EFFECT OF LIMING AND PHOSPHORUS ON GROWTH AND YIELD OF TOMATO

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EFFECT OF LIMING AND PHOSPHORUS ON GROWTH AND YIELD OF TOMATO

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CERTIFICATE

This is to certify that thesis entitled, **"EFFECT OF LIMING AND PHOSPHORUS ON GROWTH AND YIELD OF TOMATO"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN SOIL SCIENCE,** embodies the result of a piece of *bona fide* research work carried out by **MD. ARIFUL HAQUE MASUM, Registration no. 09-03631** under my supervision and guidance. No part of the 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.

……….....…..……………………….

Dated: **(Prof. Dr. Alok Kumar Paul)**

Place: Dhaka, Bangladesh **Supervisor**

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ABSTRACT

The present experiment was carried out at the Farm of Sher-e-Bangla Agricultural University, Dhaka-1207 to find out the effect of liming and phosphorus on growth and yield of tomato during the pried from October 2014 to April, 2015. The experiment consisted of four level of phosphorus viz. 0, 20, 40, 60 kg P ha^{-1} and three levels of dolomite (viz. 0, 1, 1.5 t ha^{-1}) as liming material. The two factors experiment was set up in Randomized Complete Block Design (RCBD) with three replications. In total, there were 12 treatment combinations in this study. A unit plot was 2m×2m and the treatments were distributed randomly in each block. Data on growth and yield parameters were recorded and analyzed statistically. Results showed that different levels of phosphorus and liming significantly differed in all growth and yield contributing characters. The highest plant height (85.26 cm), number of primary branches (13.65), fruit length (6.82 cm) and yield of fruit (66.29 t ha^{-1}) was obtained from 60 kg P ha^{-1} treatment. The maximum plant height (85.02 cm), number of primary branches (12.40), fruit length (6.77 cm) and yield of fruit (55.18 t ha^{-1}) was recorded from 1.5 ton dolomite ha^{-1}. The highest plant height (91.24 cm), number of primary branches (15.03), fruit length (8.20 cm) and yield of fruit (82.55 t ha^{-1}) was recorded with the treatment combination of 60 kg P ha^{-1} + 1.5 t ha^{-1} of dolomite. On the other hand, the lowest yield of fruit (24.4 t ha^{-1}) and for all cases lowest result was found in no phosphorus and no liming. The highest N, P and K concentration in soil was recorded from 60 kg P ha^{-1} treatment. The highest N, P and K concentration in soil was recorded from 1.5 ton dolomite ha^{-1} treatment. The highest N, P and K concentration in soil was recorded from 60 kg P ha^{-1} with 1.5 ton dolomite ha^{-1} treatment.

CONTENTS

CONTENTS (Contd.)

LIST OF TABLES

LIST OF APPENDICES

LIST ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
HRC	=	Horticulture Research Centre
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agriculture Organization
N	=	Nitrogen
et al.	=	And others
TSP	=	Triple Superphosphate
MOP	=	Muriate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources & Development Institute
wt	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

CHAPTER I

INTRODUCTION

One of the most palatable vegetables which usually occupies the maximum number of our daily dishes and also takes its possession in market is tomato (*Lycopersicon esculentum* Mill.). It is a member of the Solanaceae family which possesses versatile use. Due to the excellent adaptability to wider range of soil and climatic conditions it is widely grown in any parts of the world (Ahmed, 1976). The climatic condition of Bangladesh favors tomato to grow in winter season and it can be cultivated in all parts of the country (Haque *et al.,* 1999). It is originated in tropical America (Salunkhe *et al.,* 1987), mainly in the region of the Andes Mountain in Peru and Bolivia (McCollum, 1992). It ranks third in the worlds vegetable production next to potato and sweet potato (FAO, 2003) and as a processing crop ranks first among the vegetables (Choudhury, 1979 and Shanmugavelu, 1989).

Food value of tomato is very rich because of higher contents of vitamins A, B and C including calcium and carotene (Bose and Som, 1990). It is much popular as salad in the raw state and is made into soups, juice, ketchup, pickles, sauces, conserved puree, paste, powder and other products (Ahmed, 1986 and Bose and Som, 1990).

In Bangladesh, it is cultivated as winter vegetable, which occupied an area of 59000 acres of land, and the total production of tomatoes were 190 thousands metric tons in Bangladesh (BBS, 2011). Thus the average yield of tomato is 14.35 t/ha, while it was 41.81 t/ha in the world (FAO, 2007), which is very low in comparison with that of other countries, namely India (15.67 t/ha), Japan (52.82 t/ha) and USA (63.66 t/ha). The yield of tomato in our country is not satisfactory enough in comparison to requirement (Aditya *et al.,* 1999). The low yield does not indicate the low yield potentiality of this crop in Bangladesh but indicates the fact of improper management of cultural practices. Fertilizer management practices are one of the most important cultural practices particularly in tomato due to the intensive cropping and gradual decline in soil nutrients. This situation can be alleviated by proper fertilizer management practices (Tindall, 1983). So, judicial use of fertilizers may provide us with increased yield of tomato.

Phosphorus is the most important nutrient elements for tomato production. Optimum level of P application increases the vegetative growth, yield and yield attributes and each nutrient element had a positive effect on vegetative growth as well as yields (Rahman *et al.,* 1996 and Shil *et al.,* 1997).

Phosphorus availability is considered one of the major growth-limiting factors for plants in many natural ecosystems. Plants have developed several adaptive mechanisms to overcome P stress (Marschner, 1995). Phosphorus is an essential element in the energy transfer processes; it is needed in the formation of fat, in transformation of starch to sugar, at flowering and fruiting stages.

Mono super phosphate has been most widely used a P fertilizer for agricultural purposes in Egypt. Supplying vegetable crops with organic and inorganic fertilizers was proved to be very essential for production of higher yield and for improving its quality (Mengal and Kirkby, 1987).

High levels of soil acidity (low soil pH) can cause reduction of root growth, nutrient availability, reduction of crop yields and deterioration of soil physical properties (Adams, 1984). In general it affects the biological, chemical and physical properties of soil, which in turn affect the sustainability of crop production. In order to produce a better yield on acid soils, farmers are recommended to apply liming materials rich in calcium and magnesium to increase the soil pH and thus eliminate Al toxicity and increase nutrient availability, especially phosphorus. Liming is common recommendations for improvement of acid soils in Croatia (Kisic *et al*., 2002, Kovacevic *et al.*, 2006, Loncaric *et al.,* 2006, Rastija *et al*., 2007, 2008, Kovacevic and Rastija 2010, Andric *et al.,* 2012).

Application of finely crushed limestone, or other liming material, is the only practical way to neutralize soil acidity. Limestone is most effective if sufficient is applied to raise the pH from 4.5 to 5.5 and it is well incorporated into the soil. Where acidity occurs deeper than the plough layer, the limestone will only neutralize subsurface soil acidity if the pH of the surface soil is maintained above 5.5.

The liming materials most commonly used are agricultural limestone and dolomite, but other materials are also available. Liming with dolomite considerably affected soil chemical properties and raised soil pH from initially acid or very acid to neutral or slightly alkaline reaction. Improvement of soil acidity resulted in great increases of plant available phosphorus.

Liming to increase the pH of the surface 10 cm significantly above 6.0 should be avoided as it may induce deficiency of other plant nutrients such as zinc, boron and manganese in well weathered soils. Where the soil is acidic to depth it may take many years for the lime effect to move to 20 cm, especially for heavy soils.

Soil acidification is a permanent natural process that is present in most soils used for plant production. If proper measures for the correction of excessive soil acidity were not applied, those soils would eventually become more acidic. Improving the acid soils fertility through the application of different liming materials is a widely recognized practice to enhance crops productivity (Mesic, 2001; Rengel, 2003). However, at the same pH value different soils response differently to the same amount of lime material and positive responses may not be achieved immediately. The solubility and nutrients availability is strongly dependent on soil pH.

Phosphorus de ciency is due to inherent low soil P, high P xation by Al and Fe oxides and insufficient fertilizer use to replace soil P removed through crop harvests (Buresh *et al.*, 1997). Lime reduces the levels of exchangeable Al3+, Fe3+ and Mn4+ in acid soils and thus reduces P sorption. This makes both the native soil P and applied P fertilizers available for plant uptake. Combined applications of P fertilizer and lime increased and maintained higher soil available P than where either of them was applied alone. This was because of the likely reduction in P sorption by lime, thus making the P fertilizer more available for plants (Buresh *et al.,* 1997). Therefore, combined applications of lime and P fertilizer are important in increasing and maintaining higher residual soil available P in P-deficient acid soils.

