EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND YIELD OF TOMATO

A THESIS

BY

MD. RAKEBUL ISLAM BAPPY

Student No. 1801343

Session: 2024-2025

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MASTER OF SCIENCE (M.S.)

IN

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DEPARTMENT OF AGRICULTURAL CHEMISTRY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY
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JUNE, 2025

DEDICATED

TO MY

BELOVED FAMILY

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The Author

ABSTRACT

A pot experiment was conducted inside the net house at Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period of November 2024 to February 2025, to study the effect of nitrogen and phosphorus on growth and yield of tomato. The experiment was laid out in a Complete Randomized Design (CRD) having seven treatments with three replications: T_1: N_0P_0, T_2: N_1P_1, T_3: N_1P_2, T_4: N_2P_1, T_5: N_2P_2, T_6: N_3P_1, T_7: N_3P_2 .Different doses of N (0, 0.35, 0.45, 0.55 g pot^{-1}) and P(0, 0.20, 0.25 g pot^{-1}) were applied in soil based on 0, 80, 100, 120 kg ha^{-1} and 0, 45, 50 kg ha^{-1} respectively in soil. Nitrogen and phosphorus fertilization to the soil influenced the plant growth and yield contributing characters of tomato. The highest value of different parameters such as plant height (The maximum plant height 66.33, 91.67, 106.00 and 118.00 cm was observed in T_7 treatment at 30 , 45 ,60 DAT and at harvest respectively), number of leaf plant^{-1} (14.33, 17.00, 19.33 was observed in T_7 at 30, 45 and 60 DAT respectively), number of branches (5.99 and 6.67 was observed in T_7 treatment at 45 and 60 DAT respectively), number of flowers plant^{-1} (33.00, 46.00 was observed in T_7 at 45 and 60 DAT respectively), no of fruit plant^{-1} (43.33 was observed in T_7), weight of fruit (2.10 kg plant^{-1} was observed in T_7 treatment), root length (24.40 cm was observed in T_7), fresh root weight (14.27 g plant^{-1} was observed in T_7), dry weight of root (4.33 g plant^{-1} was observed in T_7), fresh and dry weight of shoot (305.73 g plant^{-1} and 16.36 g plant^{-1}) both were observed in T_7 treatment. The lowest values of all the parameter of growth and yield contributing characters were found in control T_1 treatment. Although highest amount of nutrient in the fruit like Ca, Mg and K (133.00, 88.00 and 106.87 mg/1000gm) fruit were observed in T_2 treatment and lowest amount of nutrient in the fruit were observed in T_7 treatment. It is showed that the performance of the treatment T_7 was the best among all the other treatment. Therefore, the study reveals that the soil application of 120 kg N ha^{-1} and 50 kg P ha^{-1} might be an efficient practice for achieving economical tomato production but increasing amount N and P application reduced chemical content (Ca, Mg, K) of tomato fruit.

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CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most popular and nutritious vegetable crop in the world which belongs to the family Solanaceae. It has been originated in tropical America particularly in Peru, Bolivia and Ecuador. It is grown in Bangladesh in both winter and summer season around all parts of the country (Haque *et al.*, 1999). But it is grown well in the winter month of Bangladesh as the temperature is congenial at that period of time for optimum growth and yield. In Bangladesh total area occupying tomato cultivation was around 29 thousand hectares with total production of about 0.448 million tons (BBS, 2021). In Bangladesh tomato is cultivated all over the country due to its adaptability to wide range of soil and climate (Ahmed, 1995). There is a high demand for tomatoes in Bangladesh throughout the year however production is mainly concentrated mostly during the winter season. According to recent statistics, tomato was cultivated in Bangladesh on approximately 25 thousand hectares of land yielding approximately 2.35 million metric tons the cultivated area under tomato in Bangladesh is 6.81% with an average yield of 5.45 t ha^{-1}.

Temperatures between 20^0C and 27°C are ideal for tomato growth. Fruit doesn't set well when the average temperature is above 30°C or below 10°C (Adams *et al*., 2001). The lower yield characteristic of this crop namely, the absence of high-quality seeds of better varieties, inappropriate management of fertilizers, irrigation, disease control, and a lack of appropriate pruning techniques is caused by the crop's low yield potentiality. Due to its resilience to a variety of soil and climatic conditions, tomatoes are grown across Bangladesh (Sarker *et al*., 2009).

Tomato has a significant role in human nutrition because rich source of lycopene, minerals and vitamins such as ascorbic acid and beta carotene which are antioxidants and promote good health (Wilcox *et al*., 2003). It is therefore known as profitable, less risky, relatively short production cycles and labor intensive cash crop compared with many field crops (Islam, 2005). It ranks next to potato and sweet potato in respect of vegetable production in the world (Hossain *et al*., 2010). Tomato is a heavy yielder and hence requires adequate fertilizer for growth and yield (Pandey and Chandra, 2013). In

Bangladesh tomato is cultivated all over the country due to its adaptability to wide range of soil and climate (Ahmed, 1995).

Tomato contains a number of nutritional elements almost double compared to fruit apple and shows superiority with regard to food value (Barman, 2007). Regular consumption of tomatoes can prevent shorts sightedness, night blindness and other eye disease. Tomatoes have a high water content of 94.1%, 23 calories from energy, 1.90 g of protein, 1g of calcium, 7mg of magnesium, 1,000 IU of vitamin A, 31mg of vitamin C, 0.09 mg of thiamine, 0.03 mg of riboflavin, and 0.8 mg of niacin per 100 g of edible part (Ali *et al*., 2020). The antioxidant lycopene, which aids in removing potentially harmful free radicals from the body that might damage our cells, is largely responsible for the interest in tomatoes. Lycopene may improve the skin's capacity to defend itself against UV radiation and aid in the prevention of several tumor types.

Tomato’s food value is very because of higher contents of vitamin A, B, and C including calcium and carotene (Bose and Som,1990).Tomato contains a number of nutritive elements almost double compared to fruit apple and shows superiority with regard to food values (Barman, 2007). Ripe tomatoes have a high content of the antioxidents, lycopene, which plays a positive role in the prevention of certain forms of cancer (Agarwal and Rao, 2000). Tomatoes help wash out the toxins and other contaminants from the body and act as a gentle stimulant for kidneys. Regular consumption of tomatoes can prevent short sightedness, night blindness and other eye diseases. It is much popular as raw salad. It is also used as vegetable or as processed food items such as sauce, soup, juice, ketchup, pickles, paste, puree, powder, jam, and jelly. Excellent nutritional and processing qualities have made tomato very much demandable in both domestic and economic.

The tomato's red color is due to lycopene (Siddique, 2019). The tomato is grown year-round in Bangladesh, although it is most popular in the winter and summer. When compared to demand, the tomato production in our country falls short (Mazed *et al*., 2015). However, Bangladesh's poor tomato yield is not a reflection of the low yielding capacity of this crop, but rather reflects the fact that local tomato cultivars are not necessarily high yielding cultivars, and local producers' cultural methods have not been improved (Ruan *et al*., 1995). Tomatoes require a lot of heat, water, and light, especially in regions with short growing seasons. The tomato plant need at least seven hours of sunshine every day to produce adequate energy to produce fruit (Peet and Welles, 2005). Tomatoes are rich in health related compounds as they are good sources of phenolic and flavonoid compounds, lycopene and ascorbic acid (Davila *et al.,* 2014*).*The concentration of nutrients and bioactive compounds, commonly known as secondary metabolites are correlated with the prevention of human chronic degenerative diseases, such as cardiovascular diseases (CVD), cancer and neuro degenerative diseases etc (Ali *et al*., 2020).

