EFFECT OF NITROGEN AND PHOSPHOROUS ON THE GROWTH AND YIELD OF TOMATO (*Lycopersicon esculentum* Mill.)

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of Nitrogen and Phosphorous on the Growth and Yield of Tomato** (*Lycopersicon esculentum* Mill.)**"** 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 *bonafide* research work carried out by **Subrato Kumar Paul**, Registration number **26198/00491** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 31. 12. 07

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Dedicated TO

MY

Beloved Parents

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Dated: December, 2007
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ABSTRACT

The experiment was conducted in the experimental field of Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur, Bangladesh during the period from November 2006 to March 2007 to find out the effect of nitrogen and phosphorous on the growth and yield of tomato. The experiment considered of two factors as Factor A (Four levels of nitrogen): N_0: 0 kg N/ha; N_1: 80 kg N/ha; N_2: 160 kg N/ha and N_3: 240 kg N/ha, Factor B (Four levels of phosphorous): P_1 : 0 kg P_2O_5/ha; P_2: 25 kg P_2O_5/ha; P_3: 50 kg P_2O_5/ha and P_3: 75 kg P_2O_5/ha. The maximum plant height (126.92 cm) was recorded from N_2 treatment consisting of 160 kg N/ha and the minimum plant height (112.23 cm) was recorded from N_0 treatment i.e. control condition. The maximum yield (63.39 t/ha) was recorded from N_3 treatment and the minimum yield (32.60 t/ha) was recorded from N_0 treatment. The highest nitrogen content (1.88%) in shoot was recorded from N_3 treatment and the lowest nitrogen content (0.82%) was recorded from N_0 treatment. The highest phosphorous content (0.553%) in shoot was recorded from N_3 treatment and the lowest phosphorous content (0.209%) was recorded from N_0 treatment. The maximum total nitrogen (0.10%) was recorded from N_0 and the minimum total nitrogen (0.09 kg/ha) in soil was recorded from N_1, N_2 and N_3 treatment. The maximum total phosphorous (42.80 ppm) was recorded from N_3 treatment and the minimum total phosphorous (39.97 ppm) in soil was recorded from N_0 treatment. The maximum plant height (123.55 cm) was recorded from P_2 treatment comprising of 50 kg P_2O_5/ha, while the minimum plant height (117.17 cm) was recorded from P_0 treatment. The maximum yield (53.65 t/ha) was recorded from P_3 treatment and the minimum yield (43.98 t/ha) was recorded from P_0 treatment. The highest nitrogen content (1.44%) of shoot was recorded from P_3 treatment and the lowest nitrogen content (1.20%) in shoot was recorded from the P_0 treatment. The highest phosphorous content (0.420%) of shoot was recorded from P_3 treatment and the lowest phosphorous content (0.338%) in shoot was recorded from the P_0 treatment. The maximum plant height (135.17 cm), maximum yield 68.35 kg/ha were recorded under the treatment combination of N_2P_3 as 160 kg N /ha + 75 kg P_2O_5 /ha. The height nitrogen content (2.02%) in shoot was recorded under the treatment combination of N_3P_3 where as maximum phosphorus content (0.599 %) was recorded under the treatment combination N_2P_3. Minimum yield and yield attributes were found under the treatment combination of N_0P_0.

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Introduction

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belongs to the family Solanaceae is one of the most important, popular and nutritious vegetable crops in Bangladesh. It is originated in tropical America (Salunkhe *et al.*, 1987) and ranks third in terms of world vegetables production (FAO, 1997) and tops the list of canned vegetables (Choudhury, 1979). It is adapted to a wide range of climates ranging from tropics to within a few degree of the Arctic Circle. However, in spite of its broad adaptation, production is concentrated in a few area and rather dry area (Cuortero and Fernandez, 1999).

The popularity of tomato and different products produced from tomato processing is increasing day by day. It is a nutritious and delicious vegetable used in salads, soups and processed into stable products like ketchup, sauce, marmalade, chutney and juice. They are extensively used in the canning industry for canning. Nutritive value of the fruit is an important aspect of quality in tomato and public demand. 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). Tomato adds flavor to the foods and it is also rich in medicinal value.

The soil and climate condition of winter season of Bangladesh are congenial for tomato cultivation. Very recently some variety was developed for year round cultivation of tomato. Among the winter vegetable crops in Bangladesh, tomato ranks second in respect of production and third in respect of area (BBS, 2006). During the year 2005-2006, 131,000 metric tonnes of tomato were produced from 13845 hectares of land with an average yield of 9.46 t/ha (BBS, 2006). But this yield is quite low as compared to other leading tomato producing countries of the world such as China, Egypt, USA, Turkey where per hectare yield was reported as 30.39, 34.00, and 41.77 t/ha, respectively.

The lower yield of tomato in Bangladesh, however, is not an incidence of the low yielding potentiality of this crop but of the fact that the lower yield may be attributed to a number of reasons viz. unavailability of quality seeds of improved varieties, fertilizer management, disease infestation and improper moisture management. Among them fertilizer management is a vital factor that influences the growth and yield of tomato. Balanced use of fertilizer nutrients in crops will act as an insurance against possible nutrient deficiencies that may be created by the repeated use of a single nutrient (Manang *et al.*, 1982). Among the different nutrients that were required for tomato cultivation nitrogen and phosphorous are most important nutrients. On the other hand soils of Bangladesh have been deficient in nitrogen and phosphorous fertilizer. So, it is necessary to apply these nutrient elements for satisfactory growth, development and also yield of tomato (BARC, 1997). Tomato requires large quantity of readily available fertilizer nutrients (Gupta and Shukla, 1977). In indeterminate type of tomato, vegetative and reproductive stages over lap and the plants need nutrients upto fruit ripening. To get one ton fresh fruit, plants need to absorb, on average 2.5-3.0 kg N, 0.2-0.3 kg P and 3.0-3.5 kg K (Hedge, 1997).

In Bangladesh, fertilizer specially nitrogenous is the most critical input for increasing crop production and had appropriately been recognized as the central element for agricultural development (Mukhopadhyay *et al.*, 1986). More than any other nutrient, nitrogen influences vegetative growth and yield of tomato plant. Nitrogen is essential for building up of protoplasm and protein which induce cell division and initial meristematic activity when applied in optimum quantity (Singh and Kumer, 1969). Nitrogen had the largest effect on yield and quality of tomato (Xin *et al.*, 1997). It also promotes vegetative growth and flower and fruit set of tomato. (Bose and Som, 1990). Optimum nitrogen increases fruit quality, fruit size, keeping quality, color, taste and acidity (Sharma and Mann, 1971). It significantly increases the growth and yield of tomato (Banerjee *et al.*, 1997).

Next to nitrogen fertilizer phosphatic fertilizer dwell in the second most important input for increasing crop production. High level of phosphorous throughout root zone is essential for rapid root development and for good utilization of water and other nutrients by the plant. Phosphorous has profound effect on number of flowers that progressively increases the yield (Al-Afifi *et al.*, 1993 Razia and Islam, 1980) and marketable yield of tomato (Candilo, 1993).

The relationship between nitrogen and phosphorous nutrients of the tomato has received considerable attention and appears to have had a profound influence on Horticultural practices. Combined effect of nitrogen and phosphorous have also been proved quite effective in increasing growth and yield of tomato (Pandey, 1996; Pansare *et al.*, 1994 and Kuksal *et al.*, 1977). Optimum rates of nitrogen and phosphorous not only increase the yield but also increase the quality of tomato (Sharma and Mann, 1971).

Considering the above circumstances, the present investigation has been undertaken with the following objectives:

1. To evaluate the response of tomato to nitrogen and phosphorous for maximizing high yield.

2. To find out the optimum dose of nitrogen and phosphorous for growth and higher yield of tomato.

3. To study the combined effect of nitrogen and phosphorous for attaining desirable tomato yield.

4. To calculate the nutrient uptake by the plant in tomato production.

Chapter 2
Review of literature

REVIEW OF LITERATURE

Tomato is one of the important vegetable crop in Bangladesh and as well as many countries of the world. It is a high yielding year the round crop and fertilizer responsive crop. Among different fertilizer nitrogen and phosphorous are two of the essential plant nutrient elements and each plays a significant role in tomato production. But a very few studies on the related to nitrogen and phosphorous on growth, yield and development of tomato have been carried out in our country as well as many other countries of the world. The research work so far done in Bangladesh and is not adequate specific and conclusive. Nevertheless, some of the important and informative works and research findings related to the nitrogen and phosphorus fertilizer so far been done at home and abroad on this crop have been reviewed in this chapter under the following headings-

2.1 Effect of nitrogen on the growth and yield of tomato

Sainju *et al.* (2001) conducted an experiment at Agricultural Research Station, Fort Valley State University, Fort Valley to evaluated hairy vetch residue as nitrogen fertilizer for tomato in soilless medium. The ability of hairy vetch (*Vicia villosa* Roth) residue (100 g/plant) to supply N and to increase yields of tomato (*Lycopersicon esculentum*) was compared with that of N fertilization (0, 4.1, and 8.2 g N/plant) in a medium containing a mixture of 3 perlite : 1 vermiculite in a greenhouse. Leaf dry weight, leaf and stem N uptake, total dry weight and N uptake of tomato, and NH_4^+ and inorganic N concentrations in the medium at transplanting were significantly greater with than without residue. Nitrogen fertilization increased fruit number, fresh and dry yields and N uptake, stem, leaf, and root dry weights and N uptake, root length, and total dry weight and N uptake. The residue was as effective in increasing fresh fruit yield, total dry weight, and N uptake as was 4.4 to 7.9 g/plant of N fertilizer. Tomato yield and N uptake per unit amount of N supplied was greater for the residue than for N fertilization.

Research was conducted by Dufault *et al.* (2000) in Charleston, South Carolina, to determine (1) the effect of supplemental nitrogen (N) at 60 or 120 kg ha^{-1} following winter cover crops of wheat. Tomato (*Lycopersicon esculentum* Mill.) and snap bean (*Phaseolus vulgaris* L.) grown in rotation; and (2) the distribution and retention of soil nitrates in the soil profile as affected by N fertilization and cover cropping. Total marketable tomato yield increased as fertilizer N increased to 60 kg ha^{-1} in two out of four years and with 120 kg ha^{-1} in one out of four years. In all cover crop or fallow plots, as fertilizer N application levels increased, the soil nitrates also increased.

Rhoads *et al.* (1999) carried out an experiment to evaluate the influence of N rates and ground cover following tomato on soil nitrate-N movement was monitored in spring and fall [autumn] crops grown at the Florida A&M University, Florida, USA. Nitrogen rates varied from 0 to 360 lb/acre in the spring crop and from 0 to 600 lb/acre in fall tomato. Yield ranged from 1900 to 2600 boxes/acre in spring tomato, and from 1300 to 2700 boxes/acre in fall tomato. Fertilizer N rates above 180 lb/acre were excessive, as shown by yield and residual soil nitrate-N levels. Residual soil nitrate-N was proportional to N application rate. Soil nitrate-N concentration following harvest was highest in the 1 to 3 ft depth range for spring tomato and the 2 to 4 ft depth range for fall tomato.

A study was conducted by Ceylan *et al.* (2001) at Odemis, Izmir, Turkey to assess the effect of ammonium nitrate and urea fertilizers at 0, 12, 24, 36 kg N/da on nitrogen uptake and accumulation in tomato plants. The total nitrogen, NO_2-N and NO_3-N contents of leaves and fruits were determined. On the first and second harvest dates, the highest NO_3-N and NO_2-N amounts in tomato leaves and fruits were obtained upon treatment with 36 kg N/da. Ammonium nitrate application increased nitrate and nitrite accumulation compared to urea application. The highest yield was recorded upon treatment with 24 kg N/da.

An experiment was conducted in Uttar Pradesh, India, by Singh *et al.* (2000) to determine the suitable rate and application of N fertilizers for obtaining optimum growth and yield of tomato cv. Pusa Hybrid-2. N was applied at 40 kg/ha basal, 40 kg/ha top dressing, 80 kg/ha in 2 splits (40 kg/ha basal + 40 kg/ha top dressing), 50 kg/ha in 2 splits (40 kg/ha basal + 10 kg/ha foliar), 60 kg/ha (40 kg/ha basal + 20 kg/ha foliar), 70 kg/ha (40 kg/ha basal + 30 kg/ha foliar) and 80 kg/ha (40 kg/ha basal + 20 kg/ha top dressing + 20 kg/ha foliar). N at 80 kg/ha applied in 3 splits produced the highest yield and biomass. Increasing N rates resulted in increasing biomass and yield.

Two field experiments were conducted in Egypt by Awad *et al.* (2001) to study the effect of intercropping parsley and demsisa with tomato under 4 rates of N fertilizer (100, 120, 140 and 160 kg N/fed). The results showed that increasing N fertilizer rate enhanced total yield and net assimilation rate (NAR) of both mono and mixed crops, earliness index of tomato and NPK uptake of tomato in NAR, total yield, earliness index and N uptake. The best values were obtained by pure stand planting at the highest N rate (160 kg N/fed), whereas the best P and K uptake were attained at 140 and 120 kg N/fed, respectively. The highest value of N supplementation index (NSI) for tomato was obtained at 100 kg N/fed, whereas the highest values of phosphorus supplementation index (PSI) and potassium supplementation index (KSI) were recorded by plants which received 160 kg N/fed.

A field experiment was conducted by Manoj and Raghav (2001) to evaluating two F_1 hybrids of tomato, three plant spacings (75 cm × 50 cm, 75 cm × 75 cm and 75 cm × 100 cm) and five levels of nitrogen (0, 75, 150, 225 and 300 kg/ha) was conducted during 1995-96 and 1996-97 at the Research Station, Nagina of G.B. Pant University of Agriculture and Technology, Pantnagar (Uttar Pradesh, India) on sandy loam soil. Among the various levels of nitrogen, 300 kg/ha was found to be best in improving the growth and yield.