Considering the above mentioned issues, the present experiment was conducted with the following objectives.

i. To find out the optimum doses of phosphorus and lime for maximizing the growth and yield of tomato.
ii. To study the effect of lime on the availability of P for the growth and yield of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is an important vegetable crop and received much attention of the researchers throughout the world to develop its suitable production technique. Establishment and growth of tomato plants largely depend on phophorus fertilizer. Large number of researchers has studied the effect of liming and phosphorus on the growth and yield of tomato in different countries of the world, but their findings have little relevance to the agro-ecological situation of Bangladesh. However, literature available in this respect at home and abroad has been reviewed here, which will contribute useful information to the present study.

2.1 Effects of phosphorus on plant growth and yield of tomato

Habibzadeh and Moosavi (2014) carried out an experiment based on a randomized completely design in pot culture. Four phosphorus levels: 2, 5, 10, and 15 mg P kg^{-1} soil possessed phosphorus fertilization treatments as the first factor. At the second factor, arranged inoculations with two mycorrhizal fungal species (*Glomus mosseae, Glomus intraradices* and uninoculated plants) with three replications were conducted in the greenhouse of Agricultural Research Center of West Azarbaijan province Urmia, in 2013. Results showed that the above-ground dry matter of inoculated tomato at both species with 0.30 and 0.28 g/plant had the highest values. Both species had more above and under-ground fresh weight, shoot height, number of leaves and root length than control. Colonization of *G. mosseae* and *G. intraradices*, with 51.36 and 42.94% had the most values at the 2 mg P kg^{-1} soil. Different levels of phosphorus × mycorrhiza interaction showed that G. mosseae had the most leaf phosphorus (414.67 mg/100g of leaf dry weight), leaf area (99 cm^2) and root volume (1.77 cm^3) at the 15 mg P kg^{-1} soil. Leaf phosphorus, above and underground fresh weight, shoot height, leaf area, root volume, root length and number of leaves had positive correlation coefficients with above-ground dry matter. Also, phosphorus concentration was positively correlated with all measured traits. The overall results demonstrated that mycorrhizal fungi through improvement of phosphorus nutrition, promoted growth of tomato plants under very low phosphorus conditions.

Kumar *et al.* (2013) carried out an experiment during the winter season of 2009-2010 to study the effect of nitrogen, phosphorus and potassium fertilizers on the growth, yield and quality of tomato var. Azad T-6 at the Horticultural Research Farm of the Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University, Lucknow. Three types of fertilizers (nitrogen, phosphorus and potassium) in different combinations were tested in a Randomized Block Design with three replications. Tomato plants were fertilized with different rates of chemical fertilizers i.e. two doses of nitrogen fertilizers N_1 and N_2 (120 and 180 kg/ha), single dose of phosphorus P_1(80 kg/ha) and potassium K_1(75 kg/ha).

The highest plant height, the maximum number of primary and secondary branches, number of flowers and fruits/plant as well as the greatest fruit size, fruit yield/plant and fruit yield/ha were obtained from the application of the recommended dose of nutrients viz., 120 kg N +80 kg P +75 kg K/ha. The results revealed that significantly the highest plant height higher yield and yield attributing characters were recorded with the application of 100% NPK i.e. 180 kg N/ha along with 80 kg P/ha and 75 kg K/ha.

Gad and Kandil (2010) carried out in the Research and Production Station, National Research Center, El-Nobaria during the season, 2009 to evaluate the effect of cobalt and different sources of phosphorus fertilizers on the growth, yield quantity and quality of tomato. Treatments can be arranged in descending order as follows: Mono super phosphate (MSP) > Triple super phosphate (TSP) > Rock phosphate (RP). Mono super phosphate (MSP) had superior effect on all growth parameters of tomato shoots and roots yield quantity and quality as well as mineral nutrient constituents of tomato fruits compared with other phosphorus sources. Rock phosphate (RP) treatment gave the lowest values of tomato growth, yield, chemical constituents and mineral composition of tomato fruits. Cobalt addition enhanced all parameters of tomato growth and yield with all sources of phosphorus fertilizers especially with mono superphosphate.

The effects of phosphate solubilizing bacterium (*Bacillus* FS-3) application on phosphorus contents of tomato (*Lycopersicon esculentum* L.) plant, growing performance and phosphorus forms in soil were evaluated under greenhouse condition. Five different phosphorus fertilizer treatments (normal superphosphate, triple superphosphate, di-ammonium phosphate, phosphoric acid, and rock phosphate) with and without bacterium (Bacillus FS-3) were applied in pots as 344 kg P/ha. Basal fertilizers were applied to all the pots as 180 kg N/ha (NH_4NO_3 33% N), 100 kg K/ha (K_2SO_4 50% K_2O). The results obtained showed that phosphorus availability from soil increased with phosphate solubilizing bacterium (PSB) application. The amount of plant available form of soil phosphorus fraction (resin-Pi + NaHCO3-Pi + NaHCO3-Po + NaOH-Pi + NaOH-Po) increased with PSB application. In all fertilizer types, bacteria application converted approximately 20% of less available phosphorus into labile forms. Statistically significant differences were obtained in shoot and root dry weight of tomato plants treated with PSB application. In all of the fertilizers, plant shoot and root weight and P uptake were greater with PSB applications than without PSB. The highest shoot-root dry weight and P uptake of plant were determined in triple superphosphate (TSP) with PSB application treatment. The data in the present study suggest that the application of PSB (FS-3) may increase the availability of soluble phosphate by dissolving the inorganic forms of phosphate and that bacterial strain tested in this study has a potential to be used as a bio-fertilizer in sustainable and organic agriculture (Tarun *et al*., 2007).

Adebooye *et al*. (2006) conducted an experiment in the early and late seasons of 1999 and 2000 at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria, to evaluate how tomato fruit qualities were affected by phosphorus (P) nutrition. The five levels of P evaluated were 0, 13.2, 26.4, 39.6 and 52.8 kg P/ha using single superphosphate fertilizer (18% P), while the three tomato cultivars used were Ibadan Local, Roma VF and NHLe 158-13. At 26.4 kg P/ha, significantly higher fruit diameter and fruit yields were obtained. Except for the moisture content and ether extract, the P level had significant ($p<0.05$) effects on the pH, total soluble solids (TSS), lycopene, ascorbic acid, crude fibre and crude protein content of tomato fruits with the optimum values recorded at 26.4 kg P/ha. The season did not produce any significant ($p<=0.05$) effect on fruit yield and fruit diameter. The pH, moisture content and lycopene contents were significantly higher during the early season than late season while TSS, crude fibre, crude protein and ascorbic acid were significantly ($p<0.05$) higher in the late season than early season. The season had no significant effect on ether extract content. The study established that 26.4 kg P/ha was the optimum P level for the tomato cultivars used in this study.

Shukla *et al*. (2006) conducted an experiment in farmers field in DedGharat village, Kandaghat block of Solan district, Himachal Pradesh, India, during 200203 and 2003-04 to study the effects of inorganic and organic fertilizers on the performance of tomato (*L. esculentum* cv. Naveen). The application of recommended rates of N, P and K (100, 75 and 55 kg/ha, respectively) with farmyard manure and vermicompost (250 and 12.5 quintal/ha, respectively) was superior in terms of yield per plant, yield/ha, number of fruits per plant, average fruit weight, number of fruits per cluster, and TSS [total soluble solids] content. The combined effects of N, P, K, farmyard manure and vermicompost on harvest duration and pericarp thickness were not significant. Vermicompost with N, P and K induced early flowering, whereas early picking was obtained with the application of vermicompost and P.

