpur, Bangladesh.

BARI (Bangladesh Agricultural Research Institute). (2012). Wheat varieties released by Bangladesh Agricultural Research Institute

BBS (Bangladesh Bureau of Statistics). (2011). Statistical Year Book of Bangladesh. Min. Plan., Govt. Peoples Repub. Bangladesh. pp. 1-330.

BARC (Bangladesh Agricultural Research Council) (2005). Fertilizer Recommendation Guide-2005. *Soil Pub.* **45**. Farmgate, Dhaka.

BBS (Bangladesh Bureau of Statistics). (2012). Statistical Yearbook of Bangladesh.Ministry of Planning. Govt. of the People's Republic of Bangladesh. Dhaka

Bingham, G., 1966. Varietal response in wheat to water supply in the field and male sterility caused by a period of drought in a glasshouse experiment. Ann. Applied Biol., **57**: 365-377.

Biswas, P. K. 1987. A study on the relative merits of mixed cropping under two levels of irrigations. MS Thesis, Dept. Agron. Sher-e-Bangla Agric. Univ. Mymensingh. pp. 38-40.

Baque, M. A., Karim, M.A. and Hamid, A. (2002).Role of potassium on water relation behavior of *Triticum aestivum* under water stress conditions. *Progress. Agric*. **13** (1 &2): 71-75.

BBS (Bangladesh Bureau of Statistics). (2013). Annual Survey Report. Bangladesh Bur. Stat. Div. Min. Plan., Govt. Peoples Repub. Bangladesh. p. 37.

Bheemaiah, K. A. and Ananthanarayana, R. (1984). Nutrition of groundnut in relation to calcium interaction of soil. *J. Indian Soc. Soil Sci*. **32** : 766-776.

BARC (Bangladesh Agricultural Rural Council). (1997). Fertilizer recommendation guide. Published by Bangladesh Agril. Res. Council, Farmgate, 1215.

Baon, J. B., Smith, S. E., Alston, A. M., & Wheeler, R. D. (1992). Phosphorus efficiency of three cereals as related to indigenous mycorrhizal infection. *Australian J. Agric. Resea.* **43**: 479-491

Christopher, J., Dudenhoeffer, Peter, P. Motavalli, Dunn, D. and Keith W. (2012). Corn production as affected by phosphorus enhancers, phosphorus source and lime. *J. Agric. Sci*. **4**: 10.

CIMMYT (International Maize and Wheat Improvement center). (2013). WHEAT: CGIAR Research Program (CRP) led by CIMMYT. [http://wheat.org/who-we-are/about-us]

Caires, E.F., Correa, J.C.L., Churka, S., Barth,G. and Garbuio F.J. (2006). Surface application of lime ameliorates subsoil acidity and improves root growth and yield of wheat in an acid soil under no-till system. *Scientia. Agricola.* **63**(5):502-509.

Chaudhury, M. R. and Baruah, T. C., 1999, Effect oflime sludge of Nagaon paper mill on soil properties in a Typic Dystrochept growing wheat. *J. of Agric. Sci. Soc. North India*, **12**(2) : 281-285.

Dixit, S. P., Sharma, P. K., (2003).Effects of phosphorus and lime on productivity, phosphorus uptake by onion in a Typic Haplustalf of Himachal Pradesh. *Indian J. Agric. Sci.* **74**(8) : 479-481.

Dosai, A. A. K. (2002). Changes in soil acidity as influenced by lime application in groundnut in Alfisols of Konkan. *Indian J. Agric. Sci*. **73**(11) : 618-619.

Deka, N. C., Dutta, R. and Gogoi, P. K. (2001). Effect of levels of lime and nitrogen on nutrient uptake and residual soil fertility in groundnut. Legume Research, **24**(2) : 118-120

Danielc, Triboïe. (2002). Changes in wheat of protein aggregation during grain development: effects of temperatures and water stress. *Eur. J. Agron*. **16**: 1-12.

Erickson, I. J., Ketring, D.L., Stone, J.F. (1991). Response of internal tissue water balance of peanut to soil water. *Agron. J.* **83**: 248-253.