The price of inorganic fertilizers has skyrocketed, as is already widely known, to the point where small and marginal farmers often cannot afford them. Consequently, farmers typically do not have the financial means to apply synthetic macro nutrients in sufficient or big amounts (Mehdizadeh *et al*., 2013.

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 (Sharina and Mann, 1971). It significantly increases the growth and yield of tomato (Banerjec *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-Afiui *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 find out the optimum dose of nitrogen and phosphorous for growth and higher yield of tomato.
2. To study the combined effect of nitrogen and phosphorous for attaining desirable tomato yield.
3. To calculate the nutrient uptake by the plant in tomato production.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most important vegetable crops. It is still inadequate among various research work, investigations have been made in various parts of the world using nitrogen and phosphorus to determine for its successful cultivation. Boron is an essential macronutrient and plays an important role for tomato production. Tomato is grown worldwide for local use or Cash an export crop. Numerous investigators in various parts of the world have investigated the response of tomato of nitrogen and phosphorus for its cultivation. Nitrogen and phosphorus is an essential macronutrient for growth and development of tomato production. Nitrogen is primarily involved in vegetative growth, including leaf and stem development, and is a key component of chlorophyll, essential for photosynthesis. Phosphorus, on the other hand, is vital for root development, seed production, and energy transfer within the plant. This chapter deals with a brief and relevant review of many researchers in relation to effect of nitrogen and phosphorus on growth and yield of tomato in Bangladesh perspective and also in the other parts of the world. The related review of literature was presented under the followings:

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 : I vermiculite in a greenhouse. Leaf dry weight, leaf and stem N uptake, total dry weight and N uptake of tomato, and Nl14 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 the effect of supplemental nitrogen (N) at 60 or 120 kg ha following winter cover crops of wheat. Tomato *(Lycopersicon esculentum* Mill.) and snap bean *(Phaseolus vulgaris* L.) grown in rotation and 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 1060 kg/ha in two out of four years and with 120 kg/ha 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 *el 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 Odeniis, lzmir, 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), 50kg/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 (PSI) were recorded by plants which received 160 kg N/led.

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 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 at 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 *or* 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)) 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. 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 NIL deposit fertilizer on plant growth and nitrogen uptake of tomatoes. Nib 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 NFL 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 40mg g' to as little as 15 mg g^{-1}. Over the life of welt-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 35mg 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 *el 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 (HER). 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 HER 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 HER 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 randomized 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 05 (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.

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 ROR. It was observed that the plant nitrogen concentration increased with increasing P supply.

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 greenhouse tomato (ev-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.

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 20mM 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. 50kg P_2O_5/ha and 50 kg K_2O/ha (NPK). The F, 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 -I rest of the NPK (1'2); neem cake at 3 q/ha + rest of the NPK (1'3); poultry manure at 3 tones/ha + rest of the NPK (T_2): 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 bio-fertilizers increased the N, P and K concentrations in the plants of okra, pea and tomato. The integrated nutrient management also significantly increased shoot thy 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 ISO kg N, 270 kg P_2O, 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.

CHAPTER III

MATERIALS AND METHODS

This chapter associated with the materials and methods that were followed in conducting the experiment to know the effect of application of N and P on the growth and yield contributing characters of tomato. It including on experimental materials, site, climate, weather, experimental design, materials use for experiment treatments, land preparation, fertilizing transplantation of seedlings, intercultural operation, harvesting, collection of data and statistical analysis which are given below:

3.1 Description of the experimental site

3.1.1. Location of experimental site

The experiment was conducted at net house of at Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, 5200. During the period from 14 November 2024 to 8 February 2025 to assess the growth and yield of tomato by applying nitrogen and phosphorus .Geographically the experiment site was at 25^{0}13" N latitude and 88^{0}23" E longitude with an elevation of 37.5 m above sea level. It belongs to Agro Ecological Zone (AEZ -1) named Old Himalayan Piedmont Plain.

3.2 Climate

The experimental area which was located under the subtropical climate zone is characterized by high temperature and high humidity, heavy rainfall and relatively long day during kharip season (April–September). During the Rabi season (October–March) with scanty rainfall, low temperature, low humidity.

3.3 Soil sample collection and pot preparation

Soil was collected from net house, HSTU, Dinajpur from a depth of 0-15 cm. The collected sample was sun dried for a week and weeds were removed. After drying and grinding the soil sample was passed through a 10 mesh sieve. Ten (10) kilogram soil was taken into each of the pot. A small hole was made under the pot for proper drainage .Thus the pots were ready for sowing tomato seedling.

3.4 Settings of pots for the experiment

The pots were placed at net house, HSTU, Dinajpur in 7 rows and 3 columns. The row to row and column to column distance was maintained randomly at 0.8 m and 0.8 m respectively and total number of pot was 21(7×3).

3.5 Description of soil

The experimental site was medium height land which belongs to Old Himalayan Piedmont plain under the AEZ -1 having non calcareous brown flood plain soil. The soil was collected from the Agricultural Chemistry research field, HSTU. The pH value of soil was 5.77. The morphological (Table 3.1), Physical (Table 3.2) and chemical (Table 3.3) characteristics of collected soil were presented in tabular form.

Table 3.1 Morphological characteristics of the soil agricultural chemistry research field, HSTU

Morphology	**Characteristics**
Location	Agricultural Chemistry research field, HSTU
AEZ	Old Himalayan Piedmont Plain(AEZ-1)
General soil type	Non calcareous brown floodplain soil
Parent material	Piedmont alluvial
Drainage	Moderately well drained
Flood level	Above flood level

Table 3.2 Physical characteristics of the soil in agricultural chemistry research field, HSTU

Partial size distribution	Value
Sand (%)	46.4
Silt (%)	39.4
Clay (%)	17.2
Textural class	Loamy

Table 3.3 Chemical characteristics of the soil in agricultural chemistry research field, HSTU

Characteristics	Analytical data
pH	5.77
Organic Carbon (%)	0.54
Organic matter (%)	0.93
Total N (%)	0.08
Available P (ppm)	40.9
Exchangeable K (meq.100 g^{-1} Soil)	0.20
Available S (ppm)	3.02
Available B (ppm)	0.17

3.6 Treatments of the experiments

The experiment consists of seven treatment with three replication. The treatment combinations were given below:

$T_1 = N_0 P_0$
$T_2 = N_1 P_1$
$T_3 = N_1 P_2$
$T_4 = N_2 P_1$
$T_5 = N_2 P_2$
$T_6 = N_3 P_1$
$T_7 = N_3 P_2$

Here, N = Nitrogen application, P = Phosphorus application

Different doses of N, P was applied in soil which was based on 0, 80, 100, 120 kg ha^{-1} and 0, 45, 50 kg ha^{-1} respectively

1. N_0 = 0 g pot^{-1}
2. N_1 = 0.35 g pot^{-1}
3. N_2 = 0.45 g pot^{-1}
4. N_3 = 0.55 g pot^{-1}

1. P_0 = 0 g pot^{-1}
2. P_1 = 0.20 g pot^{-1}
3. P_2 = 0.25 g pot^{-1}

Urea and Triple Super Phosphate was used as a source of nitrogen and phosphorus respectively.