High ammonium nitrogen (NH_4N) concentration in solution may adversely affect greenhouse tomato yield, but it has been reported that small NH_4N fractions improve yield and may increase vegetative growth and nutrient element uptake. The objective of this study was conducted by Sandoval *et al.* (2001) to determine the tomato yield response to 0 : 100, 10 : 90, 20 : 80, 30 : 70, and 40 : 60 NH_4N : NO_3N ratios supplied at the vegetative, vegetative plus flowering, flowering plus fruiting, and fruiting stages, and over the entire plant life cycle. Neither the length of NH_4N supply nor the NH_4N concentration in solution affected tomato yield. Plant height was not affected by NH_4N concentration in either the winter or spring experiments, and neither was fruit firmness measured for fruit at the mature green stage. Fresh and dry weights were unaffected by NH_4N concentration.

Bot *et al.* (2001) carried out an experiment to evaluate the response of adult tomato plants growing in rock wool in a greenhouse to N withdrawal from the nutrient solution was studied over a 6-week period during fruit production. The major effect of N withdrawal included the impairment of growth of fast growing organs. Fruit growth was impaired, leading to a reduction in yield. The growth of young leaves was also inhibited. The stores of nitrate N were depleted after removal of N in the solution, but it took 45 days for the plants to metabolize completely their nitrate reserves.

Tomato cv. Pusa Gaurav was treated with N at 0, 40, 80 and 120 kg/ha and K at 0, 30 and 60 kg/ha in a field experiment conducted in Madhya Pradesh, India during rabi 1992-93 and 1993-94 by Gupta and Sengar (2000). N application resulted in increases in plant height, number of fruits per plant, fruit weight and fresh yield. Increasing N rate produced a corresponding increase in yield and yield components, except total soluble solids (TSS) content. K increased vegetative growth, yield and TSS content.

Sainju *et al.* (2000) conducted an experiment on cover crops can influence soil properties and crop yield they examined the influence of legume and N fertilizer application (0, 90, and 180 kg N ha^{-1})) on the short and long-term effects on soil C and N and tomato yield and N uptake. N uptake similar to that produced by 90 and 180 kg N ha^{-1}. Nitrogen fertilizer application increased PNM and inorganic N after split application and tomato yield and N uptake but decreased organic C and N and PCM.

Hoffland *et al.* (2000) conducted an experiment to study how nitrogen availability affects within plant allocation to growth and secondary metabolites. Tomato plants were grown at six levels of nitrogen availability. When nitrogen availability increased, plant relative growth rate increased, but tissue carbon/nitrogen ratio in the second oldest true leaf and allocation to large glandular trichomes as well as to the defense compounds rutin, chlorogenic acid decreased but leaf protein concentration increased.

This study was conducted by Chang *et al.* (2000) to investigate the effect of nitrogen supply by NH_4 deposit fertilizer on plant growth and nitrogen uptake of tomatoes. NH_4 deposit fertilizer was applied using the "CULTAN" (Controlled Uptake Long Term Ammonium Nutrition) method. It was prepared by mixing one-third ammonium sulfate and two-thirds urea as nitrogen sources and by combining gypsum as a binder and loamy soil and compost as diffusion regulators in the beaker. In the first experiment, the application of NH_4 deposit fertilizer with 7.5 g gypsum as a binder resulted in increased tomato fruit yield and nitrogen uptake efficiency compared to control. In the second experiment, the application of NH_4 deposit fertilizer with loamy soil and compost as a diffusion regulator and adjusted C/N ratio to 16 also resulted in increased nitrogen uptake of fruits.

There are few growth studies evaluating within-season effects of N on vegetative growth and N accumulation of tomato conducted by Scholberg (2000). Growth analysis of field grown tomato for a number of Florida (USA) locations and management systems is presented here. Severe N stress resulted in fewer and smaller, but thicker, leaves. With increasing N, average leaf area index increased from 0.75 to 3.0, but radiation use efficiency (RUE) typically increased less than 30%. Lower RUE under N limited conditions reflected a decrease in N concentration of the most recently matured leaves from 40 mg g^{-1} to as little as 15 mg g^{-1}. Over the life of well-fertilized crops, leaf N concentrations dropped from 55 to 65 mg g^{-1} during initial growth to 20 to 35 mg g^{-1} at final harvest. Corresponding N concentrations for fruit and for stems were 30 to 35 mg g^{-1} and 15 to 25 mg g^{-1}. Severe N stress affected leaf and stem N concentrations most drastically, whereas N in fruits was less variable.

Hoffland *et al.* (1999) conducted an experiment on tomato plants with varying N availability were grown by adding N daily in exponentially increasing amounts to a nutrient solution at different rates. Leaves of plants grown at low N availability had a high leaf C:N ratio (21 g/g). The level of soluble carbohydrates correlated positively with susceptibility, independent of the growth method. It is therefore suggested that the effect of N availability on susceptibility can be explained by variation in levels of soluble carbohydrates which hence may play a role in the infection process.

The effects of low and high water vapor deficit regimes and electrical conductivities of 3.8 or 4.8 mS/cm on the growth and N uptake of 7-month-old tomatoes in NFT were investigated for 3 months by Bellert *et al.* (1998). Growth and N uptake were not modified by the treatments. N accumulated in the aerial biomass in proportion to the dry matter. Total N concentration of the foliage was relatively constant and richer than that of vascular organs and fruits. A model is proposed to link total N concentration to dry matter accumulation.

In field trials on a red ferrallitic soil in northern Havana in 1994-95, tomato cv. Campbell-28 plants were fertilized with 0, 60, 120, 180 or 240 kg N/ha, starting 38 days after sowing was conducted by Adjanohoun *et al.* (1996). Although increasing rates of applied N had no effect on average fruit weight, they significantly increased fruit numbers although application of 240 kg N/ha was excessive and significantly reduced yield compared with 120 or 180 kg N/ha (the highest yield, obtained with 180 kg N/ha, was 38 t/ha). A mathematical expression describing the curve of yield response is presented, and from it the optimum application rate was determined to be 158 kg N/ha, giving a fruit yield of 38.9 t/ha.

The tomato cv. Momotaro was grown using the nutrient film technique (NFT) in 1/2- and 3/4- to full-strength Enshi shoho balanced feed (Hohjo *et al.* 1995). In the first experiment, nutrient solutions were adjusted to contain NO_3N : NH_4N ratios of 10:0, 9:1 and 8:2. Shoot and root FW were increased by an increasing proportion of NH_4-N with both strengths of solution, whereas Ca and Mg uptake were decreased by an increasing proportion of NH_4-N only with the higher solution strength. Total yield was reduced by increasing the proportion of NH_4N, particularly with the higher strength of solution, a combination that also caused a marked increase in the incidence of blossom-end rot (BER). In the second experiment, NO_3-N : NH_4N ratios of 10:0 and 8:2 and Ca concentrations of 2, 4 and 6 meq/litre were used. The higher proportion of NH_4N significantly increased shoot and root FW, incidence of BER and leaf contents of N, P and K, whilst decreasing the leaf content of Ca. Increasing the Ca content of the medium caused an increase in early yield and leaf Ca content, and a decrease in BER and leaf Mg content. The combination of 8:2 NO_3N : NH_4N and the lowest Ca concentration reduced total yield and leaf Ca content and significantly increased BER.

Trpevski *et al.* (1992) carried out in trials with 3 N was applied at 0, 40, 80 or 120 kg/ha to soil manured with 40 t FYM/ha in early spring. The 2 higher N rates increased the yield of San Pjer but reduced the yield of the other 2 cultivars. The effects of treatments on fruit N, dry matter, organic acid and vitamin C contents were generally not significant.

An experiment were conducted by Kooner and Randhawa (1990) at Punjab Agricultural University, Ludhiana to study the interaction of rates and sources of N with cultivars on the yield and processing quality of tomatoes in winter and spring seasons. Four rates of N (50, 100, 150 and 200 kg/ha) were applied as 2 sources, calcium ammonium nitrate (CAN) and urea, in a randomised, split plot design. PC produced significantly higher yields (222.7 kg/ha) than PK (208.9 kg/ha) in the spring planting while in the winter planting OS (163.9 kg/ha) and CS (113.9 kg/ha) were the best. Yields increased linearly with increasing N rate up to 150 kg/ha and CAN was the best source of N. TSS, juice percentage, ascorbic acid content and titratable acidity increased with increasing N up to 150 kg/ha.

In a study on the effect of nitrogen fertilization and plant intensification, Midan *et al.* (1985) observed that increasing nitrogen rates linearly increased the number of fruits per plant. However, medium and higher nitrogen rates gave best total yields. With different nitrogen rates, three times of application improved fruit per plant weight and total yield. Patil and Bojappa (1984) conducted an experiment to study the effects of cultivars and graded levels of nitrogen and phosphorus on certain quality attributes of tomato. The experiment consisted of the cultivars Pusa Ruby, Sious and Sweet-72. The plant received nitrogen at 70, 110 and 150 kg/ha and phosphorous (P) at 44 or 61.6 kg/ha with basal dressing of potassium (K) at 49.8 kg/ha and FYM at 25 t/ha. The highest fruit content of total sugars and next highest dry matter content were in sweet-72 while juice percentage was highest in pusa Ruby. Rising nitrogen rates increased fruit total increased fruit total sugars and juice percentage but decreased the dry matter content. Phosphorous had no appreciable effect as any of the indices studied.

Belichki (1984) reported that nitrogen was the most important nutrient. Flower and fruit numbers per plant were increased by nitrogen up to 240 kg/ha and fruit size was greatest 120 kg/ha. Staneve (1983) conducted an experiment to investigate the effect of nitrogen supply on photosynthesis, leaf area and total dry matter in tomato and found that photosynthesis was inhabited by N deficiency. Leaf development and dry matter accumulation were greatest at 10meq/L N and declined at higher concentrations.

2.2 Effect of phosphorous

A short term experiment was conducted by Kaya and Higgs (2001) with tomato cultivars Blizzard, Liberto and Calypso was carried out in a controlled temperature room to investigate the effectiveness of phosphorus (P) and iron (Fe) supplemented in nutrient solution on plant growth at high zinc concentration. Application of supplementary P and Fe resulted in marked increases in both dry weight and chlorophyll concentrations achieving values not significantly different to the control. Application of supplementary P and Fe decreased Zn concentration in the leaves and roots of plants grown at high Zn, but Zn concentrations were still at toxic levels. Phosphorus and Fe concentration in leaves declined to a deficient level in the high Zn treatment, but was markedly increased in the roots. Application of supplementary P and Fe corrected both P and Fe deficiencies in leaves of plants grown at high Zn and reduced root P and Fe concentrations.

A study was conducted by Groot and Marcelis (2001) to evaluate the importance of leaf area ratio (LAR) and net assimilation rate (NAR) in determining the phosphorus effects on relative growth rate (RGR). To examine the effects of phosphorus and light on the growth of young tomato plants, an experiment with a wide range of P supply rates, 0.07-0.32 g g^{-1}

day^{-1}, and one free access treatment was conducted at two light levels. This study demonstrates, for both low and high light conditions, that at phosphorus limitation, NAR can be more important than LAR in determining RGR. It was observed that the plant nitrogen concentration increased with increasing P supply.

A field experiment was carried out at Lavras, Minas Gerais, Brazil during 1997 to study nutrient absorption and yield by tomato plants pruned and grown under high planting density with various gypsum (0.3, 0.6, 0.9 and 1.2 t/ha) and P_2O_5 (0.2, 0.4 and 0.6 t/ha) rates by Silva *et al.* (2001). A linear increase was observed in marketable fruit yield as P_2O_5 rates increased whereas a linear decrease was observed as gypsum rates increased. Leaf P content decreased from 3.0 to 1.7 g/kg with an increase in gypsum rates and leaf Mg content averaged 4.7 g/kg.

Kaya *et al.* (2001) conducted an experiment with three tomato cultivars were grown hydroponically in a controlled temperature room for 6 weeks to investigate the effectiveness of foliar application of supplementary potassium and phosphorus to the leaves of plants grown at high NaCl concentration (60 mM). Supplementary 5 mM K and P as KH_2PO_4 was supplied via leaves to the plants grown at high NaCl (60 mM) twice a week for 4 weeks. The plants grown at high NaCl produced less dry matter and chlorophyll than those at normal nutrient solution for all three cultivars. Membrane permeability increased with high NaCl application and these increases in membrane permeability were decreased by supplementary K and P. Concentrations of P and K were at deficient ranges in the plants grown at high NaCl levels and these deficiencies were corrected by supplementary K and P application via leaves.

Field experiments conducted by Nanadal *et al.* (1998) from 1989 to 1991 in Haryana, India, using four levels of each of phosphorus and potash with tomato showed that increasing levels of phosphorus up to 50 kg P_2O_5 and potash up to 80 kg K_2O/ha improved the height of plant, number of flowers, weight of fruit, early and total yield, ascorbic acid content, total soluble solids and reducing and non-reducing sugars in the fruit. Though the higher doses of 75 kg P_2O_5/ha and 120 kg K_2O/ha increased fresh and dry weight of plant and advanced flowering and fruiting, they deteriorated the quality of fruit.

Song *et al.* (1998) carried out an experiment to find out the effects of phosphate starvation on growth and P uptakes of tomato seedlings were studied. The seedlings were arranged to grow in complete (P adequate) or P depleted nutrient solution. The results revealed that, under P starved conditions, the average height of the seedlings decreased, while the main roots of the seedlings were longer than those of the controls, especially under phosphate starvation for 5 and 7 days. Therefore the root : shoot ratios of the seedlings under P starved conditions were also higher than those of the controls. In addition, the early days of phosphate starvation had no obvious effect on the fresh weight accumulation by the seedlings, while the late days of starvation did reduce fresh weight accumulation.