FAO (Food and Agricultural Organization). (2013). Statistical Year Book. MO. UN, Italy, Rome. pp. 1-289.

Gogoi, P. K., Chaudhury, R. M., Dutta, R. and Deka, N. C., (2000). Effect of levels of lime and nitrogen on production of groundnut. *Crop Research*. **20** : 274-278.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for Agriculture Research. Second Edition. Published by John Wiley and Sons, New York. p. 680.

Gardner, F. P., Pearce, R. B. and Mistechell, R. L. (1985). Physiology of crop plants. Iowa State Univ. Press. Iowa, 500010. p. 66.

Google Maps. (2014). Google maps by Google Inc. [https://maps.google.com]

Holloway, R. E., Bertrand, I., Frischke, A. J., Brace, D. M., McLaughlin, M. J., & Shepperd, W. (2001). Improving fertilizer efficiency on calcareous and alkaline soils with fluid sources of P, N and Zn. *Plant Soil.***23 (**6): 209-219.

Haynes, R.. J. (1992). Effects of liming on phosphate availability in acid soils. *Plant Soil*, **68**(3): 289-308.

Hossain, M. A.,Jahiruddin, M., Ali, M. S., Ahmed, M. U. and Hoque, M. M. (1995). Effect of boron on grain set, yield and some other parameters of wheat cultivars. *Bangladesh J. Agril. Sci* **22**(1): 179-184

Hussain, N., Khan, M.B., Ahmad, R. And Saeed S. (2011).Physiochemical traits, productivity and net return of wheat as affected by phosphorus and zinc requirements under arid climates. *Pak. J. Bot*. **43**(2): 991-1002.

Hossain, A., Sarker, M. A.Z., Hakim, M.A. and Islam, Mst.T. (2011).Effect of lime, magnesium and boron on wheat (*Triticum aestivum* L.) and their residual effect on mungbean (*Vigna radiata* L.). *Int. J. Agril. Res. Innov. & Tech.* **1** (1&2): 9-15.

Hossain, F. (2004).Soil fertility monitoring and management in wheat rice system. *Annul Report* of IRRI, NARC, Islamabad,

Islam M. R., Islam, M. S., Jahiruddin, M. and Hoque, M. S. (1999). Effects of sulphur, zinc and boron on yield, yield components and nutrient uptake of wheat. *Pakistan J. Sci. Ind. Res*. **42**: (8), 137-140.

Jahiruddin, M. Hoque, M. S., Haque, A. K. M. M. and Roy, P. K. (1992). Influence of boron, copper and molybdenum on grain formation on wheat. *Crop Res*. **5**: 35-42.

Jovanovic, Z., Djalovic I., Komljenovic I., and Kovacevic V., Cvijovic M. (2006). Influence of liming on vertisol properties and yields of the field crops. *Cereal Research communications.* **34**(1): 517-520.

Jamwal, J. S., & Bhagat, K. L. (2004). Response of wheat (*Triticum aestivum*) to top dressing of diammonium phosphate in rainfed areas of Shivalik foothills. *Indian J. Agronomy*.**49**(4), 251-253.

Kisinyo, P. O., Othieno, C. O., Gudu, S. O. and Okalebo, J. R.(2013). Phosphorus Sorption and Lime Requirements of Maize Growing Acid Soils of Kenya. **2**: 2.

Khan, R., Raza, A., Hussain,A. and Sarhad J. (2007). Effect of phosphorus application on wheat and rice yield under wheat- rice system .*Agric*. **23**: 4.

Kamaruzzaman, M., Rasel, S. M. M. and Islam, M. N. (2013). Effect of lime on yield contributing characters of Wheat in Barind tract of Bangladesh. *J. Agric. Veteri. Sci*. **4:** PP 39-46.

Kisic, I., Basic, Mesic F. M. and Butorac. (2002). A.Efficiency of mineral and organic fertilization and liming in growth maize and winter wheat. *Agriculturae Conspectus Scientificus Poljoprivredna Znanstvena Smotra.* **67**(1):29-37 .

Kamprath, E. J. (1970). Soil Acidity and Response to Liming. *Technical Bulletin 4*, ISTP series, North Carolina Agricultural Experimental Station, North Carolina.