Kuchanwar *et al.,* (2005) conducted a field experiment at Horticulture Section Farm, College of Agriculture, Nagpur, Maharashtra, India, with tomato (*Lycopersicon esculentum*) as a test crop. The effects of P application at three levels (30, 60 and 90 kg P_2O_5 ha^{-1}), two levels of S (30 and 60 kg S ha^{-1}) and two levels of Fe (20 and 40 kg Fe ha^{-1}) and their combinations were investigated. The highest content of N, P, K, S and Fe (1.34, 0.74, 1.78, 0.18, 5.89 in fruits and 0.75, 0.70, 3.61 0.32, 3.55 in plants, respectively was recorded with the application of 60 kg $P2O_5$ + 30 kg S + 40 kg Fe ha^{-1}. The highest P and S was recorded with the application of 90 kg P_2O_5+ 60 kg S + 40 kg Fe ha^{-1} and 30 kg P_2O_5 + 60 kg S + 40 kg Fe ha^{-1}, respectively. The highest removal of nutrients by tomato were N-28.85 kg ha^{-1}, P_2O_5-265.52 g ha^{-1}, K 37.18 g ha^{-1}, S-379.15 g ha^{-1}, Fe-129.07 g ha^{-1} in fruit and 24.19, 20.96, 116.45, 10.32 kg ha^{-1}, 114.52 g ha^{-1} in plant, respectively with the application of 60 kg P + 30 kg S + 40 kg Fe ha^{-1} except S content in fruit, which was maximum under 30 kg P_2O_5 + 60 kg S + 40 Kg Fe ha^{-1}. The total uptake of N, P, K, S and Fe was maximum (53.04, 21.22, 153.63, 10.69 kg ha^{-1}, 249.59 g ha^{-1}, respectively) with the application of 60 kg P_2O_5 + 30 kg S + 40 kg Fe ha^{-1}.

LongJing and JingQuan (2005) evaluated the effects of phosphate levels (0, 0.165, 0.660, 2.640 mmol phosphate/litre) on growth and photosynthesis of 4-leaf tomato plants. P at 0 and 0.165 mmol/litre significantly inhibited plant growth, reduced net photosynthetic rate, stomatal conductance, and photochemical efficiency of photosystem II, and increased intercellular CO_2 concentration.

Singh *et al.* (2005) conducted an experiment to study the effects of N, P and K at 200: 100: 150, 350: 200: 250 and 500: 300: 350 kg/ha on the growth and yield of tomato hybrids Rakshita, Karnataka, and Naveen in New Delhi, India during the early winter of 2000-02. Naveen had the highest number of flower clusters per plant and the earliest picking period and fruit setting. On the other hand, Karnataka produced the highest yield during both years (2.85 and 3.07 kg/plant). Plant height , number of leavers per plant , leaf length , stem thickness, number of flower cluster per plant and picking period were the highest with the application of 500: 300: 350 kg NPK/ha during both years. Fruit yield (30.2 and 34.8 kg/ha in 2000-01 and 2001-02, respectively) and number of pickings (14 during both years) were the highest with the application of 350: 200: 250 kg NPK/ha.

Groot *et al.* (2004) evaluated the effects of N and P rates on the growth of tomato (cv. Capita). P was applied at 70, 120, 170, 220, 270 and 320 mg g^{-1} day^{-1}; N was supplied at the same concentrations, in addition to 370 mg g^{-1} day^{-1}. The relative growth rate increased sharply with increasing plant P concentration, then levelled off. The response of relative growth rate to increasing plant N concentration was gradual, levelling off at high N concentrations. This suggests that the 2 highest N rates were high enough to gain maximum growth. At mild P and N limitation, leaf area ratio and relative growth rate were more important than net assimilation rate (NAR) in explaining the change in RGR, whereas under severe P and N limitation, NAR was more important. The reduction in N and P supply increased dry matter partitioning to roots. This correlation between dry matter partitioning to roots and leaf N concentration was linear.

Hu-FanRong (2004) evaluated the effects of the distribution of soluble carbohydrates in tomato (*Lycopersicon esculentum*) at different levels of potassium and phosphorus supply. At 45 days after treatment, the shoot/root ratio decreased under phosphorus deficiency but increased under potassium deficiency. Concentrations of sucrose, reducing sugars and total soluble sugars were also affected by low nutrient supply. In K-deficient plants, the concentrations of sucrose, reducing sugars and total soluble sugars were much higher than those in the control and P-deficient plants. In contrast, the lowest concentrations of sucrose, reducing sugars and total soluble sugars were detected in the roots of K deficient plants, whereas the concentrations of sucrose, reducing sugars and total soluble sugars were particularly high in roots of P-deficient plants. Of the total amount of soluble sugars per plant, the percentage of total soluble sugars partitioned to roots reached 10.71% in K-deficient, 45.65% in P-deficient, and 28.63% and 33.11% in their respective control plants. The results indicated the distinct role of K and P in the translocation of photosynthates. Dry matter distribution between shoots and roots was adversely affected under mineral deficiencies.

Mishra *et al*. (2004) conducted a field experiment in Karnataka, India to investigate the effects of graded levels of N, P and K on the yield, quality and nutrient uptake of tomato cultivars resistant to tomato leaf curl virus (TLB 111, TLB 130 and TLB 182). The cultivar Arja Vikas was included as a control. The treatments included 100, 125 and 150% of the recommended fertilizer rate (N: P: K at 115:100:60 kg/ha). Among the cultivars TLB 182 showed the highest yield (75.90 t/ha). Among interactions, TLB 182 with 150% RDF recorded the highest fruit yield (87 t/ha). As far as the quality is concerned, TLB 182 with 150% RDF showed higher rind thickness (0.74 cm), fruit size (32.47 cm2) and pH 4.40. TLB 130 with 150% RDF showed the highest total soluble solids content (4.40%), acidity (0.48%) and ascorbic acid (46.87 mg/100 g juice). TLB 182 showed the highest N (121.29 kg/ha), phosphorus (11.74 kg/ha) and K (109.97 kg/ha) uptake with 150% RDF.

Sun *et al*. (2004) investigated the effects of N, P and K fertilizers on the growth of tomato seedlings on a sawdust: vermiculite: fly ash (6:2:2) substrate were studied. Seedling growth was highly affected by N, P, and N×P interaction. The values of growth parameters (stem height and diameter, fresh weight, dry weight, leaf area, and good seedling index) increased linearly with the increase in the rates of N and P. The highest values of the aforementioned parameters were obtained with 2.4 kg $CO(NH_2)_2$ + 29.5 kg $Ca(H_2PO_4)_2.H_2O$ + $CaSO4.H_2O$. N x P interaction also enhanced seedling growth, but the effects of P on seedling growth were dependent on the N rate. Seedling growth was adversely affected by P at a low N rate, but was enhanced by P at a high N rate. K had no significant effect on seedling growth. Thus, in sawdust-enriched substrates, complete fertilizers can be substituted by N and P fertilizers.

Chandra *et al.* (2003) concluded the effects of N: P: K rate (200:100:150, 350:200:250 or 500:300:350 kg/ha) on the performance of 4 indeterminate tomato hybrids (Rakshita, Karnataka, Naveen and Sun 7611) in a multi-span greenhouse during 2000-2001 and 2001-2002. In both years, Karnataka registered the greatest fruit diameter (6.97 and 6.98 cm), average fruit weight (83.28 and 83.88 g), fruit yield (2.85 and 3.07 kg/plant), calculated yield (8.55 and 9.21 kg/m^2), juice content (58.84 and 62.43%), gross income (94.05 and 101.31 rupees/m^2), net income (17.38 and 24.64 rupees/m^2) and benefit:cost ratio (1.23 and 1.32), and the lowest cost of cultivation (76.67 rupees/m^2 in each year). Rakshita exhibited the greatest pulp content (77.46 and 78.73%), total soluble solids (6.07 and 6.27%) and shelf life (6.40 and 6.50 days). Among the fertilizer levels, N: P: K at 350:200:250 kg/ha was superior in terms of fruit diameter, average fruit weight, yield, gross income and benefit:cost ratio. The number of fruits per plant increased with the increase in the rate of NPK. The quality parameters were not significantly affected by the NPK level in both years.