Bar Yosef (1995) conducted an experiment of nutrient uptake and dry matter production by a green house tomato (cv-144) crop was investigated in response to the concentration of P(0, 10, 30 and 60 mg P/litre) in the liquid feed and chemical properties. The leaf phosphorous content and dry matter production were increased significantly with increasing applied phosphorus. With increasing phosphorous concentration in leaves, there was an increase in leaf nitrogen and a decrease in potassium that became more pronounced above 0.65g P/100g plant dry weight. With dry matter production, there was a marked fall-off below a leaf P concentration of 0.3 g P/100g plant dry weight.

Topcuogh and Yalcin (1994) observed that different rates of lime (calcium hydroxide) and phosphorus were applied to potted tomato plants. Increasing rates of lime application increased individual fruit weight but decreased fruit yield/plant. Increasing rates of phosphorous increased vegetative growth and fruit yields.

Candilo *et al.* (1993) conducted an experiment to study the response of sulphur, phosphorus and potassium in processing tomato grown in high alkaline soil. They reported that increasing phosphorus application led to significant linear increases in cloth marketable yield and TSS content. In all interactions, the highest yields were obtained with 450 kg S K_2O and P_2O_5/ha.

2.3 Combined effect of nitrogen and phosphorous

Garton and Widders (1990) carried out an experiment on seedlings of processing tomato cv. H 2653 were grown in plug trays in a soilless growing medium. Application of nutrient solutions containing 10 or 20 mM N and 2 or 5 mM P for 10 d before transplanting altered the total ammoniacal N and P, and the soluble NO_3N and PO_4P concentrations in the shoot tissue at transplanting. Post-transplanting shoot and root growth were more rapid in late May plantings than in earlier plantings. The 20 mM N and 2 mM P pretransplant treatment caused the most rapid shoot growth following early season planting in the field at Harrow. Rapid seedling establishment after transplanting was generally not a good indicator of potential fruit yield. Withholding fertilizer temporarily before transplanting resulted in depletion in tissue N and P concentrations, slow post-transplanting shoot growth, and lower yields.

Tomato cv. Hisar Arun and okra cv. Pusa Sawani were planted during the 1991-92 and 1992-93 seasons at Haryana Agricultural University as a crop after potato by Taya *et al.* (1994). The preceding potato crop received either the recommended fertilizer regime of 150 kg N/ha, 50 kg P_2O_5/ha and 100 kg K_2O/ha (F_1). The subsequent crops received either N fertilizer at 0 (N_0), 25 (N_1), 50 (N_2) of the recommended rate or 100 kg N/ha, 50 kg P_2O_5/ha and 50 kg K_2O/ha (NPK). The F_1 treatments increased plant height at 90 days after planting, fruit number and yield in the subsequent crops of tomato and okra; the F_1 treatment also increased the NPK content of foliage, and delayed flowering in both crops. With the tomato crop, there were no significant differences in fruit number and yield. Leaf N concentration increased with increasing N rate; N application had no effect on leaf P and K contents.

Field experiments were conducted on at Uttaranchal, India, by Singh *et al.* (2004) to determine the effects of integrated nutrient management on crop nutrient uptake and yield under okra-pea-tomato cropping sequence. In the sequence, treatments were given to okra crop, while in the succeeding crops (pea and tomato), only recommended dose of fertilizers were applied on the basis of soil test. The treatments consisted of NPK recommended dose of 80:30:30 kg/ha (T_1); farmyard manure (FYM) at 15 tones/ha + rest of the NPK (T_2); neem cake at 3 q/ha + rest of the NPK (T_3); poultry manure at 3 tonnes/ha + rest of the NPK (T_4); Azospirillum + 75% N + recommended dose of P and K (T_5); vesicular arbuscular mycorrhizas (VAM) +50% P + recommended dose of N and K (T_6); phosphate solubilizing bacteria (PSB) + 75% P + recommended N and K (T_7); Azospirillum + VAM + PSB + rest of the NPK (T_8); micronutrient + recommended dose of NPK (T_9); FYM + Azospirillum + VAM + PSB + rest of the NPK (T_{10}); and recommended dose of NPK + pea straw incorporation in the soil before tomato planting (T_{11}). In the case of okra and pea crops, only the recommended dose of NPK was given in T_{11}. The treatments were applied in the first crop and their effect was observed on instant as well as succeeding crops. The integrated use of organic and inorganic sources of nutrients and biofertilizers increased the N, P and K concentrations in the plants of okra, pea and tomato. The integrated nutrient management also significantly increased shoot dry matter yield of tomato and fruit yields of okra and tomato.

A field study was undertaken in Peshawar, Pakistan in the summer of 1995-96 by Khalil *et al.* (2001) to determine the appropriate nitrogen fertilizer for maximum tomato yield and its effects on various agronomic characters of tomato. Treatments comprised: untreated control; 150 kg ammonium nitrate/ha; 150 kg ammonium nitrate/ha + 100 kg P/ha + 50 kg K/ha; 150 kg ammonium sulfate; 150 kg ammonium sulfate/ha + 100 kg P/ha + 50 kg K/ha; 150 kg urea/ha; 150 kg urea/ha + 100 kg P/ha + 50 kg K/ha. Generally, ammonium sulfate fertilizer was the most efficient source of nitrogen for tomato production, followed by urea and ammonium nitrate. The ammonium sulfate + P + K treatment was the best among all treatments with respect to days to flower initiation (57 days), days to first picking (94 days), weight of individual fruit (50.8 g), weight of total fruits per plant (1990 g) and yield (21865 kg/ha). The control resulted in the significantly lowest response with respect to different agronomic characters under study.

Mohanty and Hossain (2001) conducted a field experiments during rabi 1994/95, 1995/96 and 1996/97 at Bhawanipatna, Orissa, India to investigate the effect of nitrogen, potash and macronutrient application on the yield and yield attributes of tomato. Twelve different treatment combinations were tested and data were recorded for fruit yield, fruit weight, and benefit-cost ratio. Two treatments were found superior over the other treatments and gave the highest yields with high benefit-cost ratio over the 3-year study period: (i) 180 kg N/ha + 60 kg P/ha + 60 kg K/ha with top dressing of N twice at 30 and 60 days after planting (DAP); and (ii) 120 kg N/ha + 60 kg P/ha + 60 kg K/ha with top dressing of N twice at 30 and 60 DAP along with two sprays of macronutrients at flowering and 15 days thereafter.

Felipe and Casanova (2000) carried out an experiment to determine the effects of N (0, 90, 180 and 270 kg/ha), P (P_2O_5, 0, 135, 270 and 405 kg/ha), and K (K_2O, 0, 90, 180 and 270 kg/ha) on the yield and number of fruits of tomato were investigated in the field in

Venezuela. The best treatment, with the highest yield and number of fruits per plant, was 180 kg N, 270 kg P_2O_5, and 180 kg K_2O/ha. It was possible to decrease the application of nutrients, particularly P. The increased yield was not due to larger fruits, but to an increase in the number of fruits. N had a profound effect on the number of fruits.

A field experiment was conducted by Sharma *et al.* (1999) with involving 4 levels of nitrogen (100, 150, 200 and 250 kg N/ha), 3 levels of phosphorus (60, 120 and 180 kg P_2O_5/ha) and 3 tomato hybrids (Naveen, MTH-16 and Rupali) and a local cultivar (Solan Gola) was conducted at Solan, India, to study the response of tomato hybrids to N and P. All the hybrids gave significantly higher total fruit yields than the local cultivar. Naveen recorded the greatest total fruit yield, while remaining statistically at par with MTH-16 and Rupali. Application of 200 kg N/ha resulted in significantly greater fruit size and mean fruit weight, compared to the other application rates. A significant improvement in plant height, fruit size and total fruit yield was observed with the application of phosphorus from 60 to 180 kg P_2O_5/ha.

A fertilizer trial on tomato cultivars Acc-99 and Sweet –72 was carried out by Pandey *et al.* (1996) to study the effect of nitrogen and phosphorous at Jabalpur, India. Using nitrogen rate 0, 40, 80 or 120 kg/ha and phosphorous 0, 40 or 80 kg/ha , they concluded that the fruit yield was increased as nitrogen (N) rate increased up to 80 kg/ ha. There was no significant difference between cultivators for fruit yield but there was an interaction nitrogen and phosphorus rates. Overall the highest yield (49.95 t/ha) was obtained from Acc-90 given 80 kg/ha each of nitrogen and phosphorous.

Çerne and Briski (1993) conducted field trials on the fertilizer and irrigation requirement of tomato cv. Rudgers plants where 250 kg N and 72 kg P_2O_5/ha plus 200 or 400 kg K_2O/ha in the first year, 0 or 200 kg K_2O /ha in the second year and 0 or 40 ton stable manure/ha were received all treatments. Plots were irrigated or non-irrigated (i.e rain fed only). The combination of 400 kg K_2O/ha, stable manure and irrigation gave the highest total yield in the first and second years (1.03 and 2.25 kg/ plant respectively). The percentages of class 1 fruits were increased by irrigation in all cases.

The effects of adding Zn (5 kg/ha), Cu (3 kg/ha) or FYM (30 t/ha) to the basic N:P:K (222:160:100 kg/ha) treatment as leaf transpiration and chlorophyll content and fruit ascorbic acid and sugar contents were studied by Annanurova *et al.* (1992). The treatment was generally beneficial and the number and mean weight of fruits were increased. Application of NPK alone increased yield/plant 43.4%, compared with the untreated control.

While studying the nitrogen, phosphorous and potassium fertility regimes affect tomato transplant growth, Melton and Dufault (1991) found that as nitrogen increased from 25 to 225mg/litre, fresh shoot weight, plant height ,stem diameter leaf number ,leaf area shoot and root dry weight and total chlorophyll content of seedlings ready for transplanting increased . Phosphorous of 45mg/litre increased fresh shoot weight , plant height, stem diameter, leaf number are compared with 5 to 15 mg P/litre. Potassium did not significantly influence any of the growth variables measured in the study.

Chapter 3

Materials and Methods

MATERIALS AND METHODS

The experiment was conducted in the vegetable research field of HRC, Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur, Bangladesh during the period from November 2006 to March 2007 to find out the effect of nitrogen and phosphorous on the growth and yield of tomato. The materials and methods used for conducting the experiment were presented in this chapter under the following headings-

3.1 Experimental site

The present experiment was carried out in the experimental field of HRC Farm (BARI), Joydevpur, Gazipur, Bangladesh. The location of the experimental site is $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude (Anon., 1989).

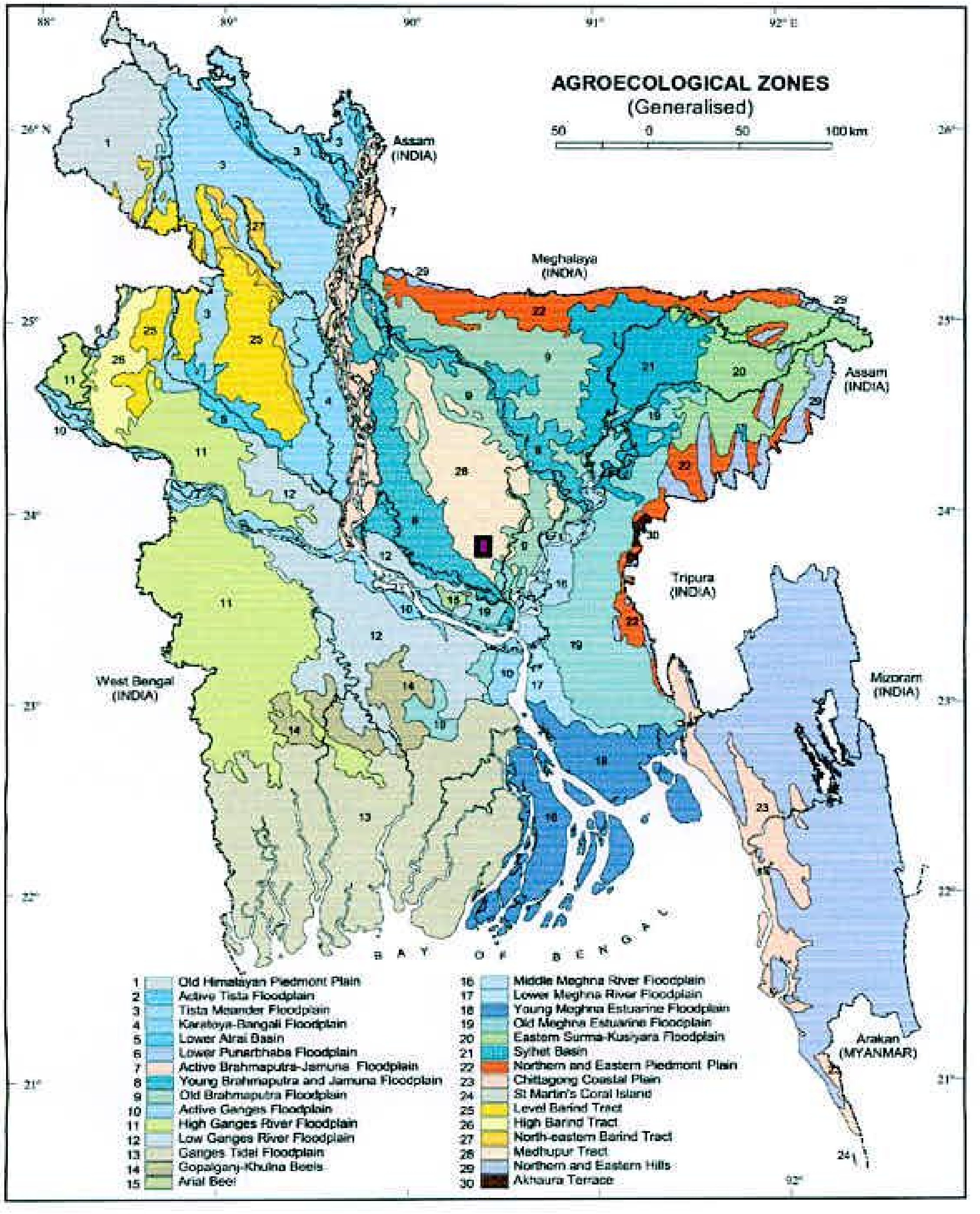
3.2 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was Red Brown Terrace Soil. The selected plot was medium high land and the soil series was Chhiata (FAO, 1988). The characteristics of the soil under the experimental plot were determined in the Soil testing Laboratory, SRDI Khamarbari, Dhaka and details of the recorded soil characteristics were presented in Table 1 and 2.