Khan, M. B., Lone M.I., Ullah, R. and Ahmed M. (2010). Effect of different phosphatic fertilizers on growth attributes of wheat (*Triticum aestivum* L.).*J. American Sci*. **6**(12)

Kaleem, S., Ansar, M., Ali, M. A., Sher, A., Ahmed, G. and Rasid, M (2009)..Effect of phosphorus on the yield and yield component of wheat variety. *Sarhad J. Agric.***25**(1):21-24.

Mumtaz, M.Z., Aslam, M., Jamil,M. and Ahmad, M. (2014).Effect of Different Phosphorus Levels on Growth and Yield of Wheat under Water Stress Conditions. *J. Environ. and Ear. Sci*. **4**: 19.

Mbakaya, D.S., Muricho, M. and Lumasayi, S (2009). Effects of liming and inorganic fertilizers on maize yield in Kakamega north and ugunja districts, western Kenya.

Martini, J. A., Kochchann, R. S., Sequeria, O. J. and Barkert, C. M.(1974). Response of soybeans to liming as related to soil acidity, Al and Mn toxicities and P in some Oxisols of Brazil. Soil Science Society of America Proceedings, **28** : 616-620.

Mathur, B. S., Rana, N. K. and Sinha, H. And Lal S. (1985). Lime as an effective source of fertilizer in acid red loam soils of Bihar. *J. Indian Soc. Soil Sci.* **33** : 328-332.

Mittra, G. N., Sahu, S. K. and Parida, S. K. (1992). Integrated nutrient management of rice-groundnut cropping system in *Aeric Haplaquepts*. *Indian J. Agric. Sci.* **62**(6) : 391-394.

Mandimba, G. R. and Kilo, C. P. (1997). Effect of liming on the performance of groundnut grown on acid soil in Congo. International Arachis Newsletter. **17**(6) : 66-67.

Mongia, A. D., Singh, N. T. and Guha, A. (1998). Response of rice to liming and P application in acid soils of South Andaman. *J. Indian Soc. Soil Sci.* 46(4) : 697-700

Mohammad, A., Mitra, B., Khan, A. G. (2004). Effects of sheared-root inoculum of Glomus intraradices on wheat grown at different phosphorus levels in the field. *Agric. Ecosy. Environ*. 103: 245-249.

Mcbeath, T. M., Armstrong, R. D., Lombi, E. McLaughlin, M. J. & Holloway, R. E. (2005). Responsiveness of wheat (*Triticum aestivum*) to liquid and granular phosphorus fertilisers in southern Australian soils. *Australian J. Soi. Res*.**43**: 203-212.

Mclay, C. A. and Ritchie G. S. P.(1993). Effect of gypsum and lime on wheat growth in pots containing an acidic subsoil .Department of Soil Science and Plant Nutrition, University of Western Australia, Nedlands, Western Australia 6009.

Mandal, L. N. and Khan, S. K. (1972).Release of phosphorus from insoluble phosphatic materials in acidic low land rice soils. *J. Indian Soc. Soil Sci.* **20**: 19-25.

Mathur, B. S., Rana, N. K. And Sinha, H. And Lal, S. (1985). Lime as an effective source of fertilizer in acid red loam soils of Bihar. *J. Indian Socie. of Soil Scie..* **33** : 328-332.

Mamun, M.N.H., Rahman, M.S., Jahangir, N. M. and Islam K. N. (2012).Effect of Phosphate Rock on the Growth and Yield of Wheat (*Triticum aestivum* L.) under Old Brahmaputra Floodplain Soils. *The Agriculturists* .**10** (1):31-37

Nakagawa, J., Imaizumi, I. and Rossetto, C. A. V. (1993). Effects of different phosphorus sources and liming on groundnut yield. *Pes. Agrop. Brasil*. **28**(4) : 421-431.

Nguyen-cong-vinh, (2003). Phosphorus fertilization strategies for groundnut grown on upland acid soils in Nghe, An Province. Better Crops International. **17**(2) : 11-15.

Osundwa, M. A. Okalebo, J. R., Ngetich, W. K. and Ochuodho, J. O. (2013). Influence of agricultural lime on soil properties and wheat (*Triticum aestivum* L.) yield on acidic soils of Uasin Gishu Country, Kenya. *American J. Experi. Agric.* **3**(4): 806-823.