3.7 Manure and fertilization

Recommended doses fertilizers for the experiment were used as follows:

Fertilizers	Doses pot^{-1}
Cow dung	**22.32 g**
Potassium	**0.22g**
Boron	**0.44mg**
Zinc	**0.90mg**

Cow dung, Potassium, Boron and Zinc was applied based on 5000 kg ha^{-1}, 50 kg ha^{-1}, 1kg ha^{-1} and 2 kg ha^{-1} respectively. Cow dung was applied to the soil before 7 days of soil preparation. All amount of K, B and Zn was applied at the time of transplanting.

3.8 Application of Nitrogen and Phosphorus

Different doses of N in soil was applied which was denoted as 0, 0.35 , 0.45 and 0.55 g per pot based on 0 , 80 ,100 and 120 kg ha^{-1} and different doses of P in the soil was applied which was denoted as 0, 0.20, 0.25, 0.30 g per pot based on 0, 45, 50, 55 kg ha^{1} with 2 spilit doses at 15DAT and 35 DAT.

3.9 Transplanting of the tomato seedlings

The tomato variety used in the experiment was BARI TOMATO 17**.** This is high yielding and indeterminate type variety. Twenty five days aged healthy and uniform sized seedlings were collected from a nursery name Raju nursery, situated in 13 mile, Dinajpur.

3.10 Intercultural operation of the tomato plant

A series of intercultural operations were performed to accelerate better growth and development of the tomato plant throughout the experimental period.

3.10.1 Watering

Tomato seedlings are very sensitive to water. It can’t tolerate water stress condition. Light irrigation was provided to young seedlings immediately after transplanting with the help of watering cane At the early stage plant were watered lightly with the help of watering cane twice (very early in the morning and late afternoon) in a day for 2-3 days. Then irrigation was necessary based on necessary.

3.10.2 Weeding

Weeding was accomplished as and whenever necessary to keep the tomato plant free from weeds, for better soil aeration and to break the soil crust and reduce competition in between the tomato plant and weeds for natural resources weeds such as nutrients. The soil around the base of each seedling was pulverized after the establishment of seedlings.

3.10.3 Gap filling

Dead or wilted seedlings were discarded from the pot and the gap filling was performed to replace healthy seedlings of each ages.

3.10.4 Sticking

After establishment of the plants, staking was provided to each plant by bamboo sticks to keep them erect. After sticking the plants started to grow up.

3.10.5 Tagging

The tomato plants were tagged properly so that they can differentiate easily according to their treatment.

3.10.6 Plant protection

Insect pests: Melathion 57 EC 2ml/L was sprayed to protect the plant from the attack of the insect pests like leaf hoppers and fruit borers. It was done fore-tingly from a week after transplanting till the last stage of the parts like leaves and branches experiments.

Viral disease: The infected plants parts like leaves and branches were removed to prevent the viral disease as for example *Alternaria* Leaf Blight to protect the other healthy plants from major infection.

3.11 Collection of data

Frequent observation were done to record to changes of plant characteristics at different stage of growth. Data on the following parameters were recorded from the sample plants during the experiments period for analyzing the data to obtain the desired objectives.

3.11.1 Plant height

The height of the same plants was recorded from the ground level to the tip of the longest stem. Then mean value was calculated to from the calculated data. Plant height measurements were started from 30 days of transplanting and continued up to 60 days of transplanting at 15 days interval for 3 times.

3.11.2 Number of leaves plant^{-1}

The number of leaves per plant was counted from plants and mean value was calculated. The counting were started from 30 days and continued up to 60 days.

3.11.3 Number of branches plant^{-1}

The number of branches per plant was recorded from plants and mean value was calculated. It started from 30 days and continued up to 60 days.

3.11.4 Number of flowers plant^{-1}

Each flower plant^{-1} was recorded for number of flowers from plants and average number of flowers per cluster calculation was done for getting desired goals.

3.11.5 Number of fruit plant^{-1}

Total fruits from each pot were counted and mean value was taken.

3.11.6 Fresh weight of fruit plant^{-1}

The weights of the collected fruits from each pot were measured with a digital weight machine and the average was taken and expressed in gram.

3.11.7 Fresh shoot weight

After measuring the shoot length, the fresh shoot weight was also measured with a digital Weighing machine and expressed in gram (g).

3.11.8 Shoot dry weight

After weighing fresh shoot weight, those shoots were placed in oven at 60^0C for 24 hours. Then those dried shoot were removed from the oven and cooled them in desiccators. Finally the dried shoot weight was measured and recorded in gram (g).

3.11.9 Root length

After final harvesting of fruits, the whole plants were uprooted carefully that the roots of the plants were not torn apart. Then the root length was measured and recorded from root collar to the longest branch of the root with the measurement scale in centimeter (cm).

3.11.10 Fresh root weight

After measuring the root length, the fresh root weight was measured with a digital weighing machine and expressed in gram (g).

3.11.11 Dry root weight

After measuring the fresh root weight, the root were placed in oven at 60^0 C for 24 hours. Then those dried root were removed from the oven and cooled them in desiccators. Finally the dried root weight was measured and recorded in gram (g).

3.12 Physio-chemical analysis of tomato fruit

3.12.1 Determination of Calcium (Ca) content

Calcium was estimated by complex metric method of titration using Na2-EDTA as Complexing Agent.5 mL of plant extract solution was taken in a 250 mL conical flask. 20 mL distilled water was added into the conical flask and shaken thoroughly.10 drop of each masking agent data and calculated the amount of calcium by the following formula:

1 mL 1M EDTA ≡ 1mL 1M Ca = 40.08 mg Ca

3.12.2 Determination of Magnesium (Mg) content

5 ml of plant extract solution was taken in a 250 ml conical flask. 20 ml distilled water was added into the conical flask and was shaken thoroughly. 10 drops of each masking agent was added to it. 5 ml of Ammonia ammonium buffer solution was added and shaken thoroughly. 5-6 drops of EBT indicator should be added into the conical flask (depending on the concentration of the indicator solution) and the flask should be shaken thoroughly.

Formula of Calculation:

1 ml 1M EDTA ≡ 1ml 1M Mg = 24.305 mg Mg

3.12.3 Determination of Potassium (K) content

Preparation of a series of potassium standard solutions containing 5, 10, 15, 20, 25, 30, 40, 50 and 60 ppm K by pipetting 5, 10, 15, 20, 25, 30, 40, 50 and 60 ml of 100 ppm K solution was taken in 9 (nine) different 100 ml volumetric flasks, respectively. The volume up to the mark was made with distilled water in each flask and the flask was shaked thoroughly. Thus, a series of potassium standard solution was prepared.