Table 1. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Bangladesh Agricultural Research Institute, Joydevpur, Gazipur
AEZ	Madhupur Tract
General Soil Type	Red Brown Terrace Soil
Land type	High land
Soil series	Chhiata
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

Map showing the experimental sites under study



■ **The experimental site under study**

Table 2. Physical and chemical properties of the initial soil

Characteristics	value
Particle size analysis.	
% Sand	48.0%
% Silt	22.0%
% Clay	30.0%
Textural class	Silty-clay
pH	6.2
Organic carbon (%)	1.20
Total N (%)	0.063
Available P (ppm)	14.7
Exchangeable K (me/100g soil)	0.11
Available S (ppm)	15.4
Available Zn (ppm)	2.2

3.3 Weather condition of the experimental site

The climate of experimental site was under the subtropical climate, characterized by three distinct seasons, the monsoon or the rainy season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Details of the metrological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from the Bangladesh Meteorological Department, Dhaka and presented in Appendix I.

3.4 Planting materials

In this research work, the seedlings of tomato were used. The seedlings of tomato variety Lalima were collected from the HRC farm of and seedlings were 30 days old.

3.5 Treatment of the experiment

The experiment considered of two factors. Details were presented below:

Factor A: Four levels of nitrogen

i. N_0 : 0 kg N/ha

ii. N_1 : 80 kg N/ha

iii. N_2 : 160kg N/ha

iv. N_3 : 240 kg N/ha

Factor B: Four levels of phosphorous

i. P_1 : 0 kg P_2O_5/ha

ii. P_2 : 25 kg P_2O_5/ha

iii. P_3 : 50 kg P_2O_5/ha

iv. P_3 : 75 kg P_2O_5/ha

There were 16 (4 × 4) treatment combinations such as N_0P_0, N_0P_1, N_0P_2, N_0P_3, N_1P_0, N_1P_1, N_1P_2, N_1P_3, N_2P_0, N_2P_1, N_2P_2, N_2P_3, N_3P_0, N_3P_1, N_3P_2, and N_3P_3.

3.6 Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. An area 28.5 m × 10.2 m was divided into three equal blocks. The layout of the experiment was prepared for distributing the treatment combinations into the every plot of each block. Each block was divided into 16 plots where 16 treatment combinations were allotted at random. There were 48 unit plots altogether in the experiment. The size of the each plot size was 2.4 m × 1.2 m. The distance maintained between two blocks and two plots were kept 1.0 m and 0.5 m respectively. The layout of the experiment is shown in Figure 1.

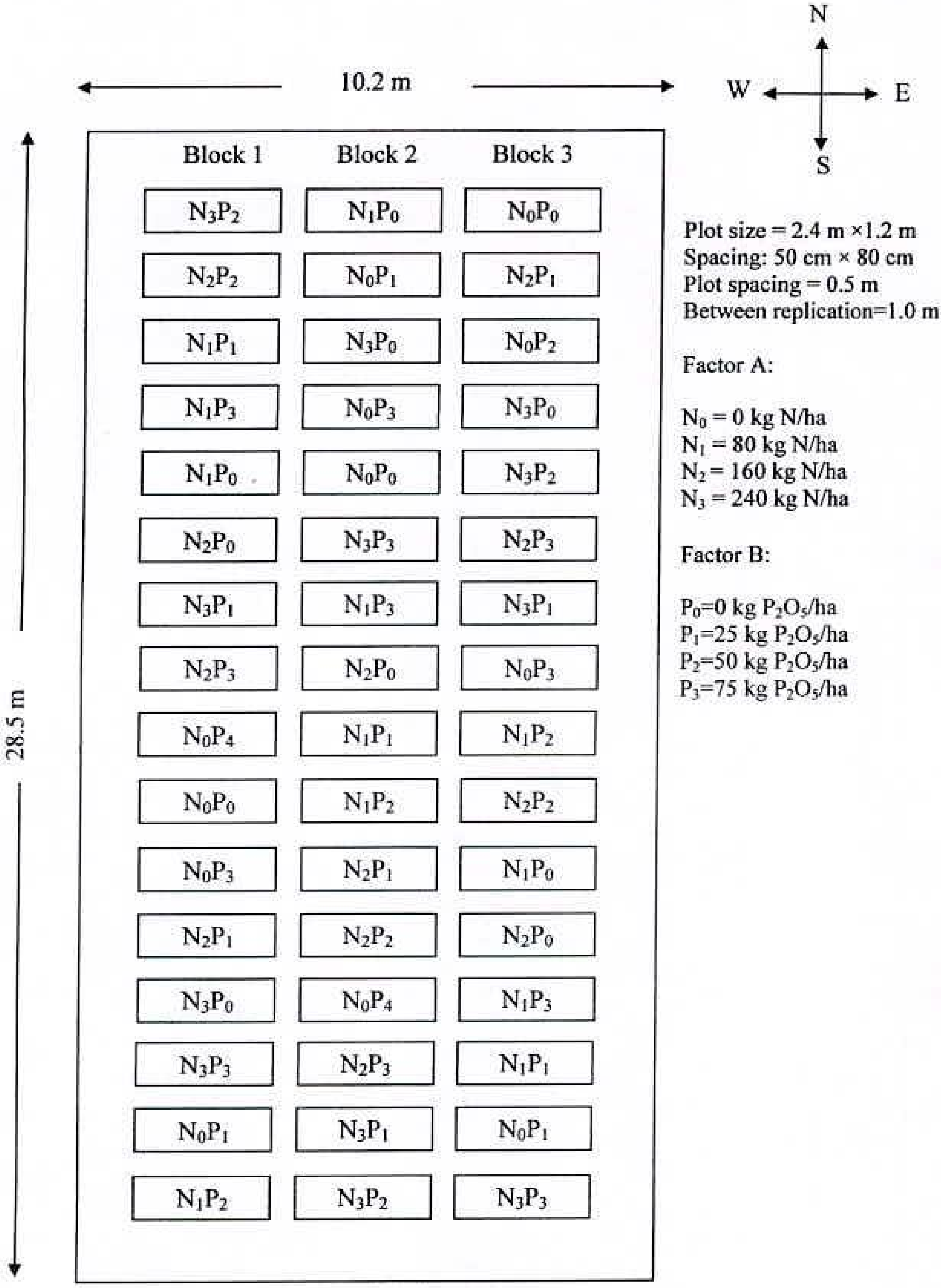


Figure 1. Field layout of two factors experiment in the Randomized Complete Block Design (RCBD)

3.7 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were drawn by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.8 Application of manure and fertilizers

The sources of N, P_2O_5, K_2O as urea, TSP and MP were applied, respectively. The entire amounts of TSP and MP were applied during the final land preparation. Urea was applied in three equal installments at 15, 30 and 45 days after seedling transplanting. Well-rotten cowdung 20 t/ha also applied during final land preparation. The following amount of manures and fertilizers were used which shown as tabular form recommended by Rashid (1993).

Table 2. Dose and method of application of fertilizer in experimental field

Fertilizers	Dose	Application (%)			
		Basal	15 DAT	30 DAT	45 DAT
Cowdung	20 tons	100	--	--	--
Nitrogen	As treatment	--	33.33	33.33	33.33
P_2O_5 (as TSP)	As treatment	100	--	--	--
K_2O (as MP)	200 kg	100	--	--	--

3.9 Intercultural operation

When the seedlings started to emerge in the beds it was always kept under careful observation. After establishment of seedlings, various intercultural operations, weeding, top dressing was accomplished for better growth and development of tomato seedlings.

3.9.1 Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots once immediately after seedling transplanting in every alternate day in the evening upto establishment of seedling. Further irrigation was done when needed. Stagnant water was effectively drained out at the time of heavy rain.

3.9.2 Weeding

Weeding was done to keep the plots free from weeds, easy aeration of soil, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully. Breaking the crust of the soil was done when needed.

3.9.3 Top Dressing

The whole nitrogen fertilizer were top-dressed in 3 equal installments. The fertilizers were applied on both sides of plant rows and mixed well with the soil by hand. Earthing up was done immediately after top-dressing of nitrogenous fertilizer.

3.10 Plant Protection

For controlling leaf caterpillars, nogos @ 1 ml/L water were applied 2 times at an interval of 10 days starting soon after the appearance of infestation. There was no remarkable attack of disease was found.

3.11 Harvesting

Different yield contributing data have been recorded from the mean of 6 selected plants at random of each unit plot.

3.12 Data collection

Data were recorded on the following parameters from the sample plants during the course of experiment.

i. Plant height (cm)

ii. Days from transplanting to first flowering

iii. Number of flower cluster per plant

iv. Number of fruits per cluster

v. Number of fruits per plant

vi. Weight of fruit per plant

vii. Yield (kg/plot)

viii. Yield (t/ha)

3.13 Chemical analysis of plant and fruit samples

3.13.1 Preparation of plant samples

Ten selected plants per plot were collected immediately after harvest. The selected plant was threshed. Both plant and fruit were cleaned and dried in an oven at 65^0 C for 48 hours. The dried samples were put into small paper bags and kept into a desiccator till being used.

3.13.2 Digestion of plant samples with sulphuric acid

For N determination, an amount of 0.1 g plant sample (plant and fruit) was taken into a 100 ml Kjeldahl flask. An amount of 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$; Se = 100:10:1), 2 ml 30% H_2O_2 and 3 ml conc. H_2SO_4 were added into the flask. The flask was swirled and allowed to stand for about 10 minutes followed by heating at 200^0C. Heating was continued until the digest was clear, and colorless. After cooling, the contents were taken into a 100 ml volumetric flask and the volume was made with distilled water. A blank digestion was prepared in a similar way. This digest was used for determining the nitrogen contents of plant samples.

3.13.3 Digestion of plant with nitric-perchloric acid mixture

An amount of 0.5 g of plant was taken into a dry clean 100 ml Kjeldahl flask, 10 ml of di-acid mixture (HNO_3 and $HClO_4$ at the ratio of 2:1) was added and kept for few minutes. Then, the flask was heated at a temperature raising slowly up to 200^0C. Heating was instantly stopped as soon as the dense white fumes of $HClO_4$ occurred and after cooling, 6 ml of 6N HCl were added to it. The content of the flask was boiled until they become clear and colorless. This digest was used for determining P, K, S and Zn.

3.13.4 Determination of element in the digest

Nitrogen, phosphorus, potassium and sulphur content in the digest were determined by similar method as described in soil analysis.

3.14. Soil Sample analysis

3.14.1 Total nitrogen

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

3.14.2 Available sulphur

Available sulphur in soil was determined by extracting the soil samples with 0.15% $CaCl_2$ solution (Page *et al.*, 1982) The S content in the extract was determined turbidimetrically and the intensity of turbid was measured by spectrophotometer at 420 nm wave length.

3.14.3 Available phosphorus

Available phosphorus was extracted from soil by shaking with 0.5 M $NaHCO_3$ solution of pH 8.5 (Olsen *et al.* 1954). The phosphorus in the extract was then determined by developing blue color using $SnCl_2$ reduction of phosphomolybdate complex. The absorbance of the molybdophosphate blue color was measured at 660 nm wave length by spectrophotometer and available P was calculated with the help of standard curve.

3.15 Statistical Analysis

The data obtained for different parameters were statistically analyzed to find out the significance difference of the different levels of nitrogen and phosphorous on yield and yield contributing characters of tomato and nutrient uptake and content by plant and fruit. The mean values of all the characters were calculated and analysis of variance was performing by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

RESULTS AND DISCUSSION

To determine the effect of different levels of nitrogen and phosphorous on yield and yield contributing characters of tomato as well as the nutrient content and their uptake by plants and fruits the present experiment was conducted. Data on different characters were recorded and analyzed to find out the effects of nitrogen and phosphorous. The analyses of variance (ANOVA) of the data on different components are given in Appendix II-V. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Yield and yield contributing character of tomato

Yield contributing characters such as plant height, days to transplanting to first flowering, number of flower cluster per plant, number of fruits per cluster, number of fruits per plant, weight of fruits per plant, yield per plot and hectare were recorded.

4.1.1 Plant height

Plant height varied significantly due to the application of nitrogen in tomato under the present trial (Appendix II). The maximum plant height (126.92 cm) was recorded from N_2 treatment consisting of 160 kg N/ha which was statistically identical (126.60 cm) with N_3 treatment as 240 kg N/ha (Figure 2) and the minimum plant height (112.23 cm) was recorded from N_0 treatment i.e. control condition which was closely (119.91 cm) followed by N_1 as 80 kg N/ha. Probably all micro and macro nutrients for 160 kg N/ha ensured the favorable condition for growth of tomato plant and the ultimate results is the tallest plant whereas above this level of nitrogen hinder the growth and plant height decreases. Melton and Dufault (1991) found that plant height of tomato was increased as highest level of nitrogen. Similar results was reported by Chung *et al*. (1992), Grela *et al*. (1988), Sharma and Mann (1971).