Orakwue, F. C. (1984). Wheats for more tropical environments. *A procee. of the interna. Sympo.* Mexico . pp. 100-106

Panda, D., Pattnaik, R. N. and Mishra, M., (1990). Effect of different sources of phosphorus and levels of lime on groundnut. *Indian J. Agron.,* 35(4) : 426-427.

Poulsen, K. H., Nagy, R., Gao, L. L., Smith, S. E., Bucher, M., Smith, F. A. & Jakobsen, I. (2005). Physiological and molecular evidence for Pi uptake via the symbiotic pathway in a reduced mycorrhizal colonization mutant in tomato associated with a compatible fungus. *New Phytologist*. **168**: 445-453.

Paliyal, S. and Verma, T. S. (1999). Effect of phosphorus on crop yields in wheat-soybean cropping sequence in acid Alfisols amended with lime and gypsum. *J. Indian Socie. Soil Sci.* **47**(2) : 377-379.

Rao, L. J. and Mittra, B. N. (1991).Effect of phosphorus and liming of lateritic soil on intercropping of pigeonpea and groundnut. *Indian J. Agron*. **36**(1): 99-100.

Rahim, A., Ranjha A.M., Rahamtullah and Waraich E.A. (2010). Effect of phosphorus application and irrigation scheduling on wheat yield and phosphorus use efficiency. *Soil & Environ*. **29**(1):15-22.

Raychaudhuri, M. and Kumar, K. (2002). Direct and residual effects of lime on soil characteristics, yield and nutrient uptake on maize and soybean in an acid hill soil of Manipur. *Indian J. Agric. Sci.* **72**(2) : 67-69.

Reeve, N. G. and Summer, M. E., (1970). Lime requirement of natal Oxisols based as exchange aluminium. *Soil Sci. Soc. America Proce.* **24** : 26-32.

Renata and Elem, J.(2013). Effect of differentiated Phosphorus and potassium Fertilization on winter Wheat yield and quality. *Agric*. **55**: 6.

Renu, P., Bhupinder, S., & Nair, T. V. R. (2005). Phosphorus use efficiency of wheat, rye and triticale under deficient and sufficient levels of phosphorus. *Indian J. Plant Physio*. **10**(3): 292-296.

Raychaudhuri, M., Rauchaudhuri, S. and Singh, A. L., (2002). Yield response of groundnut to dual inoculation and liming on an acidhill Ultisol of Manipur. *Indian J. Agric. Sci*. **73**(2): 86-88.

Richard E. SMART' and Bingham .G.E. (1974). Rapid estimates of relative water content received for publication. Department of Agricullture, Viticultural Research Stationi, Griffith, Newv South Wales, Australia. *Plant Physiol*. **53**: 258-260

Raychaudhuri, M. And Kailash, K. (2002). Direct and residual effects of lime on soil characteristics, yield and nutrient uptake on maize and soybean in an acid hill soil of Manipur. *Indian J. Agric. Sci.***72**(2) : 67-69

Raza, M.A.S. , Saleem, M. F., Shah G. M., Jamil, M. and Khan , I.H. (2013). Potassium applied under drought improves physiological and nutrient uptake performances of wheat (*Triticum Aestivum L.*). *J. Soil Sci. and Plant Nutrit*. **13**(1): 175-185.

Rerkasem B. Bell R. W. , Lodkaew S. Loneragan J. F. (1993).Boron deficiency in soybean [*Glycine max* (L.) Merr.] peanut (*Arachis hypogaea* L.) and black gram [*Vigna mungo* (L.) Hepper]: Symptoms in seeds and differences among soybean cultivars in susceptibility to boron deficiency. *Plant Soil.* **150**.(2): 289-294.

Rerkasem, B., S. Jamjod and S. lodkaew. (1991). Assessment of grain set failure and diagnosis for boron defesiency in wheat.pp:504-505

Sharma, S. N., Prashed, R. and Singh, R. K. (2000). Influence of summer legumes in rice (*Oryza sativa*)-Wheat (*Triticum aestivum L.*) cropping system on soil fertility. *Indian J. Agric. Sci.* **70**(16): 357-359.