3.13 Statistical analysis

The collected data were statistically analyzed to find out the level of significant using a Completely Randomized Design (CRD) with help of Statistix-10 package program .The mean differences compared by the least Significant Difference test (LSD test) at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

This experiment was conducted to determine the effect of nitrogen and phosphorus on the growth and yield of tomato. This chapter comprises the tabulation and discussion of the result from the experiment conducted to determine the effect of nitrogen and phosphorus on growth and yield of tomato plants. The result has been represented in various tables and figures and possible explanation have been given under following headings:

4.1 Effect of nitrogen and phosphorus on the growth and yield of tomato

4.1.1 Plant height

Plant height is one of the important parameters, which is positively correlated with the yield of tomato (Table 4.1, Appendix I.). Plant height was increased progressively with increasing days after transplanting (DAT). At 30 DAT, the shortest plants were observed in the control treatment T_1 (N_0P_0) with a height of 53.33 cm, which was significantly lower than all other treatments. The tallest plants at this stage were recorded in T_7 (N_3P_2) at 66.33 cm, which was statistically at par with T_6 (N_3P_1), T_4 (N_2P_1), and T_5 (N_2P_2), indicating that early vegetative growth responded positively to increased N and P levels. By 45 DAT, a similar trend continued with T_7 showing the maximum height (91.67 cm), followed closely by T_5 and T_4, both of which also received higher doses of N and P. The lowest height (63.33 cm) again appeared in the control (T_1). Statistically significant differences were observed among treatments, emphasizing the importance of nutrient availability during the rapid growth phase. At 60 DAT, treatments with the highest nitrogen and phosphorus levels (T_6 and T_7) exhibited the greatest plant heights (106.00 cm), both significantly taller than all other treatments. This suggests a cumulative effect of nutrient application on biomass accumulation. At harvest (120 DAT), the tallest plants were again noted in T_7 (118.00 cm), followed by T_6 (112.33 cm) and T_5 (106.67 cm). These treatments significantly outperformed the control and lower-dose treatments. The consistent performance of T_7 across all growth stages indicates a strong synergistic effect of nitrogen and phosphorus at higher doses. Wahle and Masiunas (2003) reported that tomato growth was improved with high levels of N. Phosphorus had significant influence on plant height at harvesting.

Table 4.1 Effect of nitrogen and phosphorus on plant height at different DAT

Treatments	Plant height (cm)			
	30 DAT	**45 DAT**	**60 DAT**	**At harvest (120 days)**
T_1	53.33c	63.33d	69.67e	79.33e
T_2	58.67b	76.67b	83.67d	94.00d
T_3	63.33ab	70.33c	90.00c	102.67c
T_4	64.00a	86.33a	96.00b	103.00c
T_5	62.33ab	87.00a	96.33b	106.67bc
T_6	65.00a	80.00b	106.00a	112.33ab
T_7	66.33a	91.67a	106.00a	118.00a
LSD	4.84	5.35	5.62	6.01
CV (%)	4.40	3.79	3.41	3.30

In the column having a similar letter(s) do not differ significantly at 5% level of significance, LSD = Least significant difference, CV = Co efficient of variance.

4.1.2 Number of leaves plant $^{-1}$

A good number of leaves indicates better growth and development of crop and absolutely related to the yield of tomato. The greater number of leaves means greater the photosynthetic area which may result higher fruit yield (Table 4.2, Appendix II.). At 30 DAT, the lowest number of leaves (7.00) was recorded in the control treatment T_1 (N_0P_0), which was significantly lower than all other treatments. The highest number of leaves (14.33) was observed in T_7 (N_3P_2), followed closely by T_4 (14.00). Treatments receiving higher doses of nitrogen and phosphorus (T_3–T_7) performed significantly better than the control, suggesting early foliage development is highly responsive to nutrient application. By 45 DAT, the number of leaves increased across all treatments. T_7 again produced the highest number (17.00), significantly more than all other treatments. Treatments T_3 to T_6 showed statistically similar values (ranging from 14.00 to 15.00), while T_1 (10.00) and T_2 (12.00) remained significantly lower. These findings highlight the role of nutrients in sustaining vegetative growth through the mid-growth stages. At 60 DAT, the trend continued with T_7 showing the highest number of leaves per plant (19.33), followed by T_5 (17.33) and T_6 (17.00), all of which were statistically superior to lower nutrient levels. The control (T_1) maintained the lowest number of leaves (13.00), showing limited growth due to the absence of external N and P supply. Nitrogen fertilization increased number of leaves per plant (El Noeman *et al*., 1990; Gasim, 2001).

4.1.3 Number of branches plant^{-1}

There was statistically significant differences among the number of branches plant^{-1}. Number of branches plant^{-1} of tomato showed significant result due to the application of Nitrogen and phosphorus in soil and foliar at 30, 45, 60 DAT (Table 4.3, Appendix III.). At 45 DAT, the lowest number of branches (2.00) was recorded in both T_1 (N_0P_0) and T_2 (N_1P_1), which were significantly lower than all other treatments. The highest number (5.99) was observed in T7 (N_3P_2), which was statistically superior to all other treatments. Treatments T_3–T_6 had intermediate values, ranging from 3.00 to 4.33, reflecting a positive effect of increased N and P levels. At 60 DAT, a similar trend was observed. T_7 (6.67 branches) again produced the highest number of branches per plant, followed closely by T_6 (6.33 branches). The control treatment T_1 remained the lowest at 3.67 branches. These results indicate that branch development responded positively to higher nutrient application, particularly nitrogen, which is closely associated with enhanced vegetative growth and branching. Nitrogen has a significant effect on number of branches plant^{-1} as it activates vegetative growth (Manchanda and Singh, 1988).

4.1.4 Number of flowers plant^{-1}

Number of flowers plant^{-1} of tomato was significantly influenced by the different levels of Nitrogen and Phosphorus application to soil and foliar (Table 4.3, Appendix III.). At 45 DAT, the fewest flowers (13.67) were produced under the control treatment T_1, which was significantly lower than all other treatments. The highest number of flowers was recorded in T6 (33.67) and T_7 (33.00), both of which received the highest nitrogen doses. Treatments T_3 to T_5 produced moderate flower numbers, ranging from 25.33 to 28.00.

At 60 DAT, flower production increased further, with T_6 (52.33) recording the maximum number of flowers, followed by T_7 (46.00). These values were significantly higher than those of all other treatments. The control (T_1) again had the fewest flowers (17.33), highlighting the critical role of nutrient supply in reproductive development. Availability of nitrogen and phosphorus has positive effect, especially of phosphorus, on flower initiation and on its formation (Balemi, 2008).

Table 4.2 Effect of nitrogen and phosphorus on number of leaves plant^{-1} at different DAT

Treatments	Number of Leaves plant^{-1}		
	30 DAT	45 DAT	60 DAT
T_1	7.00d	10.00d	13.00d
T_2	10.67c	12.00c	14.33cd
T_3	11.67bc	14.00b	16.0bc
T_4	14.00ab	14.67b	16.67bc
T_5	13.00abc	15.00b	17.33ab
T_6	11.67bc	15.00b	17.00ab
T_7	14.33a	17.00a	19.33a
LSD	2.54	1.62	2.41
CV (%)	12.17	6.54	8.34

In the column having a similar letter(s) do not differ significantly at 5% level of significance, LSD = Least significant difference, CV = Co efficient of variance.

Table 4.3 Effect of Nitrogen and Phosphorus on number of branches plant^{-1} and number of Flower plant-1

Treatments	Number of branches plant^{-1}		Number of flowers plant^{-1}	
	45 DAT	60 DAT	45 DAT	60 DAT
T_1	2.00d	3.67d	13.67d	17.33e
T_2	2.00d	4.67cd	22.00c	27.67d
T_3	3.67bc	5.33abc	25.67b	31.00cd
T_4	3.67bc	5.00bcd	25.33bc	31.00cd
T_5	3.00c	5.33abc	28.00b	34.33c
T_6	4.33ab	6.33ab	33.67a	52.33a
T_7	5.99a	6.67a	33.00a	46.00b
LSD	0.81	1.45	3.55	5.99
CV (%)	13.44	15.45	7.70	9.83

In the column having a similar letter(s) do not differ significantly at 5% level of significance, LSD = Least significant difference, CV = Co efficient of variance.