Table 3. Effect of nitrogen and phosphorous on plant height, days from transplanting to first flowering, number of flower cluster per plant and number of fruits per cluster of tomato

Treatment	Plant height at harvest	Days from transplanting to first flowering	Number of flower cluster per plant	Number of fruits per cluster
Nitrogen				
N_0	112.23 c	35.94 a	7.66 c	2.82 b
N_1	119.91 b	33.77 b	9.75 b	2.93 ab
N_2	126.92 a	31.46 d	12.20 a	3.09a
N_3	126.60 a	32.68 c	12.32 a	3.05 a
$LSD_{(0.05)}$	3.903	0.985	0.572	0.185
Phosphorous				
P_0	117.17 b	35.12 a	8.24 d	2.78 c
P_1	122.64 a	32.54 b	10.43 c	2.95 bc
P_2	123.55 a	31.88 b	12.03 a	3.02 ab
P_3	122.32 a	34.32 a	11.23 b	3.15 a
$LSD_{(0.05)}$	3.903	0.985	0.572	0.185

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 160 kg N/ha
N_3: 240 kg N/ha

P_0: 0 kg P_2O_5/ha
P_1: 25 kg P_2O_5/ha
P_2: 50 kg P_2O_5/ha
P_3: 75 kg P_2O_5/ha

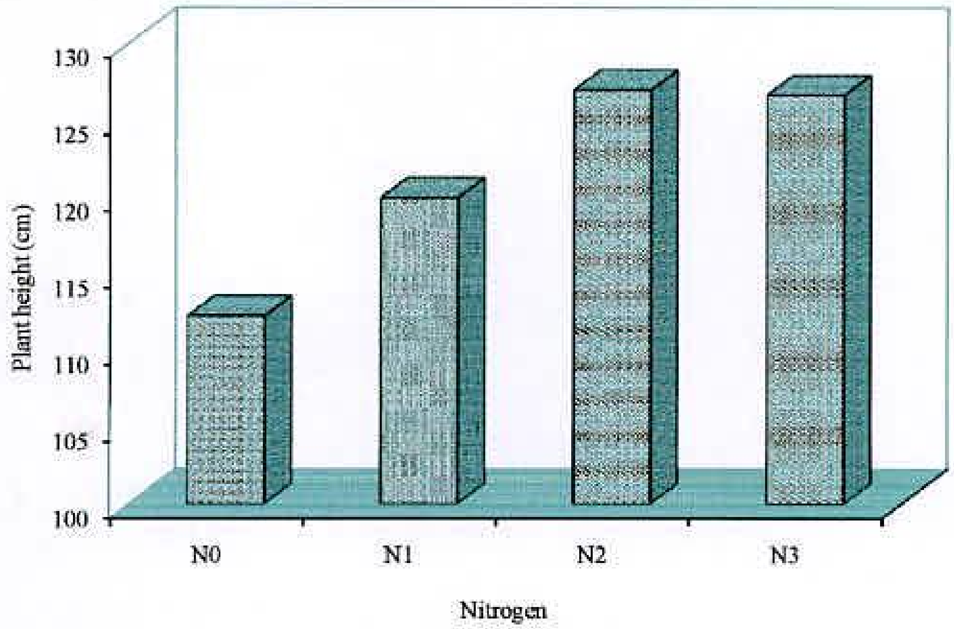


Figure 2. Effect of nitrogen on plant height of tomato

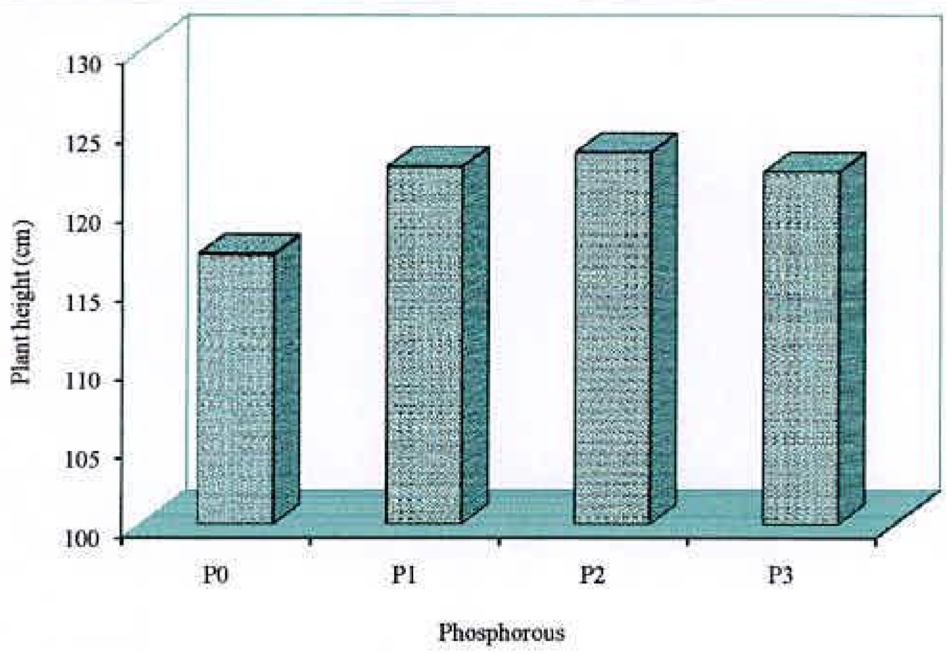


Figure 3. Effect of phosphorous on plant height of tomato

Different level of phosphorous showed statistically significant differences for plant height (Appendix II). The maximum plant height (123.55 cm) was recorded from P_2 treatment comprising of 50 kg P_2O_5/ha which was statistically identical (122.64 cm and 122.32 cm) with P_1 treatment as of 25 kg P_2O_5/ha and P_3 treatment as 75 kg P_2O_5/ha (Table 3), while the minimum plant height (117.17 cm) was recorded from P_0 treatment i.e. control condition under the present trial. With increasing level of phosphorous plant height also increases but the differences was not significant at highest level. Melton and Dufault (1991) reported that plant height was increased significantly as the level of phosphorous increased. Gupta and Shukla (1977) also reported that phosphorous application increased the plant height up to 60 kg P_2O_5/ha.

Interaction effect was also recorded between nitrogen and phosphorous in consideration of plant height under the present experiment and found statistically significant variation (Appendix II). The maximum plant height (135.17 cm) was recorded from treatment combination N_2P_3 as 160 kg N/ha + 75 kg P_2O_5/ha, while the minimum plant height (112.20 cm) was recorded from treatment combination N_0P_0 i.e. without any nitrogen and phosphorous (Table 4). These results revealed that higher dose of nitrogen and phosphorous increased the plant height.

4.1.2 Days from transplanting to first flowering

The effect of different levels of nitrogen on the days required for starting flowering varied significantly (Appendix II). The minimum required days from transplanting to first flowering (31.46 days) was recorded from N_2 treatment which was closely followed (32.68 days) by N_3 treatment (Table 3) and the maximum required days from transplanting to first flowering (35.94 days) was recorded from N_0 treatment which was closely (33.77 days) followed by N_1 treatment. Probably all micro and macro nutrients for 160 kg N/ha and ensured the favorable condition for growth of tomato plant and the ultimate results is the early flowering.

Table 4. Interaction effect of nitrogen and phosphorous on plant height, days from transplanting to first flowering, number of flower cluster per plant and number of fruits per cluster of tomato

Treatment combination	Plant height at harvest	Days from transplanting to first flowering	Number of flower cluster per plant	Number of fruits per cluster
N_0P_0	112.20 ef	37.20 ab	6.67 e	2.73 e
N_0P_1	115.01 def	33.60 cdef	7.57 de	2.83 cde
N_0P_2	112.12 ef	35.50 abc	8.07 d	2.83 cde
N_0P_3	109.60 f	37.47 a	8.33 d	2.87 cde
N_1P_0	121.89 bcd	34.73 cd	7.53 de	2.77 de
N_1P_1	120.90 bcde	33.20 defg	8.23 d	2.87 cde
N_1P_2	121.88 bcd	31.93 fgh	11.33 bc	2.87 cde
N_1P_3	114.99 def	35.20 bcd	11.90 b	3.23 abc
N_2P_0	114.18 def	34.40 cde	8.33 d	2.77 de
N_2P_1	127.28 abc	30.10 hi	12.17 b	2.90 bcde
N_2P_2	131.05 a	28.87 i	14.57 a	3.50 a
N_2P_3	135.17 a	32.47 efg	13.73 a	3.20 abcd
N_3P_0	120.40 cde	34.13 cdef	10.43 c	2.83 cde
N_3P_1	127.35 abc	33.27 cdefg	13.73 a	3.20 abcd
N_3P_2	129.15 abc	31.20 gh	14.17 a	2.87 cde
N_3P_3	129.52 ab	32.13 fgh	10.93 bc	3.30 ab
$LSD_{(0.05)}$	7.807	1.970	1.143	0.369
CV(kg/ha)	8.86	9.53	6.54	7.47

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

N_0: 0 kg N/ha	P_0: 0 kg P_2O_5/ha
N_1: 80 kg N/ha	P_1: 25 kg P_2O_5/ha
N_2: 160 kg N/ha	P_2: 50 kg P_2O_5/ha
N_3: 240 kg N/ha	P_3: 75 kg P_2O_5/ha

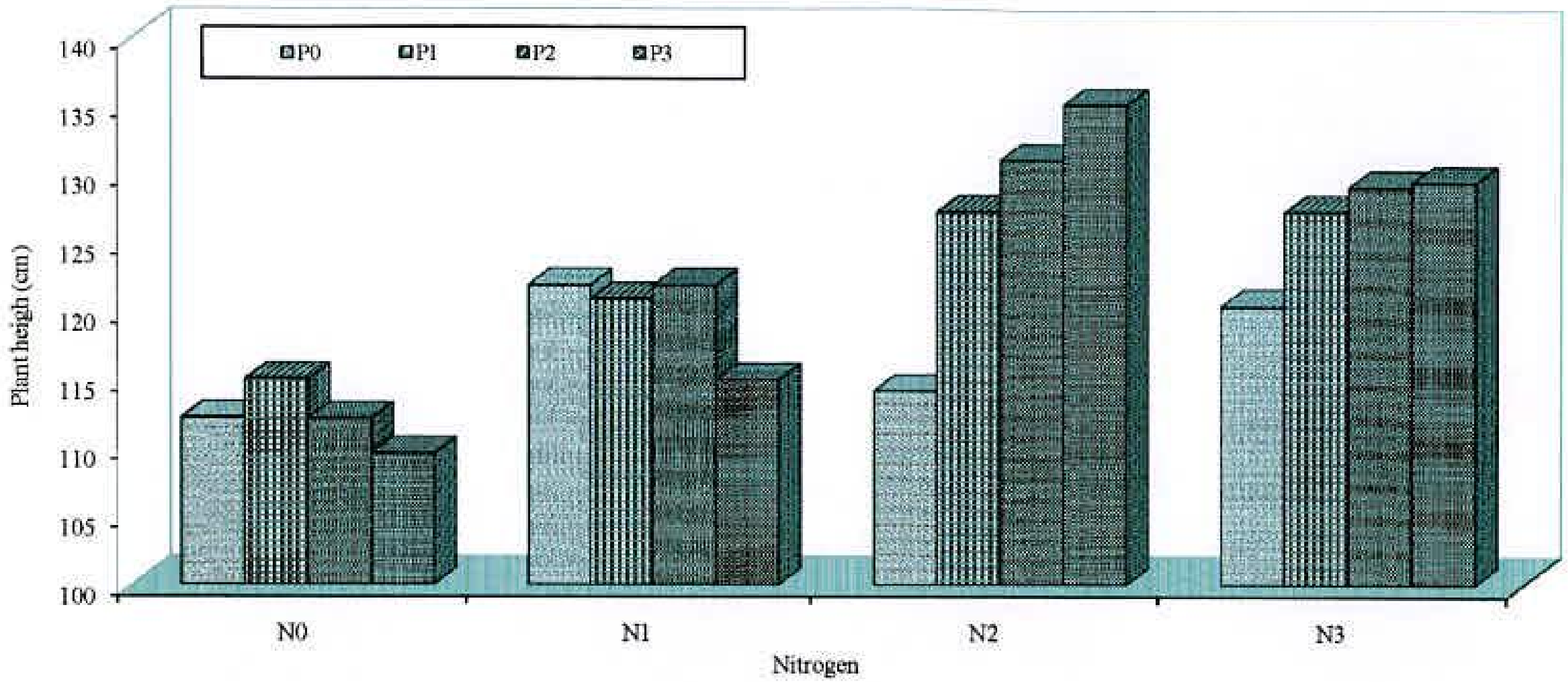


Figure 4. Interaction effect of nitrogen and phosphorous on plant height of tomato

Different level of phosphorous showed statistically significant differences for days from transplanting to first flowering (Appendix II). The minimum required days from transplanting to first flowering (31.88 days) from was recorded from P_2 treatment which was statistically identical (32.54 days) with P_1 treatment (Table 3). On the other hand the maximum (35.12 days) transplanting to first flowering was recorded from P_0 treatment.

Interaction effect was also recorded between nitrogen and phosphorous in consideration of days required from transplanting to first flowering under the present experiment and found statistically significant variation (Appendix II). The minimum required days from transplanting to first flowering (28.87 days) was recorded from treatment combination N_2P_2, while the maximum (37.20 days) was recorded from treatment combination N_0P_0 (Table 4).