Sudhir, K., Anantharanayana, R. and Deshpande, P. B., (1987). Influence of calcium, magnesium and potassium fertilization of groundnut on the yield attributes, uptake of nutrients and soil chemical characteristics. *Mysore J. Agric. Sci*. **21** : 164-168.

Sharma, K. and Gupta, J. P. (1994). Effect of phosphorus, lime and FYM on the yield and uptake of calcium and magnesium at different stagesin late sown wheat in an acid alfisol of Himalayan region. *J. Indian Soc. Soil Sci.* **42**(1) : 77-80.

Siddique , M.R.B., Hamid, A. and Islam M.S. (2000).Drought stress effects on water relations of wheat. *Bot. Bull. Acad. Sin.* **41**: 35-39

Samia, B.S. (2007). Effect of liming on soil properties and yield of wheat .MS Soil Sci. Thesis student no. 0605015, HSTU, Dinajpur.

Sarker, A., Kashem M. A., Khan T. O. (2014). Influence of lime and phosphorus on growth performance and nutrient uptake by indian spinach (*Basella alba* L.) grown in soil .*Op. J. Soil Sci.*. **4**: 98-102.

Savani, R. P., Patel, M. S. and Sutaria, G. S. (1991). Influence of sulphuric acid on the availability of applied P to groundnut in calcareous soils. *J. Indian Soc. Soil Sci.* **39**(4) : 798-800.

Samanta, M., Bhadoria, P. B. S. and Ghosh, B. C., (1994). Effect of lime and phosphorus on phosphate availability and yield of groundnut in Oxisol. *Indian J. Agron*. **39**(4) : 692-693.

Sultana, B.S., Mian, M.M.H., Islam M.R. and Rahman M.M. (2009). Effect of liming on soil properties, yield and nutrient uptake by wheat. Current World Environment . **4**(1): 39-47.

SRDI (Soil Resource Development Institute). (1991). Land and Soil Resource Utilization Guide: Mymensingh Sadar Thana, Mymensingh. (In Bangali). SRDI, Ministry of Agricultural, Dhaka, Bangladesh. p. 3.

Tanglina., Liu-shuzin, Li-chunyin and Tang-ln, (1999). Effect of soil acidity adjustment on growth and quality of tobacco. *J. Fuj. Agric. Univ.* **28**(1) : 71-76.

Tran-thi-tha-ha, (2003). Effected of phosphorus fertilizer on groundnut yield on poor alluvial and sandy soils of Thua Thien Hue. Better Crops International. **17**(2) : 16-17.

Turk, M.A. and A.M. Tawaha. (2002). Impact of seedling rate, seeding date, rate and method of phosphorus application in faba bean (*Vicia faba* L. Minor) in the absence of moisture stress. *Biotec. Agron. Socie. and Environ.* **6** : 171-178

Uzoho, B.U., Osuji G.E., Onweremadu, E.U and and Ibeawuchi I.I. (2010).Maize (zea mays) response to phosphorus and lime on gas flare affected soils. *Life Sci. J.* **7**: 4