4.1.5 Number of fruits plant^{-1}

Statistically significant variation was found on the fruit number of tomato due to the effect of soil and foliar application of boron (Fig 4.1 and Appendix IV). The highest number of fruits was observed in T_7 (N_3P_2) with a mean of 43.33 fruits per plant, closely followed by T_6 (N_3P_1) with 42.00 fruits. Both these treatments belonged to the same homogeneous group (Group a), indicating no significant difference between them but a highly significant increase compared to the other treatments. These treatments received the highest nitrogen dose (0.55 g pot^{-1}), combined with high (P_2) or moderate (P_1) phosphorus levels, respectively, which clearly enhanced reproductive performance. Moderate fruit production was observed in T_4 (N_2P_1, 22.00 fruits) and T_3 (N_1P_2, 21.00 fruits), which were grouped in Group b and bc, respectively. These treatments had moderate levels of both nitrogen and phosphorus, and the results suggest that while they improve fruiting compared to low-input treatments, they are considerably less effective than high-input treatments. Lower fruit numbers were recorded in T_5 (N_2P_2, 16.67 fruits) and T_2 (N_1P_1, 14.33 fruits), belonging to groups cd and de, respectively. Interestingly, T_5, despite having higher N and P levels than T_3 and T_4, produced fewer fruits, suggesting a possible imbalance or inefficiency at that specific nutrient combination. The control treatment T_1 (N_0P_0) produced the lowest number of fruits (10.33 fruits), falling into Group e, and was significantly inferior to all other treatments. This confirms the critical importance of both nitrogen and phosphorus in supporting reproductive development. By the supplied of major nutrients such as nitrogen and phosphorus resulted better performance in fruit formation (Balemi, 2008).

4.1.6 Weight of fruits $plant^{-1}$

There was a significant difference on the effect of Nitrogen and Phosphorus on the yield contributing characteristics fruit weight of tomato (Fig 4.2 and Appendix V). The highest fruit yield was recorded in T_7 (N_3P_2) with 2.1007 kg $plant^{-1}$, which was significantly superior to all other treatments and placed in Group A. This treatment involved the highest levels of both nitrogen (0.55 g pot^{-1}) and phosphorus (0.25 g pot^{-1}), emphasizing the beneficial synergistic effect of balanced and adequate nutrient supply on overall yield. The second-highest yield was observed in T_6 (N_3P_1) with 1.8613 kg $plant^{-1}$, falling into Group b, and was also significantly higher than all remaining treatments. The consistent superiority of T_6 and T_7 in both fruit number and yield highlights that the highest nitrogen dose is a critical factor in maximizing productivity. Intermediate yields were recorded in T_4 (N_2P_1) and T_5 (N_2P_2) with 1.2340 kg and 1.0003 kg per plant, respectively. These treatments were placed in Groups c and d, reflecting the moderate response to mid-level nitrogen and phosphorus applications. Treatments with lower nutrient levels, T_3 (N_1P_2) and T_2 (N_1P_1), produced relatively lower yields of 0.9533 kg and 0.7733 kg, respectively, and were statistically inferior to higher nutrient treatments, grouped in DE and E. The control treatment (T_1, N_0P_0) produced the lowest yield of 0.3643 kg $plant^{-1}$, classified in Group F, and was significantly lower than all other treatments. By the supplied of major nutrients such as nitrogen and phosphorus resulted better performance in fruit formation (Balemi, 2008).

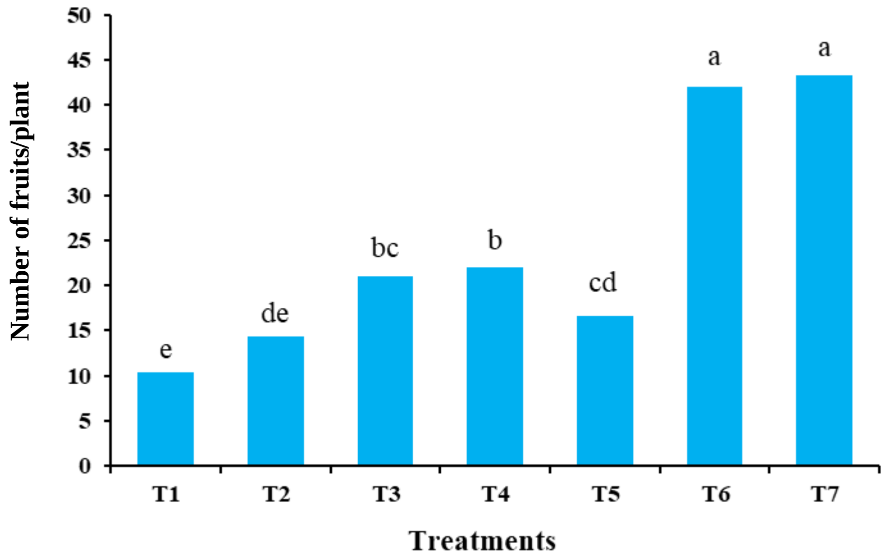

Figure 4.1 Effect of Nitrogen and Phosphorus on number of fruits per $plant^{-1}$

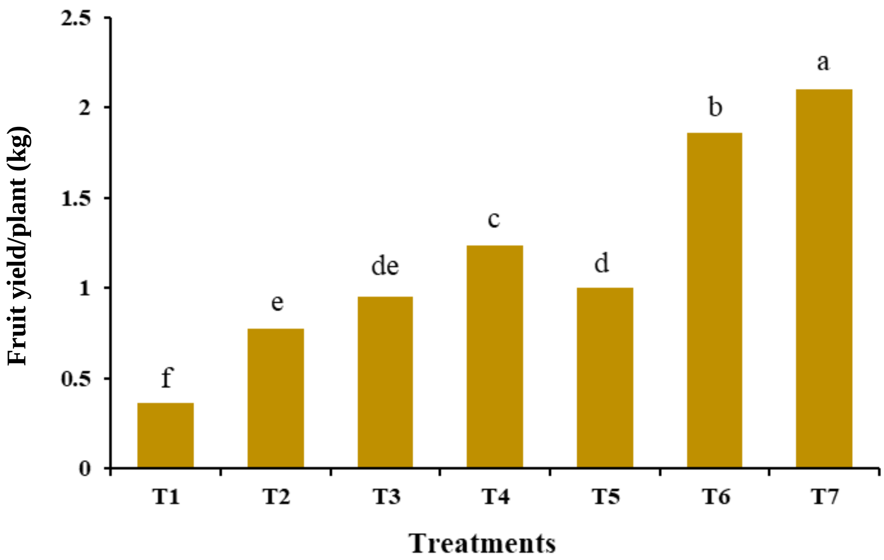

Figure 4.2 Effect of nitrogen and phosphorus on fruit weight $plant^{-1}$

4.1.7 Fresh weight of shoot

Nitrogen and Phosphorus is an essential micronutrient which helps to growth and development of tomato plant (Fig 4.3, Appendix IX). The highest fresh shoot weight was recorded in T_7 (N_3P_2) with a mean value of 305.73 g, which was significantly superior to all other treatments and grouped in Homogeneous Group A. This indicates that the combination of highest nitrogen (0.55 g pot^{-1}) and phosphorus (0.25 g pot^{-1}) levels maximized shoot growth, likely due to enhanced nutrient availability supporting vigorous vegetative development. The second-highest value was recorded in T_5 (N_2P_2) with 268.47 g, placed in Group B, followed by T_6 (N_3P_1) at 241.89 g (Group C). Interestingly, although T_6 had higher nitrogen than T_5, its slightly lower phosphorus level (P_1 vs. P_2) may have limited biomass accumulation to some extent, suggesting a notable influence of phosphorus in shoot mass enhancement alongside nitrogen. Moderate biomass was observed in T_2 (N_1P_1) with 187.20 g, classified under Group D. Treatments T_3 (N_1P_2) and T4 (N_2P_1) produced relatively low shoot weights of 105.32 g and 86.97 g, respectively, indicating a limited response despite receiving moderate doses of nitrogen and phosphorus. These were placed in Groups E and F, respectively.