El-Araby and Feleafel (2003) conducted a field experiment during summer 2001 and 2002 on calcareous soil under furrow irrigation system at Bangar El-Sukkarevery 10 days at all growth stages; withholding of irrigation for 20 days at the vegetative stage starting from 10 days after transplanting or DAT; withholding of irrigation for 20 days at the flowering stage starting from 30 DAT; and withholding of irrigation for 20 days at the fruit set stage starting from 50 DAT) and fertilizers (30 m^3 cattle manure, 10 m^3 chicken manure, 45 kg P_2O_5, 30 m^3 cattle manure + 45 kg P_2O_5, and 10 m^3 chicken manure + 45 kg P_2O_5/feddan) on the performance of tomato (cv. Super Strain B). Among the irrigation regimes, irrigation at all growth stages was generally the most effective in increasing plant height, number of leaves and branches, shoot and root dry weights, number of clusters, and leaf N, P and K contents. With regard to fertilizer treatments, 30 m^3 cattle manure + 45 kg P_2O_5/feddan generally gave the highest values for the aforementioned vegetative and flowering parameters, and leaf mineral contents. The interaction between both treatments was also the most beneficial for all traits except leaf N, P and K contents. The application of 30 m^3 cattle manure + 45 kg P_2O_5/feddan reduced the deleterious effects of irregular irrigation on the vegetative growth, flowering traits, and leaf mineral contents of tomato.

Gopal *et al.* (2003) studied the effects of P (sodium dihydrogen orthophosphate) at deficient (0.01 mM), subnormal (0.33 mM) and normal (2.0 mM) levels, and S (sodium sulphate) at deficient (0.02 mM) and normal (2.0 mM) levels on the performance of tomato cv. Pusa Ruby was studied under greenhouse conditions. At 55 days after sowing, the colour of old leaves changed from green to bluishgreen, and the diameter of the main stem and the number of leaves were reduced under P deficiency. Under S deficiency, intense chlorosis of young leaves and inhibition of plant growth were observed. P deficiency reduced biomass production, fruit yield, and contents of chlorophyll a and b, reducing sugar, non reducing sugar, total sugar, starch, organic P, phospholipid, nucleic acid and phosphorylated protein; delayed fruit maturation; and increased peroxidase, ribonuclease and acid phosphatase activities in leaves. These effects were aggravated by S deficiency, suggesting the synergistic role of both nutrients.

Groot *et al*. (2003) conducted an experiment with varied N or P supply, in order to unravel the effects of N and P limitation on growth of young tomato plants (*Lycopersicon esculentum* Mill.). Relative growth rate (RGR) initially increased sharply with increasing plant P concentration but leveled off at higher plant P concentrations. In contrast, RGR increased gradually with increasing plant N concentration before it leveled off at higher plant N concentrations. The relationship of RGR with organic leaf N and P showed the same shape as with total N and P concentrations, respectively. The difference in response is most likely due to the different roles of N and P in the machinery of the plant's energy metabolism (e.g., photosynthesis, respiration). Plant N concentration decreased with increasing P limitation. We show that this decrease cannot be explained by a shift in dry-mass partitioning. Our results suggest that the decrease in N concentration with increasing P limitation may be mediated by a decrease in leaf cytokinin levels and is less likely due to decreased energy availability at low P conditions. Dry-mass partitioning to the roots was closely linearly related to the leaf reduced-N concentration. However, treatments that were severely P limited deviated from this relationship.

Duraisami and Mani (2002) concluded that the optimum levels of N, P and K were necessary for yield maximization of rainfed tomato and for sustained soil fertility. Treatments comprised of 4 rates of N (0, 40, 80 and 120 kg/ha), 3 rates of P_2O_5 (0, 40 and 80 kg/ha) and 3 rates of K_2O (0, 40 and 80 kg/ha) in all possible combinations. All treatments recorded higher crop yield compared to the control, with 80 kg N/ha+40 kg P_2O_5/ha+80 kg K_2O/ha recording the highest yield (20.5 t/ha). TSS had an inverse relationship with N rates but increased with increasing P and K. The treatments had no significant effects on the acidity of the fruits. Soil N was highest with application of 80 kg N and 40 kg P_2O5/ha. Differences in soil N availability due to K_2O application were not significant. The available soil P varied from 9.7 to 10.9, 10.4 to 10.6 and 10.4 to 10.8 kg/ha with N, P_2O_5 and K_2O application, respectively, with the treatments having no marked effects on the available soil P. The available soil K increased with increasing K_2O application.

2.2 Effect of lime on the growth and yield of tomato

Gum (2012) carried out a study to determine the effect of compost and lime on soil chemical properties, the soil microbial community (including *Fusarium* spp.), and the incidence and severity of *Fusarium* wilt in commercially produced tomato with a history of *Fusarium* wilt. Seasonal trials were conducted in spring and fall of 2010, where soil treatments (composted yard waste and lime) were applied to plots in a randomized complete block design with three replications using a calibrated tractor spreader. Composite soil samples were collected immediately following application of soil treatments, at flowering, and at fruit set and analyzed for soil chemical properties (e.g., organic matter, pH, soil test nutrients, etc.) and soil microbes (e.g., total bacteria, *Fusarium oxysporum* spp., etc.). Incidence of *Fusarium* wilt was assessed on a periodic basis over the course of tomato production. Data showed that the application of compost and/or lime to soils prior to bedding had no effect on soil pH, EC, or Mehlich 3 nutrients, with the exception of organic matter and Mehlich 3-Mg in fall 2010. Soil organic matter increased when compost was applied at the 30 ton/acre application rate in the fall season, while Mehlich 3 Mg increased when compost was applied at the 20 and 30 ton/acre application rate. Bacteria colony counts were higher at the beginning of each season, but fungal colony counts increased and bacteria colony counts decreased as the season progressed. Wilt incidence was seen much earlier in the fall season than in the spring trial due to climatic differences between seasons; however, *Fusarium* wilt incidence was not affected by soil treatment. Single applications of organic amendments at high rates (>20 tons/acre) can increase soil organic matter in the short-term, but may not decrease the occurrence of *Fusarium* wilt.

Djuric *et al*. (2011) reported that Pseudogley is a typical type of acid soils predominating in both Serbia and the wider region. Acid soils are not suitable for the cultivation of agricultural crops due to the hampered uptake of most nutrients as induced by increased levels of hydrogen ions. In order to make pseudogley soil suitable for crop production, pH improvement measures should be employed. The objective of this study was to use liming to neutralise soil acidity and evaluate the effect of soil pH improvement measures on the Mo content in both root and leaf of the Dutch tomato (*Lycopericon esculentum* Mill.) hybrid Belle planted under controlled conditions on pseudogley soil. Molybdenum was studied in this paper due to its role in plant nitrogen metabolism. Moreover, the determination of molybdenum presence in the root and leaf is a sure indicator of successful liming effects. Three liming treatments were employed (1, 3 and 4 t/ha $CaCO_3$). The liming operation used on pseudogley induced a statistically significant increase in molybdenum ion absorption into the root system of tomato. Independently from the aforementioned, the values for the root and leaf molybdenum content of tomato in each treatment were very low and insufficient for successful growth of this plant. In order to make pseudogley suitable for successful development of agricultural production, it is necessary to increase both soil pH and the content of available molybdenum in the soil.

Ambak *et al.* (2012) conducted in a deep woody peat soil located at Pontian in the south western part of Peninsular Malaysia to determine the effect of graded levels of liming with and without micronutrient application on the growth and performance of maize and tomato plants. The results obtained revealed that the growth of the maize and tomato plants was extremely poor in the unlimed treatment (pH 3.8 to 4.0). When micronutrients were applied, the growth was enhanced and the yield increased with the increase of the lime level and reached a maximum value at the lime level of 8 t/ha (pH 5.0 to 5.3) in both plants. There was no difference in the yield above the lime levels of 8 t/ha . When micronutrients were not applied, shoot growth of maize was enhanced with the increase of the lime level up to 8 t/ha in the same manner as in the treatments with micronutrient application. However, grain formation was inhibited while in the case of tomato the shoot growth was extremely inhibited and no fruits were formed regardless of the lime levels. The inhibition of grain formation in maize was much more severe both in the lower and higher pH ranges than in the intermediate pH range. Furthermore, shoot growth of tomato was also more severely inhibited both in the lower and higher pH ranges. Contents of Cu and B of both crops were critically low for the deficiencies in the treatments without micronutrient application. In order to analyze the behavior of the micronutrients in relation to the pH in this peat soil, an incubation study was conducted. The contents of 0.1 M HC1 extractable Fe, Mn, Zn, and Cu and hot water soluble B decreased with the increase of the pH from 3.5 to about 7.0. The amount of ammonium oxalate extractable Mo increased with the increase of the pH up to pH 4.7, but it decreased with the increase of the pH above 4.7. It was suggested that the growth inhibition and the occurrence of sterility in the treatments without micronutrient application were caused by the deficiencies in Cu and/or B.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in carrying out the experiment. It includes a short description of location of the experimental plot, characteristics of soil, climate and materials used for the experiment. The details of the experiment are described below.