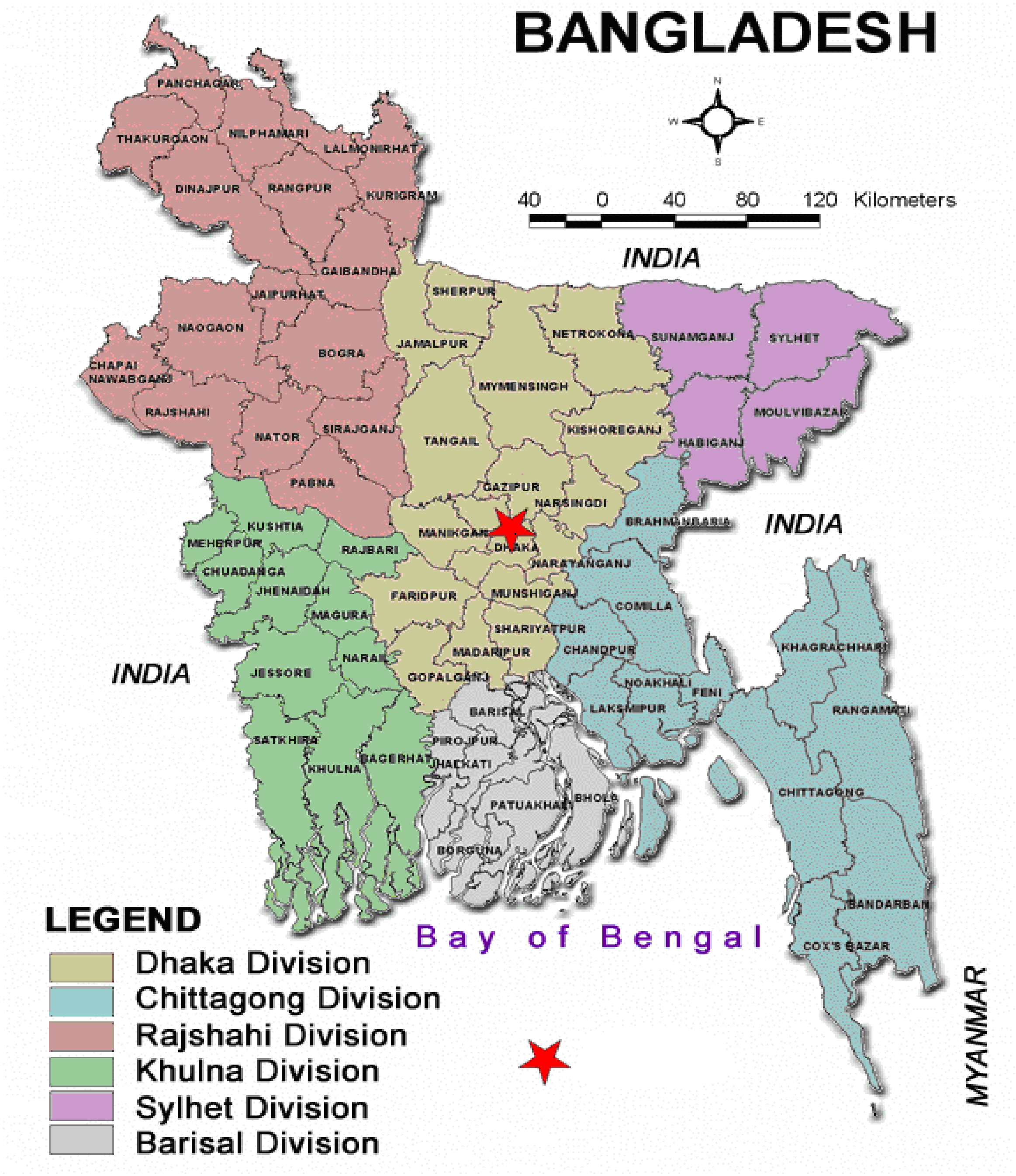
USDA (United States Department of Agriculture). (2014). National Nutrient Database for Standard Reference. *Basic Repor*t: 20080, Wheat flour, whole-grain.

Viswanatha, S. Y., Gajanan, G. N., Naidu, B. S. and Singlachar, M. A. (1990). Influence of levels of calcium saturation on yield and oil content of sunflower. *Current Research*, **19** : 133-134.

Yuan, T. L. (1960). Forms of newly fixed phosphorus in acid sandy soils. *Soil Sci. Soc. America Proc.* **24**: 447-450.

APPENDICES

Appendix I: Experimental site at Sher-e-Bangla Agricultural University, Dhaka-1207



Appendix II: Physical characteristics and chemical composition of soil of the experimental plot

Soil Characteristics	**Analytical results**
Agrological Zone	Madhupur Tract
P^H	5.4 (High acidic)
Sand (%)	23
Silt (%)	48
Clay (%)	29
Organic matter	1.01 (low)
Total N (%)	0.051(Very low)
Available phosphorous (ppm)	4.2 (Very low)
Exchangeable K (meq / 100 g soil)	0.56 (Very high)
Total S (microgram/gm. soil)	31.5 (High)
Total B (microgram / gm. soil)	0.33 (Medium)
Total Zn (microgram / gm. soil)	2.43 (Very high)

Appendix III: Monthly average air temperature, relative humidity, rainfall and sunshine hours during the experimental period (November, 2012 to March, 2013) at Sher-e-Bangla Agricultural University campus.