The lowest shoot fresh weight was observed in the control treatment (T_1; N_0P_0) with 69.53 g, which fell into Group G, and was significantly lower than all other treatments. This confirms that in the absence of supplemental nitrogen and phosphorus, vegetative growth is severely restricted. Edossa Etissa *et al*. (2013) concluded that some growth parameters and metabolic activities of tomato plant responses at different N and P doses.

4.1.8 Shoot dry weight

A significant variation was observed on the dry weight of shoot for applying different level of N and P fertilization (Fig 4.3, Appendix X.). The highest dry shoot weight was recorded in T_7 (N_3P_2) with 16.36 g, closely followed by T_6 (N_3P_1) with 16.10 g. Both treatments were grouped under Homogeneous Group A, showing no significant difference between them but significantly higher values compared to other treatments. These results confirm that the highest dose of nitrogen (0.55 g/pot), with either high or moderate phosphorus levels, significantly enhances dry matter accumulation in shoots. The third-highest dry weight was observed in T_5 (N_2P_2) with 13.19 g, falling into Group B. Although lower than T_6 and T_7, this treatment still outperformed all the lower nutrient combinations, showing the benefit of moderately high N and P application. Treatments

T_2 (N_1P_1), T_3 (N_1P_2), T_4 (N_2P_1), and the control T_1 (N_0P_0) produced significantly lower dry shoot weights, ranging from 7.57 g to 8.40 g, and all were statistically similar, placed in Group C. These treatments lacked either adequate nitrogen, phosphorus, or both, which limited their dry matter accumulation. Edossa Etissa *et al*. (2013) concluded that some growth parameters and metabolic activities of tomato plant responses at different N and P doses.

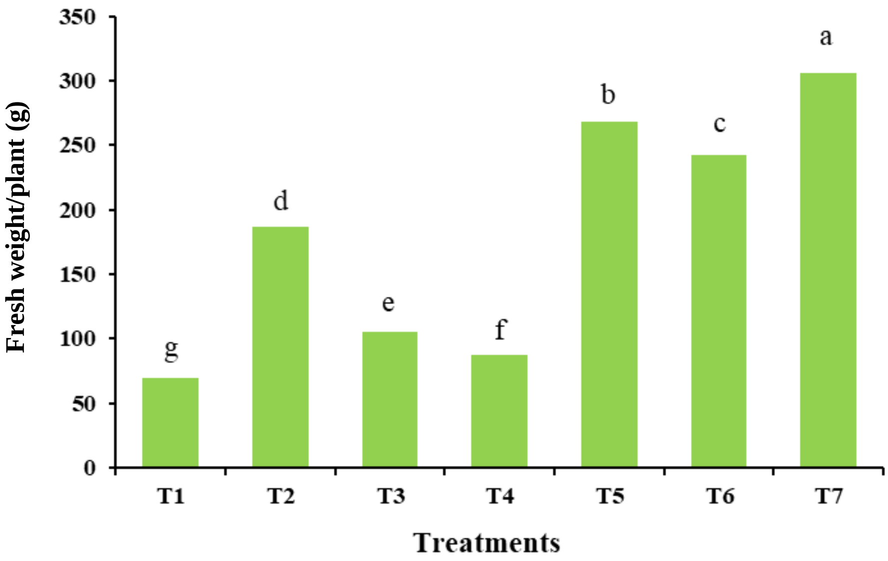

Figure 4.3 Effect of Nitrogen and Phosphorus on fresh weight of shoot plants^{-1}

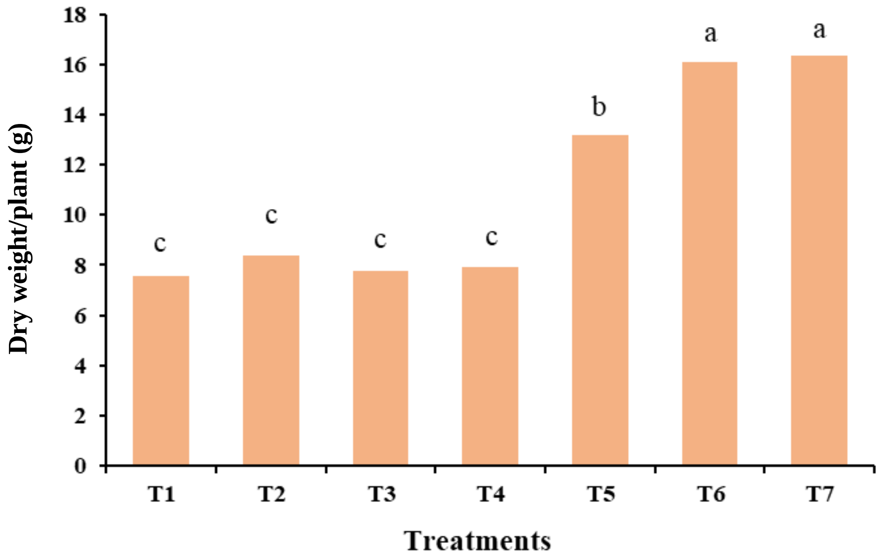

Figure 4.4 Effect of Nitrogen and Phosphorus on dry weight of shoot plant^{-1}

4.1.9 Root length

The root length of tomato was significantly influenced by applying different level of N and P fertilization. Statistically significant difference was found in root length among the different treatments (Table 4.4, Appendix VI.). The longest root length was observed in T_7 (N_3P_2) with 24.40 cm per plant, which was significantly higher than all other treatments and indicates the most vigorous root development under the highest nutrient application (0.55 g N pot^{-1} + 0.25 g P pot^{-1}). This was followed by T5 (N_2P_2) with 22.50 cm and T6 (N_3P_1) with 20.87 cm, both of which were statistically superior to most other treatments except T_7. These results confirm the role of adequate N and P supply in promoting extensive root elongation. The shortest root length was observed in the control (T_1, N_0P_0) at 12.33 cm, significantly lower than all fertilized treatments, reflecting poor root development due to nutrient deficiency.

Some growth parameters and metabolic activities of tomato plant responses at different N and P doses reported by Md. Manjurul Alam *et al.* (2017).

4.1.10 Fresh weight of root

The fresh root weight of tomato was significantly influenced by applying different level of N and P fertilization (Table 4.4, Appendix VII.). The highest fresh root weight was also recorded in T_7 (14.27 g) and T_5 (13.83 g), followed closely by T_6 (13.26 g). These treatments formed the top statistical group and suggest that both high nitrogen and phosphorus levels synergistically enhance root biomass accumulation. The lowest fresh weight was found in T_1 (7.80 g), significantly less than all other treatments, emphasizing the negative effect of no nutrient application. Intermediate values were recorded in T_3 (11.07 g) and T_4 (12.17 g), showing that mid-level applications of N and P still significantly improved root weight over the control but were not as effective as higher doses.

Some growth parameters and metabolic activities of tomato plant responses at different N and P doses reported by Md. Manjurul Alam *et al.* (2017).