4.1.3 Number of flower cluster per plant

Number of flower cluster per plant varied significantly due to the application of nitrogen in tomato (Appendix II). The maximum number of flower cluster (12.32) per plant was recorded N_3 treatment which was statistically similar (12.20) with N_2 (Table 3) and the minimum (7.66) was recorded under N_0 treatment which was closely (9.75) followed by N_1 treatment. Application of 240 kg N/ha ensured the favorable condition for growth of tomato plant and the ultimate results is the maximum number of flower cluster per plant. Grela *et al.* (1988) put forward almost similar opinion.

The effect of different levels of phosphorous on the number of flower cluster per plant varied significantly (Appendix II). The maximum number of flower cluster (12.03) per plant was recorded from P_2 treatment which was closely (11.23) followed by P_3 treatment (Table 3). On the other hand the minimum number of flower cluster (8.24) per plant was recorded from P_0 treatment under the present trial. With increasing level of phosphorous, plant growth increases and the number of flower cluster per plant also increases.

Interaction effect was also recorded between nitrogen and phosphorous in consideration of number of flower cluster per plant under the present experiment and found statistically significant variation (Appendix II). The maximum number of flower cluster (14.57) per plant was recorded from treatment combination N_2P_2. On the other hand the minimum number of flower cluster (6.67) per plant was recorded from treatment combination N_0P_0 (Table 4). These results revealed that combined higher dose of nitrogen and phosphorous is essential for attaining better growth and the ultimate results was the highest number of flower cluster per plant.

4.1.4 Number of fruits per cluster

Number of fruits per cluster varied significantly due to the application of different levels of nitrogen in tomato under the present experiment (Appendix II). The maximum number of fruits (3.09) per cluster was recorded from N_2 application which was statistically identical (3.05) with N_3 treatment (Table 3) and the minimum number of fruits (2.82) per cluster was recorded from N_0 treatment which was statistically identical (2.93) with N_1 treatment. This is an agreement with Chung *et al.* (1992), as they found that fruit set per cluster was increased with increasing nitrogen application rate.

Different levels of phosphorous showed statistically significant differences for number of fruits per cluster (Appendix II). The maximum number of fruits (3.15) per cluster was recorded from P_3 which was closely (3.02) followed by P_2 treatment (Table 3). On the other hand the minimum number of fruits (2.78) per cluster was recorded from P_0 treatment which was statistically identical (2.95) with P_1 treatment under the present trial. With increasing level of phosphorous plant growth increases and the number of fruits per cluster also increases but the differences for different level also statistically significant. Melton and Dufault (1991) reported that plant height was increased significantly as phosphorous increased. Gupta and Shukla (1977) also reported that phosphorous application increased the plant height up to 60 kg P_2O_5/ha application.

Interaction effect was also recorded between nitrogen and phosphorous in consideration of number of fruits per cluster under the present experiment and found statistically significant variation (Appendix II). The maximum number of fruits (3.50) per cluster was recorded from treatment combination N_2P_2. On the other hand the minimum number of fruits per (2.73) cluster was recorded from treatment combination N_0P_0 (Table 4). These results revealed that higher dose of nitrogen and phosphorous is influential nutrient for attaining better growth and the ultimate results the highest number of fruits per cluster.

4.1.5 Number of fruits per plant

Number of fruits per plant varied significantly due to the application of nitrogen in tomato under the present experiment (Appendix III). The maximum number of fruits (38.28) per plant was recorded from N_2 treatment which was statistically similar (37.69) with N_3 treatment (Table 5) and the minimum number of fruits (21.57) per plant was recorded from N_0 treatment which was statistically identical (28.87) with N_1 treatment. Nassar (1988) found that increased nitrogen level was tended to increase average number of fruit clusters per plant.

Different level of phosphorous showed statistically significant differences for number of fruits per plant (Appendix III). The maximum number of fruits (36.83) per plant was recorded from P_2 treatment which was statistically similar (35.59) with P_3 treatment (Table 5). On the other hand the minimum number of fruits (22.91) per plant was recorded from P_0 treatment which was closely (31.08) followed by P_1 treatment under the present experiment. With increasing levels of phosphorous plant growth increases and which ensure maximum number of flower and fruit per cluster as well as the number of fruits per plant.

Table 5. Effect of nitrogen and phosphorous on number and weight of fruits per plant and yield of tomato

Treatment	Number of fruits per plant	Weight of fruits per plant (kg)	Yield (kg/plot)	Yield (t/ha)
Nitrogen				
N_0	21.57 c	1.13 d	11.32 d	32.60 d
N_1	28.87 b	1.44 c	14.37 c	41.39 c
N_2	38.28 a	2.09 b	20.92 b	60.25 b
N_3	37.69 a	2.20 a	22.01 a	63.39 a
$LSD_{(0.05)}$	3.271	0.065	0.641	1.846
Phosphorous				
P_0	22.91 c	1.53 c	15.27 c	43.98 c
P_1	31.08 b	1.62 b	16.24 b	46.77 b
P_2	36.83 a	1.85 a	18.48 a	53.23 a
P_3	35.59 a	1.86 a	18.63 a	53.65 a
$LSD_{(0.05)}$	3.271	0.065	0.641	1.846

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 160 kg N/ha
N_3: 240 kg N/ha

P_0: 0 kg P_2O_5/ha
P_1: 25 kg P_2O_5/ha
P_2: 50 kg P_2O_5/ha
P_3: 75 kg P_2O_5/ha

Interaction effect was also recorded between nitrogen and phosphorous in consideration of number of fruits per plant under the present experiment and found statistically significant variation (Appendix III). The maximum number of fruits (50.84)per plant was recorded from treatment combination N_2P_2. On the other hand the minimum number of fruits (18.23) per plant was recorded from treatment combination N_0P_0 (Table 6). These results revealed that combined higher dose of nitrogen and phosphorous is required for attaining better growth and the ultimate results was desirable growth with maximum number of flower and fruit per cluster and highest number of fruits per plant.

4.1.6 Weight of fruits per plant

Weight of fruits per plant varied significantly due to the application of different levels of nitrogen in tomato under the present experiment (Appendix III). The maximum weight of fruits (2.20 kg) per plant was recorded from N_3 treatment which was closely (2.09 kg) followed by N_2 treatment (Table 5) and the minimum weight of fruits (1.13 kg) per plant was recorded from N_0 treatment which was closely (1.44 kg) followed by N_1 treatment. Chung *et al*. (1992) reported that increasing levels of nitrogen increased the fresh weight of tomato fruit.

Different level of phosphorous showed statistically significant differences for weight of fruits per plant (Appendix III). The maximum weight of fruits (1.86 kg) per plant was recorded from P_3 treatment which was statistically similar (1.85 kg) with P_2 treatment (Table 5). On the other hand the minimum weight of fruits (1.53 kg) per plant was recorded from P_0 treatment which was closely (1.62 kg) followed by P_1 treatment under the present experiment. With increasing of level phosphorous plant growth increases and which ensure maximum number of flower and fruit per cluster as well as the weight of fruits.

Table 6. Interaction effect of nitrogen and phosphorous on number and weight of fruits per plant and yield of tomato

Treatment combination	Number of fruits per plant	Weight of fruits per plant (kg)	Yield (kg/plot)	Yield (t/ha)
N_0P_0	18.23 g	1.03 g	10.29 g	29.64 g
N_0P_1	21.47 g	1.04 g	10.38 g	29.88 g
N_0P_2	22.82 fg	1.21 f	12.13 f	34.93 f
N_0P_3	23.75 fg	1.25 ef	12.48 ef	35.94 ef
N_1P_0	20.82 g	1.36 e	13.57 e	39.07 e
N_1P_1	23.60 fg	1.20 f	12.04 f	34.67 f
N_1P_2	32.48 de	1.61 d	16.05 d	46.23 d
N_1P_3	38.57 bcd	1.58 d	15.8 3 d	45.59 d
N_2P_0	23.07 fg	1.70 d	17.03 d	49.05 d
N_2P_1	35.28 cde	2.05 c	20.51 c	59.06 c
N_2P_2	50.84 a	2.24 ab	22.41 ab	64.55 ab
N_2P_3	43.95 b	2.37 a	23.73 a	68.35 a
N_3P_0	29.54 ef	2.02 c	20.19 c	58.16 c
N_3P_1	43.95 b	2.20 b	22.04 b	63.46 b
N_3P_2	41.20 bc	2.33 ab	23.34 ab	67.22 ab
N_3P_3	36.08 cde	2.25 ab	22.48 ab	64.73 ab
$LSD_{(0.05)}$	6.542	0.129	1.282	3.692
CV(kg/ha)	12.41	6.48	7.22	7.22

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 160 kg N/ha
N_3: 240 kg N/ha

P_0: 0 kg P_2O_5/ha
P_1: 25 kg P_2O_5/ha
P_2: 50 kg P_2O_5/ha
P_3: 75 kg P_2O_5/ha

Interaction effect was also recorded between nitrogen and phosphorous in consideration of weight of fruits per plant under the present experiment and found statistically significant variation (Appendix III). The maximum weight of fruits (2.37 kg) per plant was recorded from treatment combination N_2P_3. On the other hand the minimum weight of fruits (1.03 kg) per plant was recorded from treatment combination N_0P_0 (Table 6). These results revealed that higher dose of nitrogen and phosphorous is influential nutrient for attaining better growth and the ultimate results was desirable growth with maximum number of flower and fruit per cluster and highest weight of fruits per plant.

4.1.7 Yield per plot

Yield per plot varied significantly due to the application of nitrogen in tomato under the present experiment (Appendix III). The maximum yield (22.01 kg) per plot was recorded from N_3 treatment which was closely (20.92 kg) followed by N_2 treatment (Table 5) and the minimum yield (11.32 kg) per plot was recorded from N_0 treatment which was closely (14.37 kg) followed by N_1 treatment. Nassar (1988) found that high nitrogen level was tended to increase average number of fruit clusters per plant and also yield per plot.

Different level of phosphorous showed statistically significant differences for yield per plot per plant (Appendix III). The maximum yield (18.63 kg) per plot was recorded from P_3 treatment which was statistically similar (18.48 kg) with P_2 treatment (Table 5). On the other hand the minimum yield (15.27 kg) per plot was recorded from P_0 treatment which was closely (16.24 kg) followed by P_1 treatment under the present experiment.

Interaction effect was also recorded between nitrogen and phosphorous in consideration of yield per plot and found statistically significant variation (Appendix III). The maximum yield (23.73 kg) per plot was recorded from treatment combination N_2P_3. On the other hand the minimum yield (10.29 kg) per plot was recorded from treatment combination N_0P_0 (Table 6).

4.1.8 Yield per hectare

Yield per hectare varied significantly due to the application of nitrogen in tomato under the present experiment (Appendix III). The maximum yield (63.39 tonnes) per hectare was recorded from N_3 treatment which was closely (60.25 tonnes) followed by N_2 treatment (Table 5) and the minimum yield (32.60 tonnes) per hectare was recorded from N_0 treatment which was closely (41.39 tonnes) followed by N_1 treatment. Cheng *et al.* (1992) reported that increasing levels of nitrogen increased the fresh weight of tomato fruit and the ultimate result is the highest yield per hectare of tomato.

Different level of phosphorous showed statistically significant differences for yield per hectare per plant (Appendix III). The maximum yield (53.65 tonnes) per hectare was recorded from P_3 treatment which was statistically similar (53.23 tonnes) with P_2 treatment (Table 5). On the other hand the minimum yield (43.98 tonnes) per hectare was recorded from P_0 treatment which was closely (46.77 tonnes) followed by P_1 treatment under the present experiment. With increasing level of phosphorous plant growth increases and which ensure maximum number of flower, fruit per cluster weight of fruits per plant as well as the yield per hectare. Melton and Dufault (1991) reported that yield per hectare was increased significantly as phosphorous increased. Gupta and Shukla (1977) also reported that phosphorous application increased the yield up to 60 kg P_2O_5/ha.

Interaction effect was also recorded between nitrogen and phosphorous in consideration of yield per hectare under the present experiment and found statistically significant variation (Appendix III). The maximum yield (68.35 tonnes) per hectare was recorded from treatment combination N_2P_3. On the other hand the minimum yield (29.64 tonnes) per hectare was recorded from treatment combination N_0P_0 (Table 6).