Month	Year	Monthly average air temperature (^{0}C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
Nov.	2012	27.28	11.15	19.26	68.34	Trace	220.80
Dec.	2012	27.19	10.91	19.05	70.05	Trace	212.50
Jan.	2013	25.23	18.20	21.80	74.90	4.0	195.00
Feb.	2013	31.35	19.40	25.33	68.78	3.0	225.50
Mar.	2013	33.20	22.00	27.60	64.13	Trace	220.30

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka – 1212.

Appendix IV: Plant dry weight

1. Plant dry weight at 45 DAS

Source of variation	DF	Sum Of Squares	Mean square	F Value
Replication	2	0.139	0.070	2.0567
Factor A	2	0.293	0.147*	4.3294
Error	4	0.136	0.034	
Factor B	3	0.137	0.046*	13.3529
AB	6	0.002	0.000*	0.1146
Error	18	0.062	0.003	

***** Significant at 5% level
^{ns} Non significant

2. Plant dry weight at 55 DAS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.039	0.019	0.0920
Factor A	2	1.670	0.835*	3.9718
Error	4	0.841	0.210	
Factor B	3	10.734	3.578*	28.0390
AB	6	1.453	0.242*	1.8982
Error	18	2.297	0.128	

***** Significant at 5% level
^{ns} Non significant

3.Plant dry weight at 65 DAS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.205	0.102	0.0825
Factor A	2	4.447	2.224*	1.7933
Error	4	4.960	1.240	
Factor B	3	47.585	15.862*	30.8012
AB	6	4.004	0.667*	1.2958
Error	18	9.269	0.515	

***** Significant at 5% level
^{ns} Non significant

4.Plant dry weight at 75 DAS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	1.022	0.511	0.0845
Factor A	2	19.719	9.859*	1.6296
Error	4	24.201	6.050	
Factor B	3	282.074	94.025*	33.3959
AB	6	24.146	4.024*	1.4293
Error	18	50.678	2.815	

***** Significant at 5% level
^{ns} Non significant

5.Plant dry weight at 85 DAS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.098	0.049	0.0074
Factor A	2	23.180	11.590	1.7431
Error	4	26.597	6.649^{ns}	
Factor B	3	393.391	131.130*	25.3307
AB	6	34.098	5.683*	1.0978
Error	18	93.181	5.177	

***** Significant at 5% level
^{ns} Non significant

Appendix V: Relative water content leaf per plant

1. Relative water content leaf per plant at 75 DAS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	55.770	27.885	0.5662
Factor A	2	385.638	192.819*	3.9154
Error	4	196.988	49.247	
Factor B	3	20.281	6.760^{ns}	0.1833
AB	6	319.143	53.190*	1.4422
Error	18	663.873	53.190	

***** Significant at 5% level
^{ns} Non significant

2. Relative water content leaf per plant at 90 DAS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	40.425	20.213	1.3153
Factor A	2	12.844	6.422 ^{ns}	0.4179
Error	4	61.469	15.367	
Factor B	3	260.053	86.684*	4.0603
AB	6	30.775	5.129 ^{ns}	0.2403
Error	18	384.286	21.349	

***** Significant at 5% level
^{ns} Non significant

Appendix VI : Water saturation deficit leaf per plant

1. Water saturation deficit leaf per plant at 75 DAS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	1.070	0.535	0.2569
Factor A	2	43.047	21.524*	10.3330
Error	4	8.332	2.083	
Factor B	3	14.326	4.775*	2.5901
AB	6	3.674	0.612*	0.3321
Error	18	33.186	1.844	

***** Significant at 5% level
^{ns} Non significant

2. Water saturation deficit leaf per plant at 90 DAS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	23.115	11.558	2.9362
Factor A	2	115.490	57.745*	14.6704
Error	4	15.745	3.936	
Factor B	3	216.955	72.318*	12.2124
AB	6	34.395	5.732*	0.9680
Error	18	106.591	5.922	