3.1 Location of the experiment field

The field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh from October 2014 to April 2015.

3.2 Climate of the experimental area

The experimental area is characterized by subtropical rainfall during the month of May to September (Anon., 1988) and scattered rainfall during the rest of the year. Information regarding average monthly rainfall, temperature is recorded by Bangladesh Meteorological Department (Climate division) during the period of study.

3.3. Soil of the experimental field

Initial soil samples from 0-15 cm depth were collected from experimental field. The collected samples were analyzed at Soil Science Laboratory, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The physio-chemical properties of the soil are presented in Appendix I. The soil of the experimental plots belonged to the agro-ecological zone of Madhupur Tract (AEZ-28).

3.4 Plant materials used

In this research work, the seeds of tomato variety were used as planting materials. The tomato varieties used in the experiments were BARI Tomato-14. BARI Tomato-14 was collected from the Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) , Joydebpur, Gazipur.

3.5. Raising of seedlings

Tomato seedlings were raised in seedbed of 3 m x 1 m size. The soil was well prepared and converted into loose friable and dried mass by spading. All weeds and stubbles were removed and 10 kg well rotten cow dung was mixed with the soil. Four gram of seeds was sowed on the seedbed, according to the date. The seeds were sowed in the seedbeds 15 November, 2014. Sevin 85SP was applied around the seedbed as precautionary measure against ants, worm and other harmful insects. The emergence of the seedlings took place with 6 to 8 days after sowing. Shading by polythene with bamboo structure was provided over the seedbed to protect the young seedlings from the scorching sunshine or rain. Diathane M-45 was sprayed in the seedbeds @ 2 g L^{-1}, to protect the seedlings from damping off and other diseases. Weeding, mulching and irrigation were done as and when required.

3.6 Treatments and layout of the experiment

The experiment consisted of two factors; (A) four level of phosphorus and (B) three level of Dolomite. The levels of the two factors were as follows:

Factor A: level of phosphorus

a) P_0: 0 kg/ha
b) P_1: 20 kg/ha
c) P_2: 40 kg/ha
d) P_3: 60 kg/ha

Factor B: level of Dolomite

a) D_0: 0 t/ha
b) D_1: 1.0 t/ha
c) D_2: 1.5 t/ha

3.7 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) having two factors and replicated three times. An area was divided into three equal blocks. Each block was consists of 12 plots where 12 treatments were allotted randomly. These there were 36 unit plots altogether in the experiment. The size of each plot was 3 m × 2 m. The distance between two blocks and two plots were kept 1.00 m and 0.80 m, respectively.

3.8 Cultivation procedure

3.8.1. Land preparation

The land for growing the crop was first opened with a tractor. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was ready. Finally, the unit plots were prepared as 15 cm raised beds. Ten pits were made in each plot in two rows maintaining a recommended spacing of row to row distance was 60 cm and plant to plant distance was 40 cm (BARI, 2000).The field layout and design or the experiment was followed immediately after land preparation.

3.8.2. Manure and fertilizers and its methods of application

Manure and fertilizers were applied in the experimental field as per the following doses in accordance with the recommendation of BARI (1996).

Manure/ fertilizer	Total amount per hectare	Applied during land preparation	Applied in pit before one week of transplanting	Applied as top dressing in rows	
				1st installment after 3 weeks of transplanting	2nd installment after 5 weeks of transplanting
Cowdung	10 t	5 t/ha	5 t/ha	-	-
Urea	550 kg	-	200 kg/ha	175 kg/ha	175 kg/ha
TSP	As per treatment	-	As per treatment	-	-
MP	250 kg	-	250 kg/ha		
Dolomite	As per treatment	During final land preparation full amount of dolomite was applied and irrigated			

3.8.3 Transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots in the afternoon of 15 November, 2015 planting. The seedbed was watered before uprooting the seedlings from the seedbed to minimize damage of the roots. The seedlings were watered after transplanting. Shading was provided using polythene with bamboo structure from seed sowing to harvesting to protect the tomato seedlings from the adverse weather conditions of late winter season. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.8.4 Intercultural operations

After transplanting the seedlings, various kinds of intercultural operations were accomplished for better growth and development of the plants, which are as follows:

a) Gap filling

When the seedlings were well established, the soil around the base of each seedling was pulverized. A few gaps filling was done by healthy seedlings of the same stock where initial planted seedling failed to survive.

b) Weeding and Mulching

Weeding and mulching were accomplished as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the crust. It also helped in soil moisture conservation.

c) Staking and Pruning

When the plants were well established, staking was given to each plant by Daincha (*Sesbania* sp.) or bamboo sticks to keep them erect. Within a few days of staking, as the plants grew up, the plants were given a uniform moderate pruning.

d) Irrigation

Light irrigation was provided immediately after transplanting the seedlings and it was continued till the seedlings established in the field. Thereafter irrigation was provided as per when needed.

e) Plant protection

Insect pests: Malathion 57 EC was applied @ 2 mL L^{-1} against the insect pests like cut worm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly for a week after transplanting to a week before first harvesting. Furadan 10 G was also applied during final land preparation as soil insecticide.

Diseases: During foggy weather precautionary measured against disease infection of summer tomato was taken by spraying Diathane M-45 fortnightly @ 2 g L^{-1}, at the early vegetative stage. Ridomil gold MZ was also applied @ 0.5 g L^{-1} against early blight disease of tomato.

3.9 Harvesting

Fruits were harvested at 5-day intervals during early ripe stage when they attained slightly red color. Harvesting was started from 15 February, 2015 and was continued up to 10 March, 2015.

3.10 Data collection

Ten plants were selected randomly from each plot for data collection in such a way that the border effect could be avoided for the highest precision. Data on the following parameters were recorded from the sample plants during the course of experiment.

3.10.1 Plant height (cm)

Plant height was measured at final harvest of randomly selected 10 sample plants in centimeter from the ground level to the tip of the main stem and mean value was calculated.

3.10.2 Number of leaves per plant

It was recorded by the following formula :

$$\text{Number of leaves per plant} = \frac{\text{Total number of leaves from ten sample plants}}{10}$$

3.10.3 Number of primary branches per plant

It was measured by the following formula :

$$\text{Number of branches per plant} = \frac{\text{Total number of primary branches from ten sample plant}}{10}$$

3.10.4 Number of secondary branches per plant

It was measured by the following formula :

$$\text{Number of branches per plant} = \frac{\text{Total number of secondary branches from ten sample plant}}{10}$$

3.10.5 Fruit length (cm)

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 10 randomly selected fruits from each plot and their average was taken in centimeter (cm) as the length fruit.

3.10.6 Fruit diameter (cm)

Diameter of fruit was measured at the middle portion of 10 randomly selected fruits from each plot with a slide calipers and their average was taken in centimeter (cm) as the diameter of fruit.

3.10.7 Yield of fruits per hectare (t/ha)

It was measured by the following formula

$$\text{Fruit yield per hectare (t/ha)} = \frac{\text{Fruit yield per plot (kg) x 10000}}{\text{Area of plot in square meter x 1000}}$$

3.11 Post harvest soil sampling

After harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil sample of each plot were air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.12 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. organic matter, pH, total N and available P and K contents. The soil samples were analyzed by the following standard methods as follows:

3.12.1 Textural class

Mechanical analysis of soil were done by hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the values of % sand, % silt and % clay to the Marshall's textural triangular co-ordinate following the USDA system.

3.12.2 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 (Jackson, 1962).

3.12.3 Organic matter

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1935). The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

3.12.4 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml H_2SO_4 were added. The flasks were swirled and heated 160 ^{0}C and added 2 ml H_2O_2 and then heating at 360 ^{0}C was continued until the digest was clear and colorless. After cooling, the content was taken into 50 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al*., 1982).

Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water.

Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink.

The amount of N was calculated using the following formula:

$$\% N = (T\text{-}B) \times N \times 0.014 \times 100 / S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.12.5 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated the standard P curve (Page *et al,*. 1982).

3.12.6 Available potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al.* 1982).

3.13 Statistical analysis

The recorded data on various parameters were statistically analyzed by using MSTAT statistical package programmed. The mean for all the treatments was calculated and analysis of variance for all the characters was performed by F-test. Difference between treatment means were determined by Duncan`s new Multiple Range Test (DMRT) according to Gomez and Gomez (1984).