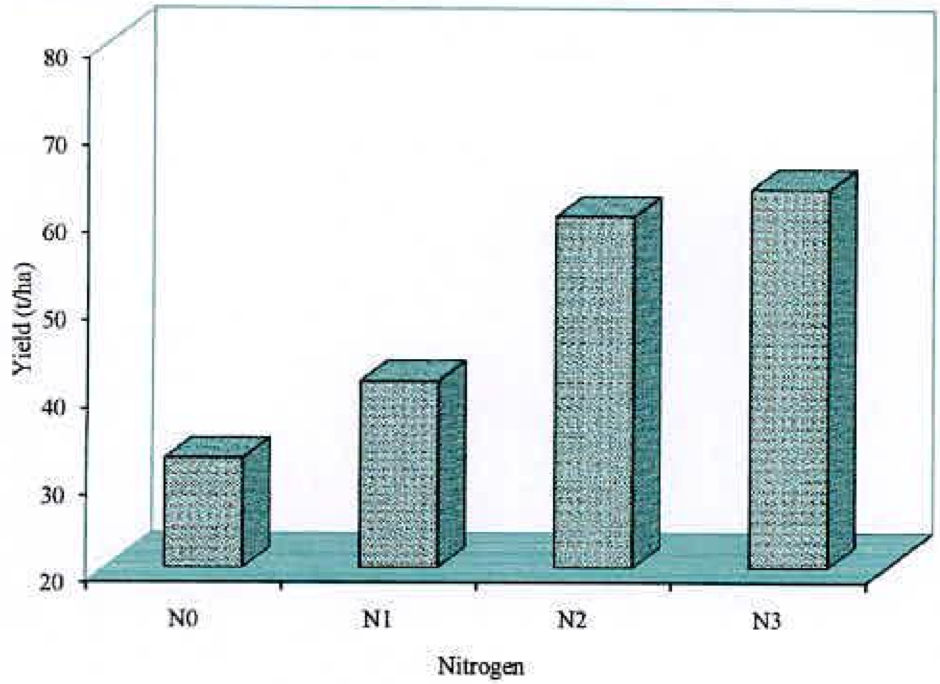


Figure 5. Effect of nitrogen on yield of tomato

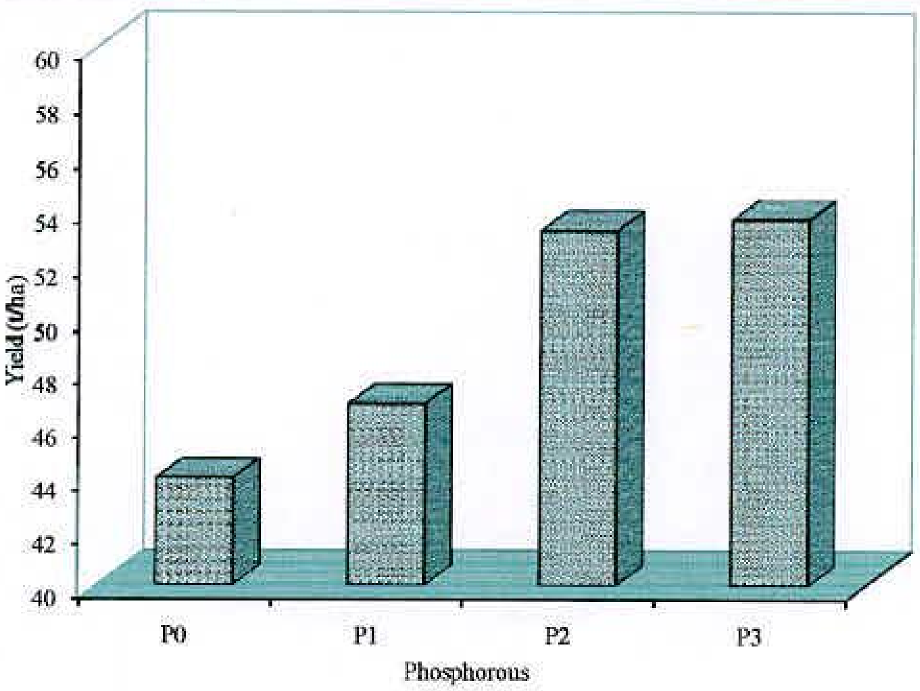


Figure 6. Effect of phosphorous on yield of tomato

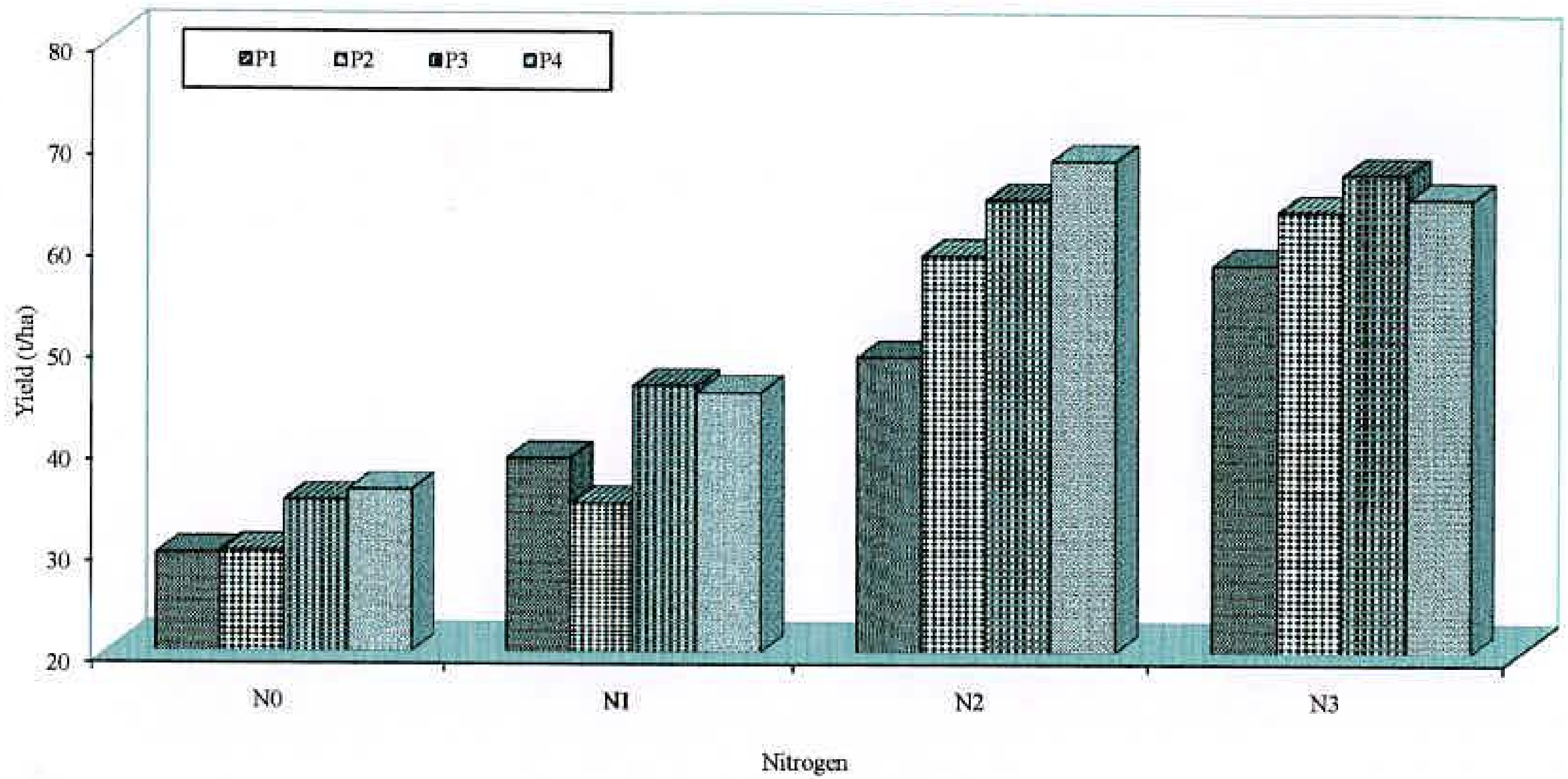


Figure 7. Effect of nitrogen and phosphorous on yield of tomato

4.2 Nutrient content in shoot

Nutrient such as nitrogen and phosphorous content in shoot was estimated for different level of nitrogen and phosphorous application and also their different combination.

4.2.1 Nitrogen (N)

Effect different level of nitrogen showed a statistically significant variation for nitrogen content in shoot of tomato under the present trial (Appendix IV). The highest nitrogen content (1.88%) in shoot was recorded from N_3 treatment which was closely (1.45%) followed by N_2 treatment and the lowest nitrogen content (0.82%) was recorded from N_0 treatment which was closely (1.08%) followed by N_1 treatment (Table 7). Highest application of nitrogen accelerated nitrogen uptake by plant and the ultimately results is the highest nitrogen content in tomato shoot.

Different level of phosphorous showed statistically significant differences for nitrogen content in tomato shoot (Appendix IV). The highest nitrogen content (1.44%) of shoot was recorded from P_3 treatment which was closely (1.32%) followed by P_2 treatment (Table 7). On the other hand the lowest nitrogen content (1.20%) in shoot was recorded from the P_0 treatment which closely followed (1.28%) with P_1.

Significant interaction effect was also recorded between nitrogen and phosphorous for nitrogen content in shoot under the present trial (Appendix IV). The highest nitrogen content (2.02%) in shoot was recorded from treatment combination N_3P_3 as 240 kg N/ha + 75 kg P_2O_5/ha and the lowest (0.80%) was recorded from treatment combination N_0P_1 i.e. no nitrogen + 25 kg P_2O_5/ha (Table 8).

Table 7. Effect of nitrogen and phosphorous on nitrogen and phosphorous content in shoot of tomato

Treatment	Content in shoot (%)	
	N	P
Nitrogen		
N_0	0.82 d	0.209 d
N_1	1.08 c	0.261 c
N_2	1.45 b	0.496 b
N_3	1.88 a	0.553 a
$LSD_{(0.05)}$	0.0495	0.039
Phosphorous		
P_0	1.20 c	0.338 c
P_1	1.28 b	0.369 bc
P_2	1.32 b	0.392 ab
P_3	1.44 a	0.420 a
$LSD_{(0.05)}$	0.049	0.039

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 160 kg N/ha
N_3: 240 kg N/ha

P_0: 0 kg P_2O_5/ha
P_1: 25 kg P_2O_5/ha
P_2: 50 kg P_2O_5/ha
P_3: 75 kg P_2O_5/ha

Table 8. Interaction effect of nitrogen and phosphorous on nitrogen and phosphorous content in shoot of tomato

Treatment	Content in shoot (%)	
	N	P
N_0P_0	0.89 i	0.184 e
N_0P_1	0.80 ij	0.229 e
N_0P_2	0.76 j	0.248 de
N_0P_3	0.85 ij	0.174 e
N_1P_0	0.81 ij	0.254 de
N_1P_1	1.08 h	0.217 e
N_1P_2	1.16 gh	0.253 de
N_1P_3	1.25 fg	0.319 cd
N_2P_0	1.27 f	0.358 c
N_2P_1	1.40 e	0.477 b
N_2P_2	1.50 d	0.551 ab
N_2P_3	1.65 c	0.599 a
N_3P_0	1.81 b	0.557 ab
N_3P_1	1.83 b	0.551 ab
N_3P_2	1.85 b	0.518 ab
N_3P_3	2.02 a	0.586 a
$LSD_{(0.05)}$	0.099	0.079
CV(ppm/%)	4.54	12.61

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

N_0: 0 kg N/ha	P_0: 0 kg P_2O_5/ha
N_1: 80 kg N/ha	P_1: 25 kg P_2O_5/ha
N_2: 160 kg N/ha	P_2: 50 kg P_2O_5/ha
N_3: 240 kg N/ha	P_3: 75 kg P_2O_5/ha

4.2.2 Phosphorous (P)

Effect of nitrogen showed a statistically significant variation for phosphorous content in shoot of tomato under the present trial (Appendix IV). The highest phosphorous content (0.553%) in shoot was recorded from N_3 treatment which was closely followed (0.496%) by N_2 treatment and the lowest phosphorous content (0.209%) was recorded from N_0 treatment which was closely (0.261%) followed by N_1 treatment (Table 7). Highest application of nitrogen accelerated phosphorous uptake by plant and the ultimately results is the highest phosphorous content in tomato shoot.

Different level of phosphorous showed statistically significant differences for phosphorous content in tomato shoot (Appendix IV). The highest phosphorous content (0.420%) of shoot was recorded from P_3 treatment which was statistically similar (0.392%) with P_2 treatment (Table 7). On the other hand the lowest phosphorous content (0.338%) in shoot was recorded from the P_0 treatment which closely followed (0.369%) with P_1.

Significant interaction effect was also recorded between nitrogen and phosphorous for phosphorous content in shoot under the present trial (Appendix IV). The highest phosphorous content (0.599%) in shoot was recorded from treatment combination N_2P_3 as 160 kg N/ha + 75 kg P_2O_5/ha and the lowest (0.174%) was recorded from treatment combination N_0P_3 (Table 8).

4.3 Nutrient content in post harvest soil

Available nutrient such as nitrogen, phosphorous, and sulphur, in soil was estimated for different level of nitrogen and phosphorous application and also their different combination in the present experiment.

4.3.1 Nitrogen (N)

Different level of nitrogen showed a significant variation for total nitrogen in soil under the present trial (Appendix V). The maximum total nitrogen (0.10%) was recorded from N_0 and the minimum total nitrogen (0.09%) in soil was recorded from N_1, N_2 and N_3 treatment (Table 9).

Application of different level of phosphorous showed statistically significant differences for total nitrogen in soil (Appendix V). The) total nitrogen in soil (0.09%) was recorded from all level of phosphorous (Table 9).

Significant interaction effect was also observed between nitrogen and phosphorous for total nitrogen in soil under the present trial (Appendix V). The maximum total nitrogen (0.09%) in soil was recorded from the treatment combination of N_0P_0 and the minimum total soil nitrogen (0.08%) was recorded from N_3P_3 treatment combination (Table 10).

4.3.3 Available phosphorous (P)

Different level of nitrogen showed a significant variation for available phosphorous in soil under the present trial (Appendix V). The maximum available phosphorous (42.80 ppm) was recorded from N_3 treatment which was closely followed (42.57 ppm) with N_2 treatment and the minimum available phosphorous (39.97 ppm) in soil was recorded from N_0 treatment which was closely followed (40.13 ppm) with N_1 treatment (Table 9).