***** Significant at 5% level
^{ns} Non significant

Appendix VII: Water retention capacity leaf per plant

1. Water retention capacity leaf per plant at 75 DAS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.282	0.141	4.3602
Factor A	2	0.455	0.227^{ns}	7.0340
Error	4	0.129	0.032	
Factor B	3	0.022	0.007^{ns}	0.0453
AB	6	0.374	0.062*	0.3840
Error	18	2.921	0.162	

***** Significant at 5% level
^{ns} Non significant

2. Water retention capacity leaf per plant at 90 DAS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.454	0.227	0.8008
Factor A	2	0.769	0.384^{na}	1.3561
Error	4	1.134	0.283	
Factor B	3	0.236	0.079*	0.4327
AB	6	1.111	0.185^{ns}	1.0170
Error	18	3.278	0.182	

***** Significant at 5% level
^{ns} Non significant

Appendix VIII: Plant height

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	20.782	10.391	0.4640
Factor A	2	196.814	98.407*	4.3941
Error	4	89.580	22.395	
Factor B	3	83.554	27.851 ^{ns}	1.8193
AB	6	8.113	1.352*	0.0883
Error	18	275.553	15.308	

***** Significant at 5% level
^{ns} Non significant

Appendix IX: Spike length

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	5.296	2.6147	2.6147
Factor A	2	22.034	11.017*	10.8795
Error	4	4.051	1.013	
Factor B	3	2.130	0.710 ^{ns}	0.6412
AB	6	0.046	0.008 *	0.0069
Error	18	19.930	1.107	

***** Significant at 5% level
^{ns} Non significant

Appendix X: Spikelet per spike

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	3.069	1.534	0.7798
Factor A	2	55.136	27.568*	14.0096
Error	4	7.871	1.968	
Factor B	3	25.693	8.564 *	2.3313
AB	6	2.420	0.403 *	0.1098
Error	18	66.127	3.674	

***** Significant at 5% level
^{ns} Non significant

Appendix XI: Grain per spike

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.722	0.361	0.0106
Factor A	2	229.056	114.528*	3.3657
Error	4	136.111	34.028	
Factor B	3	88.972	29.657 ^{ns}	0.8697
AB	6	4.944	0.824 ^{ns}	0.0242
Error	18	613.833	34.102	

***** Significant at 5% level
^{ns} Non significant

Appendix XII: Weight of 1000 grains

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	3.742	1.871	0.3540
Factor A	2	34.042	17.021 ns	3.2200
Error	4	21.144	5.286	
Factor B	3	93.113	31.038 ns	1.8034
AB	6	7.467	1.244 ns	0.0723
Error	18	309.800	17.211	

***** Significant at 5% level
ns Non significant

Appendix XIII: Grain yield

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	0.287	0.143	0.2509
Factor A	2	6.345	3.172 *	5.5530
Error	4	2.285	0.571	
Factor B	3	5.600	1.867*	9.2973
AB	6	0.710	1.867 * 0.118	0.5890
Error	18	3.614	0.201	

***** Significant at 5% level
ns Non significant

Appendix XIV: Straw yield

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	4.963	2.481	1.0645
Factor A	2	31.379	15.690*	6.7308
Error	4	9.324	2.331	
Factor B	3	0.678	0.226 ns	0.3417
AB	6	0.483	0.081*	0.1218
Error	18	11.905	0.661	

***** Significant at 5% level
ns Non significant

Appendix XV: Biological yield

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	5.843	2.921	0.6364
Factor A	2	65.940	32.970*	7.1831
Error	4	18.360	4.590	
Factor B	3	9.808	3.269 *	3.6026
AB	6	0.444	0.074*	0.0815
Error	18	16.334	0.907	

***** Significant at 5% level

^{ns} Non significant

Appendix XVI: Harvest index

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	2	78.029	39.015	1.2985
Factor A	2	24.856	12.428*	0.4136
Error	4	120.181	30.045	
Factor B	3	289.693	96.564*	3.3432
AB	6	34.536	5.756^{ns}	0.1993
Error	18	519.914	28.884	

***** Significant at 5% level

^{ns} Non significant