CHAPTER 4

RESULTS AND DISCUSSIONS

The present experiment was conducted to know the effect of liming and phosphorus on growth and yield of tomato. Data on different levels of yield and yield contributing characters were recorded to find out the optimum levels of phosphorus and effective liming on tomato. The results have been presented, discussed and possible interpretations are given under the following headings:

4.1 Plant height

Plant height differed significantly due to the application of different levels of phosphorus. The tallest plant (85.26 cm) was produced by P_3 (60 kg P/ha), which was statistically identical with P_1 and P_2 treatment (Table 1). The shortest plant (75.34 cm) was produced by P_0 (0 kg P/ha). The plant height was increased possibly due to the readily available phosphorus, which might have encouraged more vegetative growth and development. Melton and Dufault (1991) reported that plant height was increased significantly as phosphorus level increased.

Different liming showed significant variations on the plant height. The longest plant height(85.02 cm) was recorded from D_2 (1.5 t/ha) which was statistically similar with D_1 treatment (Table 2). The shortest (75.52 cm) was obtained from control (D_0).

Low soil pH can cause reduction of root growth, nutrient availability, reduction of crop yields and deterioration of soil physical properties (Adams 1984).

Liming increases the soil pH and make the nutrients available which might have encouraged the more vegetative growth.

A significant variation was found due to combined effect of phosphorus and liming in terms of plant height (Table 3). The longest plant height (91.24 cm) was recorded from the combined effect of P_3D_1 (60 kg P/ha + 1.5 ton/ha), which was statistically similar with P_3D_1 treatment. while P_0D_0 (0 kg P/ha + no liming) gave the shortest (66.50 cm) plant height (Table 3). Phosphorus de ciency is due to inherent low soil P, high P xation by Al and Fe oxides and insuf cient fertilizer use to replace soil P removed through crop harvests (Buresh *et al*., 1997; Obura *et al*., 2001). Lime reduces the levels of exchangeable Al3+, Fe3+ and Mn4+ in acid soils and thus reduces P sorption. This makes both the native soil P and applied P fertilizers available for plant uptake (The *et al*., 2006). The more available P and other nutrients, plants uptake more which might have caused the more height .

Table 1. Effect of phosphorus on the growth parameters of tomato

Treatment	Plant height (cm)		Number of leaves per plant		Number of primary branches per plant		Number of secondary branches per plant	
P_0	75.34	b	12.47	b	9.64	b	7.53	c
P_1	79.79	ab	14.17	ab	10.88	b	9.07	b
P_2	82.21	ab	13.83	ab	11.39	b	10.51	ab
P_3	85.26	a	15.35	a	13.65	a	11.38	a
LSD $_{(0.05)}$	7.501		2.25		2.19		1.44	
CV (%)	5.58		6.21		7.60		9.00	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P ha^{-1} i.e. control, P_1: 20 kg P ha^{-1}, P_2: 40 kg P ha^{-1}, P_3: 60 kg P ha^{-1}

Table2. Effect of different level of liming on the growth parameters of tomato

Treatment	Plant height		Number of leaves per plant		Number of primary branches per plant		Number of secondary branches per plant	
D_0	75.52	b	11.91	b	10.15	b	7.97	b
D_1	81.42	ab	14.54	ab	11.61	ab	9.73	ab
D_2	85.02	a	15.42	a	12.40	a	11.18	a
LSD (0.05)	6.414		3.04		1.62		1.94	
CV (%)	5.58		6.21		7.60		9.00	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

D_0: 0 t ha^{-1} i.e. control, D_1: 1.0 t ha^{-1}, D_2: 1.5 t ha^{-1}

Table 3. Combined effects of phosphorus and liming on the growth parameters of tomato

Treatment	Plant height		Number of leaves per plant		Number of primary branches per plant		Number of secondary branches per plant	
P_0D_0	66.50	e	9.20	h	8.10	e	5.85	h
P_0D_1	79.24	cd	13.43	efg	9.70	d	7.35	g
P_0D_2	80.30	cd	14.77	bcde	11.10	bcd	9.40	cde
P_1D_0	76.84	d	12.03	g	10.10	cd	7.80	fg
P_1D_1	78.10	d	15.10	bcd	11.03	bcd	9.00	def
P_1D_2	84.44	bc	15.37	abc	11.50	bc	10.42	bcd
P_2D_0	81.04	cd	12.87	fg	10.50	bcd	8.78	efg
P_2D_1	81.50	cd	13.93	cdef	11.70	bc	10.82	bc
P_2D_2	84.10	bc	14.70	bcde	11.96	b	11.92	ab
P_3D_0	77.70	d	13.53	defg	11.90	b	9.44	cde
P_3D_1	86.84	ab	15.70	ab	14.00	a	11.73	ab
P_3D_2	91.24	a	16.83	a	15.03	a	12.97	a
LSD $_{(0.05)}$	4.89		1.47		1.47		1.47	
CV (%)	5.58		6.21		7.60		9.00	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P ha^{-1} i.e. control, P_1: 20 kg P ha^{-1}, P_2: 40 kg P ha^{-1}, P_3: 60 kg P ha^{-1}

D_0: 0 t ha^{-1} i.e. control, D_1: 1.0 t ha^{-1}, D_2: 1.5 t ha^{-1}

4.2 Number of leaves per plant

In case of number of leaves per plant, significant difference was observed due to the application of different levels of phosphorus (Table 1). The maximum (15.35) number of leaves per plant was recorded from P_3 which was statistically similar with P_1 and P_2 treatment. While the treatment P_0 gave the minimum (12.47) number of leaves per plant .

There were significant variations on the number of leaves/plant due to different liming. The maximum (15.42) number of leaves per plant was recorded from D_2, which was statistically similar with D_1 treatment. The minimum (11.91) was obtained from D_0 (Table 2).

Combined effect of phosphorus and liming showed a significant variation in terms of number of leaves/plant. The maximum (16.83) number of leaves per plant was recorded from the combined effect of P_3D_2, which was statistically similar with P_3D_1 treatment. While P_0D_0 gave the minimum (9.2) number of leaves per plant (Table 3). Combined applications of P fertilizer and lime increased and maintained higher soil available P than where either of them was applied alone. This was because of the likely reduction in P sorption by lime, thus making the P fertilizer more available for plants (Buresh *et al*., 1997; The *et al.,* 2006), which might the possible cause of more vegetative growth.

4.3 Number of primary branch

Number of primary branch showed significant variation due to the application of different levels of phosphorus. The maximum number of primary branch (13.65) was recorded from P_3 (60 kg P/ha), while the control treatment (0 kg N/ha) gave the minimum (9.64) number of primary branch (Table 1). These results indicate that phosphorus increases the growth of tomato, which ensured the maximum number of primary branch than control.

Application of dolomite level of lime showed significant variation on number of primary branch (Table 2). The maximum number of primary branch (12.40) was recorded from D_2 (Dolomite 1.5 t/ha), which was statistically similar with D_1 treatment. The minimum (10.15) was obtained from D_0 (control). From the results it was found that liming @ 1.5 t/ha was more effective than other liming materials under the trial.

A significant variation was found for the combined effect of phosphorus and liming in terms of number of primary branch (Table 3). The maximum (15.03) number of primary branch was recorded from the combined effect of P_3D_2 that was statistically identical (14.00) with P_3D_1, on the other hand P_0D_0 gave the minimum (8.10) number of primary branch.

4.4 Number of secondary branch

Number of secondary branch differed significantly due to the application of different levels of phosphorus (Table 1). The maximum number of secondary branches (11.38) were recorded from P_3 (60 kg P/ha), which was statistically similar with P_2 treatment. While P_0 (0 kg P/ha) gave the minimum number of secondary branch (7.53).These results indicate that phosphorus increases the number of secondary branch than control.

Different liming also showed significant variations on the number of secondary branch (Table 2). The maximum number of secondary branch (11.18) was recorded from D_2 (1.5 t/ha), which was statistically similar with D_1 treatment. The minimum (1.97) was obtained from D_0 (no liming). From the results it was found that liming @ 1.5 t/ha was more effective than other liming materials under the trial.

The combined effect of phosphorus and liming showed a significant variation in terms of number of secondary branch (Table 3). The maximum number of secondary branch (12.97) was recorded from P_3D_2 (60 kg P/ha + 1.5 t/ha of dolomite), which was statistically similar with P_2D_2 and P_3D_1 treatment while the P_0D_0 treatment gave the minimum number of secondary branches (5.85).