4.1.11 Dry weight of root

The dry root weight of tomato was significantly influence by applying different level of N and P fertilization (Table 4.4, Appendix VIII.). Dry weight of roots followed a similar trend. T_7 had the maximum dry root biomass (4.33 g), significantly higher than all other treatments. This was followed by T_5 (4.07 g) and T_6 (3.93 g), indicating that both nutrient-rich treatments improved long-term biomass retention. The lowest dry root weight was again found in T_1 (2.20 g), with T_2 (2.73 g) slightly higher but still significantly lower than the top-performing treatments.

Interestingly, T_3 (3.63 g) and T_4 (3.37 g), despite moderate N and P levels, performed better than T_2 and T_1, showing the positive effect of phosphorus, particularly when paired with moderate nitrogen. Some growth parameters and metabolic activities of tomato plant responses at different N and P doses reported by Md. Manjurul Alam *et al.* (2017).

Table 4.4 Effect of Nitrogen and Phosphorus on the root length, fresh weight of root and dry weight of root

Treatments	Root length (cm plant^{-1})	Fresh weight of root (g plant^{-1})	Dry weight of root (g plant^{-1})
T_1	12.33d	7.80e	2.20f
T_2	14.63cd	10.13d	2.73e
T_3	14.83cd	11.07cd	3.63cd
T_4	16.63c	12.17bc	3.37d
T_5	22.50ab	13.83a	4.07ab
T_6	20.87b	13.26ab	3.93bc
T_7	24.40a	14.27a	4.33a
LSD	3.03	1.55	0.33
CV (%)	9.40	7.41	5.35

In the column having a similar letter(s) do not differ significantly at 5% level of significance, LSD = Least significant difference, CV = Co efficient of variance.

4.2 Effect of Nitrogen and Phosphorus on chemical content of tomato fruit

4.2.1 Calcium content

The significant difference was recorded due to the application of N and P (Table 4.5, Appendix XI). High nitrogen, especially in the ammonium (NH_4^+) form, can reduce Ca uptake and translocation due to competition at the root level. Phosphorus has a less direct effect on Ca. The highest calcium content was observed in T_2 (133.00 mg/1000g) and T1 (129.53 mg/1000g), which did not differ significantly (Group a). Surprisingly, higher doses of nitrogen and phosphorus (e.g., T_6 and T_7) resulted in significantly lower calcium accumulation in fruits, with T_7 recording the lowest value (101.59 mg/1000g)

4.2.2 Magnesium content

The significant difference was observed due to the application of N and P (Table 4.5, Appendix XII). Moderate N increases Mg uptake, but excess N can suppress Mg due to competition and dilution effects. Excessive P can interfere with Mg uptake, possibly through competitive inhibition or imbalance in cation uptake. A similar trend was noted for magnesium. T_2 (88.53 mg/1000g) and T_1 (85.23 mg/1000g) had the highest Mg content, while the lowest was recorded in T_7 (66.80 mg/1000g). Treatments with high N and P (T_6 and T_7) resulted in reduced Mg concentration in fruit tissue.

4.2.3 Potassium content

The significant difference was observed due to the application of N and P (Table 4.5, Appendix XIII). However, very high N may reduce K concentration in fruits if growth outpaces nutrient availability (dilution effect). Excessive P may not significantly improve K uptake and may even cause nutrient imbalance. Potassium content remained high and statistically similar across most treatments, especially from T_1 to T_3, all of which recorded over 105 mg/1000g. However, T_4 to T_7 exhibited a declining trend, with T_7 having the lowest K content (83.07 mg/1000g).

Table 4.5 Effect of nitrogen and phosphorus on amount of chemical nutrients in tomato fruits (mg/1000g)

Treatments	Amount nutrients in the fruit (mg/1000g)		
	Ca	**Mg**	**K**
T_1	129.53a	85.23a	106.80a
T_2	133.00a	88.53a	106.87a
T_3	111.65d	78.60c	105.10a
T_4	117.77c	81.37bc	93.87b
T_5	123.30b	80.53bc	84.87c
T_6	105.33e	71.60d	92.70b
T_7	101.59e	66.80d	83.07c
LSD	3.95	6.55	6.04
CV (%)	1.89	4.67	3.53

In the column having a similar letter(s) do not differ significantly at 5% level of significance, LSD = Least significant difference, CV = Co efficient of variance.

CHAPTER V

SUMMARY AND CONCLUSIONS

The pot experiment was conducted at the selected open space inside the net house of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period of November 2024 to February 2025 to study the effect of nitrogen and phosphorus on growth and yield of winter tomato (*Solanum lycopersicum*). The experiment was laid out in a Complete Randomized Design (CRD) having seven treatments with three replication viz T_1: N_0P_0, T_2: N_1P_1, T_3: N_1P_2, T_4: N_2P_1, T_5: N_2P_2, T_6: N_3P_1, T_7: N_3P_2 .Different doses of N (0, 0.35, 0.45, 0.55 g pot^{-1}) and P(0, 0.20, 0.25 g pot^{-1}) was applied in soil which was based on 0, 80, 100, 120 kg ha^{-1} and 0, 45, 50 kg ha^{-1} respectively in soil. Effect of nitrogen and phosphorus on the growth and yield of tomato that resulted in a considerable reflection on the following parameters i.e. plant height, leaf number, branch number, number of flower, number of fruits, weight of fruits, fresh shoot weight, dry shoot weight, root length, fresh root weight, dry root weight ,nutrients content in fruit. Then data were analyzed statistically and mean differences were adjusted by Duncan‘s Multiple Range Test (DMRT) for interpretation of the results. The effect of different treatments on growth and yield contributing characters were statistically significant at 5% level of probability. The results of the experiment revealed that the vegetative growth of tomato (plant height, number of leaves plant^{-1}, number of flower plant^{-1}, number of fruits plant^{-1}, weight of fruitsplant^{-1}, fresh shoot weight plant^{-1}, dry shoot weight plant^{-1}, root length plant^{-1}, fresh root weight plant^{-1}) yield contributing character (number of fruits plant^{-1}, weight of fruitsplant^{-1}) and nutrient content in all the fruit samples (Calcium, Magnesium and Potassium) responded significantly due to the application of nitrogen and phosphorus in different doses.