Table 9. Effect of nitrogen and phosphorous on nitrogen, phosphorous and sulphur available in post harvest soil of tomato

Treatment	Nutrient present in post harvest soil		
	Total N (%)	Available P (ppm)	Available S (ppm)
Nitrogen			
N_0	0.10 a	39.97 d	14.50 a
N_1	0.09 b	40.13 c	14.51 a
N_2	0.09 b	42.57 b	12.26 b
N_3	0.08 b	42.80 a	15.62 a
$LSD_{(0.05)}$	0.008	0.124	1.514
Phosphorous			
P_0	0.09	40.64 c	13.92 b
P_1	0.09	41.17 b	13.31 b
P_2	0.09	41.28 b	13.98 b
P_3	0.09	42.37 a	15.68 a
$LSD_{(0.05)}$	--	0.124	1.514

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 160 kg N/ha
N_3: 240 kg N/ha

P_0: 0 kg P_2O_5/ha
P_1: 25 kg P_2O_5/ha
P_2: 50 kg P_2O_5/ha
P_3: 75 kg P_2O_5/ha

Table 10. Interaction effect of nitrogen and phosphorous on nitrogen, phosphorous, potassium and sulphur uptake by plant and available in post harvest soil of tomato

Treatment combination	Nutrient present in post harvest soil		
	Total N (%)	Available P (ppm)	Available S (ppm)
N_0P_0	0.10 a	39.60 h	13.59 cde
N_0P_1	0.10 ab	39.91 g	13.47 cde
N_0P_2	0.10 abc	40.00 fg	15.13 bcd
N_0P_3	0.09 abcd	40.38 d	15.80 bc
N_1P_0	0.09 bcd	40.05 efg	17.13 b
N_1P_1	0.09 abcd	39.96 g	14.51 bcde
N_1P_2	0.09 abcd	40.28 de	14.26 cde
N_1P_3	0.09 abcd	40.25 def	12.13 de
N_2P_0	0.09 abcd	40.10 efg	11.48 e
N_2P_1	0.09 bcd	42.05 c	11.29 e
N_2P_2	0.09 abcd	42.14 c	12.47 cde
N_2P_3	0.08 cd	45.98 a	13.80 bcde
N_3P_0	0.08 bcd	42.82 b	13.47 cde
N_3P_1	0.08 bcd	42.77 b	13.97 bcde
N_3P_2	0.08 cd	42.73 b	14.08 bcde
N_3P_3	0.08 d	42.86 b	20.98 a
$LSD_{(0.05)}$	0.017	0.247	3.029
CV(%)	3.99	5.36	12.77

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 160 kg N/ha
N_3: 240 kg N/ha

P_0: 0 kg P_2O_5/ha
P_1: 25 kg P_2O_5/ha
P_2: 50 kg P_2O_5/ha
P_3: 75 kg P_2O_5/ha

Application of different level of phosphorous showed statistically significant differences for available phosphorous in soil (Appendix V). The maximum available phosphorous (42.37 ppm) in soil was recorded from P_3 treatment, while the minimum available phosphorous (40.64 ppm) in soil was recorded from the P_0 treatment under the present trial (Table 9).

Significant interaction effect was also observed between nitrogen and phosphorous for available phosphorous in soil under the present trial (Appendix V). The maximum available phosphorous (45.98 ppm) in soil was recorded from the treatment combination N_2P_3 and the minimum available soil phosphorous (39.60 ppm) was recorded from treatment combination N_0P_0 (Table 10).

4.3.3 Available sulphur (S)

Different level of nitrogen showed a significant variation for available sulphur in soil under the present trial (Appendix V). The maximum available sulphur (15.62 ppm) was recorded from N_3 treatment which was statistically similar (14.51 ppm) with N_1 treatment and the minimum available sulphur (12.26 ppm) in soil was recorded from N_2 treatment which was statistically similar (14.50 ppm) with N_1 treatment (Table 9).

Application of different level of phosphorous showed statistically significant differences for available sulphur in soil (Appendix V). The maximum available sulphur (15.68 ppm) in soil was recorded from P_3 treatment, while the minimum available sulphur (13.31 ppm) in soil was recorded from the P_1 treatment under the present trial (Table 9).

Significant interaction effect was also observed between nitrogen and phosphorous for available sulphur in soil under the present trial (Appendix V). The maximum available sulphur (20.98 ppm) in soil was recorded from the treatment combination N_0P_0 and the minimum available soil sulphur (13.47 ppm) was recorded from treatment combination N_0P_1 (Table 10).

Chapter 5

Summary & conclusion

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur, Bangladesh during the period from November 2006 to March 2007 to find out the effect of nitrogen and phosphorous on the growth and yield of tomato. The seedlings of tomato variety Lalima were collected from the BARI farm of BARI field and seedlings were 30 days old. The experiment considered of two factors as Factor A (Four levels of nitrogen): N_0: 0 kg N/ha; N_1: 80 kg N/ha; N_2:160 kg N/ha and N_3: 240 kg N/ha, Factor B (Four levels of phosphorous): P_1: 0 kg P_2O_5/ha; P_2 : 25 kg P_2O_5/ha; P_3: 50 kg P_2O_5/ha and P_3: 75 kg P_2O_5/ha. There were 16 (4 × 4) treatment combinations. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on yield contributing characters and yield of tomato and nitrogen and phosphorous uptake by plant and their availability on soil.

The maximum plant height (126.92 cm) was recorded from N_2 treatment consisting of 160 kg N/ha and the minimum plant height (112.23 cm) was recorded from N_0 treatment i.e. control condition. The minimum required days from transplanting to first flowering (31.46 days) was recorded from N_2 treatment and the maximum required days from transplanting to first flowering (35.94 days) was recorded from N_0 treatment. The maximum number of flower cluster (12.32) per plant was recorded N_3 treatment and the minimum (7.66) was recorded under N_0 treatment. The maximum number of fruits (3.09) per cluster was recorded from N_2 application and the minimum number of fruits (2.82) per cluster was recorded from N_0 treatment. The maximum number of fruits (38.28) per plant was recorded from N_2 treatment and the minimum number of fruits (21.57) per plant was recorded from N_0 treatment. The maximum weight of fruits (2.20 kg) per plant was recorded from N_3 treatment and the minimum weight of fruits (1.13 kg) per plant was recorded from N_0 treatment. The maximum yield (18.63 kg) per plot was recorded from P_3 treatment and the minimum yield (15.27 kg) per plot was recorded from P_0 treatment. The maximum yield (63.39 tonnes) per hectare was recorded from N_3 treatment and the minimum yield (32.60 tonnes) per hectare was recorded from N_0 treatment. The highest nitrogen content (1.88%) in shoot was recorded from N_3 treatment and the lowest nitrogen content (0.82%) was recorded from N_0 treatment. The highest phosphorous content (0.553%) in shoot was recorded from N_3 treatment and the lowest phosphorous content (0.209%) was recorded from N_0 treatment. The maximum total nitrogen (0.10%) was recorded from N_0 and the minimum total nitrogen (0.09 kg/ha) in soil was recorded from N_1, N_2 and N_3 treatment. The maximum total phosphorous (42.80 ppm) was recorded from N_3 treatment and the minimum total phosphorous (39.97 ppm) in soil was recorded from N_0 treatment.

The maximum plant height (123.55 cm) was recorded from P_2 treatment comprising of 50 kg P_2O_5/ha, while the minimum plant height (117.17 cm) was recorded from P_0 treatment. The minimum required days from transplanting to first flowering (31.88 days) from was recorded from P_2 treatment and the maximum (35.12 days) transplanting to first flowering was recorded from P_0 treatment. The maximum number of flower cluster (12.03) per plant was recorded from P_2 treatment and the minimum number of flower cluster (8.24) per plant was recorded from P_0 treatment. The maximum number of fruits (3.15) per cluster was recorded from P_3 and the minimum number of fruits (2.78) per cluster was recorded from P_0 treatment. The maximum number of fruits (36.83) per plant was recorded from P_2 treatment and the minimum number of fruits (22.91) per plant was recorded from P_0 treatment. The maximum weight of fruits (1.86 kg) per plant was recorded from P_3 treatment and the minimum weight of fruits (1.53 kg) per plant was recorded from P_0. The maximum yield (18.63 kg) per plot was recorded from P_3 treatment and the minimum yield (15.27 kg) per plot was recorded from P_0 treatment. The maximum yield (53.65 t/ha) per hectare was recorded from P_3 treatment and the minimum yield (43.98 t/ha) per hectare was recorded from P_0 treatment. The highest nitrogen content (1.44%) of shoot was recorded from P_3 treatment and the lowest nitrogen content (1.20%) in shoot was recorded from the P_0 treatment. The highest phosphorous content (0.420%) of shoot was recorded from P_3 treatment and the lowest phosphorous content (0.338%) in shoot was recorded from the P_0 treatment. The total nitrogen in soil (0.09%) was recorded from all level of phosphorous. The maximum total phosphorous (42.37 ppm) in soil was recorded from P_3 treatment, while the minimum total phosphorous (40.64 ppm) in soil was recorded from the P_0 treatment.

The maximum plant height (135.17 cm) was recorded from treatment combination N_2P_3 as 160 kg N/ha + 75 kg P_2O_5/ha, while the minimum plant height (112.20 cm) was recorded from treatment combination N_0P_0. The minimum required days from transplanting to first flowering (28.87 days) was recorded from treatment combination N_2P_2, while the maximum (37.20 days) was recorded from treatment combination N_0P_0. The maximum number of flower cluster (14.57) per plant was recorded from treatment combination N_2P_2 and the minimum number of flower cluster (6.67) per plant was recorded from treatment combination N_0P_0. The maximum number of fruits (3.50) per cluster was recorded from treatment combination N_2P_2 and the minimum number of fruits per (2.73) cluster was recorded from treatment combination N_0P_0. The maximum number of fruits (50.84) per plant was recorded from treatment combination N_2P_2 and the minimum number of fruits (18.23) per plant was recorded from treatment combination N_0P_0. The maximum weight of fruits (2.37 kg) per plant was recorded from treatment combination N_2P_3, while the minimum weight of fruits (1.03 kg) per plant was recorded from treatment combination N_0P_0. The maximum yield (23.73 kg) per plot was recorded from treatment combination N_2P_3. On the other hand the minimum yield (10.29 kg) per plot was recorded from treatment combination N_0P_0. The maximum yield (68.35 tonnes) per hectare was recorded from treatment combination N_2P_3. On the other hand the minimum yield (29.64 tonnes) per hectare was recorded from treatment combination N_0P_0.The highest nitrogen content (2.02%) in shoot was recorded from treatment combination N_3P_3 as 240 kg N/ha + 75 kg P_2O_5/ha and the lowest (0.80%) was recorded from treatment combination N_0P_1. The highest phosphorous content (0.599%) in shoot was recorded from treatment combination N_2P_3 as 160 kg N/ha + 75 kg P_2O_5/ha and the lowest (0.174%) was recorded from treatment combination N_0P_3. The maximum total nitrogen (0.09%) in soil was recorded from the treatment combination N_0P_0 and the minimum total soil nitrogen (0.08%) was recorded from N_3P_3 treatment combination. The maximum total phosphorous (45.98 ppm) in soil was recorded from the treatment combination N_2P_3 and the minimum total soil phosphorous (39.60 ppm) was recorded from treatment combination N_0P_0.

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 performances;
2. Another levels of nitrogen and phosphorous fertilizer and time of applications may be included in the further study.
3. Further study may be conducted with other varieties of tomato.

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Appendices

Appendix V. **Analysis of variance of the data nitrogen, phosphorous and sulphur available in post harvest soil of tomato as influenced by nitrogen and phosphorous**

Source of variation	Degrees of freedom	Mean square		
		Nutrient present in post harvest soil		
		Total N (%)	Available P (ppm)	Available S (ppm)
Replication	2	0.184	0.078	0.080
Nitrogen (A)	3	0.508*	0.782*	0.921**
Phosphorous (B)	3	0.585*	0.924*	1.046**
Interaction (A×B)	9	0.260	0.183	0.228
Error	30	0.138	0.165	0.153

Appendix II. Analysis of variance of the data on plant height, days from transplanting to first flowering, number of flower cluster per plant and number of fruits per cluster of tomato as influenced by nitrogen and phosphorous

Source of variation	Degrees of freedom	Mean square			
		Plant height at harvest	Days from transplanting to first flowering	Number of flower cluster per plant	Number of fruits per cluster
Replication	2	6.398	1.918	12.518	16.358
Nitrogen (A)	3	87.129**	98.901**	103.747**	126.395**
Phosphorous (B)	3	7.182*	17.015**	18.996**	38.058**
Interaction (A×B)	9	0.164	0.173	0.671	0.284
Error	30	2.007	3.015	2.961	5.319

Appendix III. Analysis of variance of the data on number and weight of fruits per plant and yield of tomato as influenced by nitrogen and phosphorous

Source of variation	Degrees of freedom	Mean square			
		Number of fruits per plant	Weight of fruits per plant (kg)	Yield (kg/plot)	Yield (t/ha)
Replication	2	0.013	1.193	1.182	9.204
Nitrogen (A)	3	14.673**	59.235**	166.357**	457.059**
Phosphorous (B)	3	4.965**	9.832**	125.978**	75.864**
Interaction (A×B)	9	0.436	2.412	3.893	18.611
Error	30	0.496	1.208	2.054	9.320

Appendix IV. Analysis of variance of the data on nitrogen and phosphorous content in shoot of tomato as influenced by nitrogen and phosphorous

Source of variation	Degrees of freedom	Mean square	
		Content in shoot (ppm)	
		N	P
Replication	2	0.028	0.844
Nitrogen (A)	3	2.316**	4.169**
Phosphorous (B)	3	0.346*	1.074*
Interaction (A×B)	9	0.009	0.110
Error	30	0.098	0.282

Appendix I. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from November 06 to March 07

Month	*Air temperature (°c)		*Relative humidity (%)	*Rainfall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
November 06	21.4	13.4	65	00	6.2
December 06	20.6	12.5	66	00	6.5
January 07	24.5	12.4	68	00	5.7
February 07	27.1	16.7	67	30	6.7
March 07	31.4	19.6	54	11	8.2