4.5 Length of fruit

Length of fruit had significant variation due to the application of different levels of phosphorus (Table 4). The maximum length of fruit (6.82 cm) was recorded from P_3 which was statistically similar with P_1 and P_2 treatment. The P_0 treatment gave the minimum length of fruit (5.11 cm).

Different liming had significant variations on the length of fruit (Table 5). The maximum length of fruit (6.77 cm) was recorded from D_2, which was statistically similar with D_1 treatment. The minimum length of fruit (6.30 cm) was obtained from D_0.From the results it can be said that liming @ 1.5 t/ha was more effective than other liming materials under the trial.

A significant variation was found due to combined effect of phosphorus and liming in case of length of fruit (Table 6). The maximum (8.20 cm) length of fruit was recorded from the combined effect of P_3D_2, while P_0D_0 combined treatment gave the minimum (4.16 cm) length of fruit.

Table 4. Effect of phosphorus on the yield parameters of tomato

Treatment	Fruit length (cm)		Fruit diameter (cm)		Yield of fruits per hectare (ton)	
P_0	5.11	b	4.68		29.81	d
P_1	5.90	ab	4.99		38.63	c
P_2	6.34	ab	5.26		48.42	b
P_3	6.82	a	5.49		66.29	a
LSD (0.05)	1.50		NS		2.62	
CV (%)	9.55		11.31		2.52	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P ha^{-1} i.e. control, P_1: 20 kg P ha^{-1}, P_2: 40 kg P ha^{-1}, P_3: 60 kg P ha^{-1}

Table 5. Effect of different liming on the yield parameters of tomato

Treatment	Fruit length (cm)		Fruit diameter (cm)		Yield of fruits per hectare (ton)	
D_0	5.30	b	4.50		33.71	c
D_1	6.07	ab	5.32		48.47	b
D_2	6.77	a	5.50		55.18	a
LSD (0.05)	1.28		NS		3.54	
CV (%)	9.55		11.31		2.52	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

D_0: 0 t ha^{-1} i.e. control, D_1: 1.0 t ha^{-1}, D_2: 1.5 t ha^{-1}

Table 6. Combined effects of phosphorus and liming on the yield parameters of tomato

Treatment	Fruit length (cm)		Fruit diameter (cm)		Yield of fruits per hectare (ton)	
P_0D_0	4.16	e	3.31	c	24.40	j
P_0D_1	5.56	cd	5.28	ab	29.60	i
P_0D_2	5.60	cd	5.46	ab	35.43	g
P_1D_0	5.55	cd	5.04	ab	31.55	h
P_1D_1	5.44	d	4.87	b	41.32	f
P_1D_2	6.70	b	5.07	ab	43.03	f
P_2D_0	6.10	bcd	4.90	b	29.33	i
P_2D_1	6.37	bcd	5.51	ab	56.22	d
P_2D_2	6.55	bc	5.36	ab	59.70	c
P_3D_0	5.36	d	4.76	b	49.57	e
P_3D_1	6.90	b	5.61	ab	66.73	b
P_3D_2	8.20	a	6.11	a	82.55	a
LSD (0.05)	0.98		0.97		1.94	
CV (%)	9.55		11.31		2.52	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P ha^{-1} i.e. control, P_1: 20 kg P ha^{-1}, P_2: 40 kg P ha^{-1}, P_3: 60 kg P ha^{-1}

D_0: 0 t ha^{-1} i.e. control, D_1: 1.0 t ha^{-1}, D_2: 1.5 t ha^{-1}

4.6 Diameter of fruit

Fruit diameter was not differed significantly due to the application of different level of phosphorus(Table 4). The highest (5.49 cm) diameter of fruit was recorded from P_3, while P_0 (0 kg P/ha) gave the minimum (4.68cm) diameter of fruit but they are statistically identical. This finding was almost in agreement with Gupta and Shukla (1977).

Different liming did not show any significant variations on the diameter of fruit(Table 5). The maximum (5.50 cm) diameter of fruit was recorded from D_2 and the minimum (4.50 cm) was obtained from D_0 but they are statistically identical.

Combined effect of phosphorus and liming showed significant variation in terms of diameter of fruit (Table 6). The maximum (6.11 cm) diameter was recorded from P_3D_2, which was statistically similar with P_0D_1, P_0D_2, P_1D_0, P_1D_2, P_2D_1, P_2D_2 and P_3D_1 treatment while P_0D_0 gave the minimum (3.31 cm) diameter of fruit.

4.7 Total yield of tomato

The total yield of tomato varied significantly due to the application of different levels of phosphorus (Table 4). The highest yield of fruit (66.29 t/ha) was obtained from P_3, while (P_0) gave the lowest yield (29.81 t/ha). The results clearly showed that the fruit yield per hectare was increased with the increasing levels of phosphorus except the highest level (39 kg P/ha). Dhinakaran and

Savithri (1997) found that phosphorus significantly increased the yield of tomato (43 kg P/ha). This result is almost similar to Pandey *et al.* (1996). They reported that fruit yield was increased with the increasing rates of phosphorus upto 80 kg/ha. Rao *et al.* (1989) reported that yields were increased with 21.5 kg P/ha compared with no phosphorus, but there was no further increased with 43 kg P/ha. Razia and Islam (1980) found that phosphorus application significantly and progressively increased the yield of tomato with increasing rates of application up to 38.7 kg P/ha.

Different liming had significant variations on the yield of tomato (Table 5). The maximum (55.18 t/ha) yield of fruit was recorded from D_2 treatment and the minimum (33.71 t/ha) was obtained from D_0 treatment.

Combined effect of phosphorus and liming had a significant variation in terms of yield of fruit (Table 6). The maximum (82.55 t/ha) yield of fruit was recorded from P_3D_2 (60 kg P/ha + 1.5 t/ha of dolomite), while P_0D_0 (0 kg P/ha + no liming) gave the minimum (24.40 t/ha, respectively) yield of fruit.

4.8 Nitrogen concentration in post harvest soil of tomato field

The effect of different doses of phosphorus fertilizer showed a statistically non-significant variation in the nitrogen concentration in post harvest soil (Table 7) of tomato field. The total N content of the post harvest soil varied from 0.062% to 0.064%. Among the different doses of phosphorus fertilizer, P_3 (60 kg/ha) treatment showed the highest N concentration (0.064%) in soil. The lowest value was 0.062% under control treatment and P_0.

The effect of different doses of liming fertilizer showed a statistically non significant variation in the nitrogen concentration in post harvest soil (Table 8) of tomato field. The total N content of the post harvest soil varied from 0.061% to 0.062%. The highest total N content (0.062%) was observed in D_2 (1.5 t/ha) treatment. The lowest value of N (0.061%) was observed under control (D_0) treatment.

Significant effect of combined application of different doses of phosphorus and liming fertilizer on the nitrogen concentration was observed in post harvest soil of tomato field (Table 9). The highest concentration of nitrogen in post harvest soil (0.073%) was recorded in the treatment combination of P_3D_2. On the other hand, the lowest nitrogen concentration (0.056%) in post harvest soil was found in P_0D_0.