The maximum plant height (66.33, 91.67, 106.00 and 118.00 cm was observed in T_7 treatment at 30, 45, 45 DAT and at harvest respectively) and the shortest plant height (53.33, 63.33, 69.67 and 79.33 cm at 30, 45 and 60 DAT and at harvest respectively) was observed in control T_1 (0 kg NP ha^{-1}) treatment. The maximum number of leaves 14.33, 17.00, 19.33 plant^{-1} was observed in T_7 (120 kg N ha^{-1} and 50 kg P ha^{-1}) treatment at 30, 45 and 60 DAT respectively. The minimum number of leaves (7, 10 and 13 plant^{-1} at 30, 45 and 60 DAT, respectively) was always observed in T_1 (control) treatment. The highest number of branch plant^{-1} (5.99 and 6.67) was observed in T_7 at 45 and 60 DAT respectively and the lowest number of branch plant^{-1} (2 and 3.67) was observed in control T_1 treatment. At 45 and 60 DAT the highest number of flowers plant^{-1} (33.00, 46.00) was observed in T_7 (120 kg N ha^{-1} and 50 kg P ha^{-1}) treatment and lowest number of flower plant^{-1} (13.67 and 17.33) was observed in control T_1 treatment. The treatment T_7 produced the highest fresh and dry shoot weight (305.73 and 16.33 gplant^{-1}, respectively) but the lowest value of fresh and dry shoot weight (69.53 and 7.57 g plant^{-1}, respectively) was obtained from the control treatment T_1. The outmost root length (24.40 cm) was measured at T_7 (120 kg N ha^{-1} and 50 kg P ha^{-1}) treatment and the lowest (12.33 cm) was measured at T_1 treatment. Similarly in case of fresh root weight the lowest fresh root weight (7.80 g plant^{-1}) was found in treatment T_1 (control) and the highest (14.27 g plant^{-1}) were recorded in T_7 (120 kg N ha^{-1} and 50 kg P ha^{-1}) treatment and highest dry root weight (4.33) was found in T_7 and lowest dry root weight (2.20g plant^{-1}) was recorded in control T_1 treatment. The minimum fruits number and fruit weight (10.33 plant^{-1} and 0.364 kg plant^{-1}, respectively) were found in treatment T_1 (control) and the maximum fruits number and fruit weight (43.33 plant^{-1} and 2.10 kg plant^{-1} respectively) was recorded in T_7 treatment. Although highest amount of nutrient in the fruit like Ca, Mg and K (133.00, 88.00 and 106.87 mg/100gm) fruit were observed in T_2 treatment and lowest amount of nutrient in the fruit like Ca, Mg and K (101.59, 66.80 and 83.07 mg/100gm) was recorded in T_7.

The correlation study showed significant correlation among the different parameters. The plant height at the time of harvest, the number of fruit and the number of flower at 60 DAT was positively correlated with the yield of tomato.

Conclusions:

Based on the findings of the present study it may be concluded that**:**

- The overall results indicated that treatment T_7 (120 kg N ha^{-1} and 50 kg P ha$^{-1)}$ produced the maximum growth and yield of tomato and showed apparently lowest nutrient content in fruit.
- Studies on the effects of nitrogen and phosphorus on tomato have demonstrated that soil application of n and p is generally more beneficial for increasing plant height. This is attributed to enhanced nitrogen and phosphorus availability in the root zone, which promotes better nutrient uptake and sustained growth responses.

- Research has shown that application of nitrogen and phosphorus in soil significantly enhances plant height and biomass in tomatoes. This improvement is due to better nutrient availability, which supports photosynthesis and metabolic activities, leading to robust vegetative growth. Soil applications at doses such as 120kg ha^{-1} N and 50 kg ha^{-1} P resulted in notable increases in plant height.

Recommendation

- Considering the above observation it may be suggested to apply 120 kg N ha^{-1} and 50 kg P ha^{-1} (T_7) for the production of tomato in pot culture.
- This approach ensures better plant growth and maximizes yield.
- Further research in the field level at the different AEZ (Agro-ecological zones) of Bangladesh should be carried out before making any recommendation.

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APPENDICES

Appendix I. Analysis of variance (ANOVA) of plant height at different days after transplanting (DAT) of tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Mean of square Plant height (cm)			
		30 DAT	45 DAT	60 DAT	120 DAT
Replication	2	1.28	16.33	7.19	3.86
Treatment	6	59.87	302.22	498.54	481.60
Error	12	7.39	9.06	9.97	11.41

Appendix II. Analysis of variance (ANOVA) of number of leaves at different days after transplanting (DAT) of tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Mean of square Number of leaves per plant		
		30 DAT	45 DAT	60 DAT
Replication	2	6.05	6.33	2.33
Treatment	6	18.52	15.71	12.86
Error	12	2.04	0.83	1.83

Appendix III. Analysis of variance (ANOVA) of number of flowers and branches per plant at different days after transplanting (DAT) of tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Mean of square			
		Number of flowers per plant		Number of branches per plant	
		45 DAT	60 DAT	45 DAT	60 DAT
Replication	2	2.48	30.33	0.76	3.00
Treatment	6	140.19	407.86	3.82	3.04
Error	12	3.98	11.33	0.21	0.67

Appendix IV. Analysis of variance (ANOVA) of number of fruits per plant of tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Number of fruits per plant			
		Sum of square	Mean square	F	Probability (P)
Replication	2	18.67	9.333		
Treatment	6	3133.14	522.190	61.43	0.0000
Error	12	102.00	8.500		
Total	20	3253.81			

Appendix V. Analysis of variance (ANOVA) of fruit yield per plant of tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Fruit yield per plant			
		Sum of square	Mean square	F	Probability (P)
Replication	2	0.02394	0.01197		
Treatment	6	6.68700	1.11450	100.61	0.0000
Error	12	0.13294	0.01108		
Total	20	6.84387			

Appendix VI. Analysis of variance (ANOVA) of root length per plant of tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Root length per plant			
		Sum of square	Mean square	F	Probability (P)
Replication	2	16.263	8.1314		
Treatment	6	374.290	62.3816	21.74	0.0000
Error	12	34.430	2.8692		
Total	20	424.983			

Appendix VII. Analysis of variance (ANOVA) of root fresh weight per plant of tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Root fresh weight per plant			
		Sum of square	Mean square	F	Probability (P)
Replication	2	1.207	0.6033		
Treatment	6	95.458	15.9097	20.86	0.0000
Error	12	9.153	0.7628		
Total	20	105.818			

Appendix VIII. Analysis of variance (ANOVA) of root dry weight per plant of tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Root dry weight per plant			
		Sum of square	Mean square	F	Probability (P)
Replication	2	0.0867	0.04333		
Treatment	6	10.5267	1.75444	50.94	0.0000
Error	12	0.4133	0.03444		
Total	20	11.0267			

Appendix IX. Analysis of variance (ANOVA) of shoot fresh weight per plant of tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Shoot fresh weight per plant			
		Sum of square	Mean square	F	Probability (P)
Replication	2	70	35.1		
Treatment	6	161845	26974.2	668.13	0.0000
Error	12	484	40.4		
Total	20	162400			

Appendix X. Analysis of variance (ANOVA) of shoot dry weight per plant of tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Shoot dry weight per plant			
		Sum of square	Mean square	F	Probability (P)
Replication	2	5.496	2.7478		
Treatment	6	294.226	49.0377	51.73	0.0000
Error	12	11.375	0.9479		
Total	20	311.097			

Appendix XI. Analysis of variance (ANOVA) of amount of calcium per mg/1000g tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Calcium (mg/1000g)			
		Sum of square	Mean square	F	Probability (P)
Replication	2	13.48	6.738		
Treatment	6	2562.06	427.010	86.40	0.0000
Error	12	59.31	4.942		
Total	20	2634.84			

Appendix XII. Analysis of variance (ANOVA) of amount of magnesium per mg/1000g tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Magnesium (mg/1000g)			
		Sum of square	Mean square	F	Probability (P)
Replication	2	9.94	4.968		
Treatment	6	1025.28	170.880	12.59	0.0001
Error	12	162.89	13.574		
Total	20	1198.11			

Appendix XIII. Analysis of variance (ANOVA) of amount of Potassium per mg/1000g tomato under the effects of varying nitrogen and phosphorus application

Source of variation	Degree of freedom	Potassium (mg/1000g)			
		Sum of square	Mean square	F	Probability (P)
Replication	2	9.64	4.818		
Treatment	6	1871.91	311.984	27.09	0.0000
Error	12	138.19	11.516		
Total	20	2019.73			

Appendix XIV. Some pictures during research period