Table 7. Effect of phosphorus fertilizer on the nitrogen, phosphorus and potassium concentrations in soil of tomato field

Treatment	%N		P (ppm)		K (meq /100g soil)	
P_0	0.062		12.08	b	0.19	
P_1	0.063		15.43	ab	0.21	
P_2	0.063		17.05	ab	0.18	
P_3	0.064		18.62	a	0.23	
LSD $_{(0.05)}$	NS		2.70		NS	
CV (%)	0.06		7.79		0.25	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P ha^{-1} i.e. control, P_1: 20 kg P ha^{-1}, P_2: 40 kg P ha^{-1}, P_3: 60 kg P ha^{-1}

Table 8. Effect of liming on the nitrogen, phosphorus and potassium concentrations in soil of tomato field

Treatment	%N		P (ppm)		K (meq/100g soil)	
D_0	0.061		14.52	b	0.17	
D_1	0.061		17.97	a	0.21	
D_2	0.062		19.11	a	0.22	
LSD $_{(0.05)}$	NS		3.66		NS	
CV (%)	0.06		7.79		0.25	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

D_0: 0 t ha^{-1} i.e. control, D_1: 1.0 t ha^{-1}, D_2: 1.5 t ha^{-1}

Table 9. Combined effect of phosphorus and liming fertilizer on the nitrogen, phosphorus and potassium concentrations in soil of tomato field

Treatment	%N		P (ppm)		K (meq/100g soil)	
P_0D_0	0.056	b	11.75	e	0.24	
P_0D_1	0.057	b	13.07	ed	0.23	
P_0D_2	0.060	b	12.25	de	0.19	
P_1D_0	0.064	ab	13.30	d	0.17	
P_1D_1	0.062	b	16.95	c	0.20	
P_1D_2	0.068	ab	17.80	c	0.17	
P_2D_0	0.059	b	18.57	bc	0.22	
P_2D_1	0.066	ab	19.06	bc	0.21	
P_2D_2	0.065	ab	20.01	b	0.19	
P_3D_0	0.062	b	18.38	bc	0.23	
P_3D_1	0.069	ab	20.97	ab	0.18	
P_3D_2	0.073	ab	22.42	a	0.25	
LSD (0.05)	0.02		2.44		NS	
CV (%)	0.06		7.79		0.25	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

P_0: 0 kg P ha^{-1} i.e. control, P_1: 20 kg P ha^{-1}, P_2: 40 kg P ha^{-1}, P_3: 60 kg P ha^{-1}

D_0: 0 t ha^{-1} i.e. control, D_1: 1.0 t ha^{-1}, D_2: 1.5 t ha^{-1}

4.9 Phosphorus concentrations in post harvest soil of tomato field

The effect of different doses of phosphorus fertilizer showed a statistically significant variation in the phosphorus concentration in post harvest soil (Table 7) of tomato field. The total P content of the post harvest soil varied from 12.08ppm to 18.62ppm. Among the different doses of phosphorus fertilizer, P_3 (60 kg/ha) treatment showed the highest P concentration (18.62ppm) in soil. The lowest value was 12.08ppm under control treatment.

The effect of different doses of liming fertilizer showed a statistically significant variation in the P concentration in post harvest soil (Table 8) of tomato field. The total P content of the post harvest soil varied from 14.52ppm to 19.11ppm. The highest total P content (19.11ppm) was observed in D_2 (1.5 t/ha) treatment and the lowest value of 14.52ppm under control (D_0) treatment.

Significant effect of combined application of different doses of phosphorus and liming fertilizer on the phosphorus concentration was observed in post harvest soil of tomato field (Table 9). The highest concentration of P in post harvest soil (22.42ppm) was recorded in the treatment combination of P_3D_2 treatment. On the other hand, the lowest phosphorus concentration (11.75ppm) in post harvest soil was found in P_0D_0 treatment.

4.10 Potassium concentrations in post harvest soil of tomato field

The effect of different doses of phosphorus fertilizer showed a statistically significant variation in the potassium concentration in post harvest soil (Table 7) of tomato field. The total K content of the post harvest soil varied from 0.18meq/100g soil to 0.23meq/100g soil. Among the different doses of phosphorus fertilizer, P_3 (60 kg/ha) treatment showed the highest potassium concentration (0.23meq/100g soil) in soil. The lowest value was 0.18meq/100g soil under P_2 treatment.

The effect of different doses of liming fertilizer showed a statistically insignificant variation in the potassium concentration in post harvest soil (Table 8) of tomato field. The highest total K content (0.1725meq/100g soil) was observed in D_2 (1.5 t/ha) treatment and the lowest value of 0.2225meq/100g soil under control (D_0) treatment.

Non significant effect of combined application of different doses of phosphorus and liming fertilizer on the potassium concentration was observed in post harvest soil of tomato field (Table 9). The highest concentration of potassium in post harvest soil (0.25meq/100g soil) was recorded in the treatment combination of P_3D_2. On the other hand, the lowest K concentration (0.1725meq/100g soil in post harvest soil was found in P_1D_2.

CHAPTER 5

SUMMARY AND CONCLUSION

The present experiment was carried out at the Farm of Sher-e-Bangla Agricultural University, Dhaka-1207 to find out the effect of liming and phosphorus on growth and yield of tomato during the pried from October 2014 to April 2015. The experiment consisted of four level of phosphorus viz. 0, 20, 40, 60 kg P/ha and three different of liming (viz. 0, 1, 1.5 t/ha).

The two factors experiment was set up in Randomized Complete Block Design (RCBD) with three replications. In total, there were 12 treatment combinations in this study. A unit plot was 2 m× 2 m and the treatments were distributed randomly in each block. Data on growth and yield parameters were recorded and analyzed statistically. The differences were evaluated by Least Significant Difference (LSD) test.

Phosphorus had significant influence on the all parameter. The highest plant height (85.26 cm) and number of leaves per plant (15.35) were obtained from application of 60 kg P/ha (P_3) treatment. The maximum (13.65) number of primary branch and number of secondary branch (11.38) was recorded from P_3 (60 kg P/ha) treatment. Phosphorus had significantly influenced the length of fruit and diameter of fruit. The maximum fruit length (6.82 cm) and diameter (5.49 cm) were obtained from the application of (P_3) treatment. The total yield of tomato varied significantly due to the application of different levels of phosphorus. The highest yield of fruit (66.29 t/ha) was obtained from P_3 treatment and (P_0) treatment gave the lowest (29.81 t/ha).

Liming has any significant influence on the plant height of tomato. The longest (85.02 cm) plant height was recorded from D_2 (1.5 t/ha) treatment. The maximum (15.42) number of leaves per plant was recorded from D_2 treatment. The maximum (12.40) number of primary branch and (11.18) number of secondary branch was recorded from D_2 treatment. The maximum fruit length (6.77 cm) and fruit diameter (5.50 cm) were obtained from D_2 treatment. Different liming had significant variations on the yield of tomato. The maximum (55.18 t/ha) yield of fruit was recorded from D_2 treatment and the minimum (33.71 t/ha) was obtained from D_0 treatment.

Combined effect of Phosphorus and liming showed a significant variation in terms of all parameter. The longest (91.24 cm) plant height was recorded from the combined effect of P_3D_1 (60 kg P/ha + 1.5 t/ha) treatment. The maximum (12.97) number of secondary branch was recorded from P_3D_2 (60 kg P/ha + 1.5 ton/ha of dolomite) treatment. The maximum (8.20 cm) length of fruit was recorded from the combined effect of P_3D_2 treatment. The maximum (6.11 cm) diameter was recorded from P_3D_2 treatment... The maximum (82.55 t/ha) yield of fruit was recorded from P_3D_2 (60 kg P/ha + 1.5 t/ha of dolomite) treatment, while P_0D_0 (0 kg P/ha + no liming) gave the minimum (24.4 t/ha) yield of fruit.

The effect of different doses of phosphorus fertilizer showed a statistically significant variation in the P concentration in post harvest soil. The P_3 (60 kg/ha) treatment showed the highest N concentration (0.064 %), P concentration (18.62ppm) and potassium concentration (0.23meq/100g soil) in soil.

The effect of different doses of liming showed a statistically significant variation in the P concentration in post harvest soil of tomato field. The highest total N content (0.062%), P concentration (19.11ppm), potassium concentration (0.22meq/100g soil) were observed in D_2 (1.50 t/ha) treatment.

Significant effect of combined application of different doses of phosphorus and liming fertilizer on the nitrogen concentration was observed in post harvest soil of tomato field. The highest concentration of nitrogen in post harvest soil (0.073%), concentration of P (22.42ppm) and concentration of potassium (0.25meq/100g soil) were recorded in the treatment combination of P_3D_2 treatment.

From the results of the study it may be concluded that combined application of lime @ 1.5 t/ha and phosphorus @ 60 kg P/ha showed that the best performance in respect of growth and yield contributes of BARI Tomato-14.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.
2. Another level of lime and phosphorus fertilizer may be included for further confirmation of the results.

CHAPTER VI

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APPENDIES

Appendix I: Soil characteristics of experimental farm of Sher-e-Bangla agricultural University are analyzed by soil science laboratory, SAU, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Farm, Sher-e-Bangla Agricultural University, Dhaka
AEZ	Modhupur tract (28)
General soil type	Deep red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
Particle size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
pH	5.56
Organic matter (%)	1.00
Total N (%)	0.06
Available P (µgm/gm soil)	42.64
Available K (meq/100g soil)	0.13