EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH, YIELD AND NUTRIENT UPTAKE OF BARI TOMATO-2 (RATAN)

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CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH, YIELD AND NUTRIENT UPTAKE OF BARI TOMATO-2 (RATAN)** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE IN SOIL SCIENCE,** embodies the result of a piece of *bona fide* research work carried out by **MD. SHARIFUL ISLAM,** Registration No.:**04-01445** 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 by him.

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Dedication

I dedicate my thesis to my parents whose efforts and ever willing support have made this dream come true

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ABSTRACT

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during November 2010 to March 2011 to evaluate the effect of nitrogen (N) and phosphorous (P) on the growth and yield of BARI tomato-2 (Ratan). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications . The treatments used were: four levels of nitrogen as N_0: o kg N/ha, N_{100}: 100 kg N/ha, N_{150}: 150 kg N/ha and N_{200}: 200 kg N/ha and four levels of phosphorous as P_0: 0 kg P_2O_5/ha, P_{50}: 50 kg P_2O_5/ha, P_{100}: 100 kg P_2O_5/ha and P_{150}: 150 kg P_2O_5 /ha with 16 treatment combinations. Yield and yield contributing characters, N, P and K concentration in plant and post harvest soil were recorded. Plant height at 60 days after transplanting, number of branches per plant, number of flowers per plant, number of fruits per plant and fruit weight per plant increased significantly with increasing N level up to 150 kg /ha, whereas fruit yield increased significantly up to 200 kg N/ha. All these parameters also increased significantly with increasing the level of P application up to 150 kg /ha. However, the treatment combination $N_{200}P_{150}$ showed the maximum plant height at harvest (93.62 cm), number of flowers per plant (49.86),number of fruits per cluster(3.99), number of fruits per plant (38.30) and rate of fruits setting (76.82%). On the other hand, the treatment combination $N_{200}P_{100}$ produced the maximum fruit weight (2.5 kg/plant) and fruit yield (89.93 t/ha). N, P and K concentrations in straw and fruit were the highest in $N_{200}P_{150}$ treatment. The treatments had no significant effect on pH of post harvest soil. However, increasing the N application up to 200 kg/ha increased soil total N and available K_0 significantly and P content up to N_{150} treatment. Application of P had no significant effect on total nitrogen but P_{150} produced the highest P and K content in soil. $N_{200}P_{150}$ combination had the highest N (0.119%) and P (44.77 ppm) concentration in plant.

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LIST OF ACRONYMS

ABBREVIATIONS	ELABORATION
%	Per cent
^{0}C	Degree Centigrade
AEZ	Agro-Ecological Zone
Anon.	Anonymous
ANOVA	Analysis of Variance
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
C	Carbon
CAN	Calcium Ammonium Nitrate
cc	Cubic Centimeter
cm	Centimeter
Conc.	Concentration
cv	Cultivar(s)
CV	Coefficient of Variance
DAP	Di Ammonium Phosphate
DAS	Days After Sowing
DAT	Days After Transplanting
DMRT	Duncan's Multiple Range Test
e.g.	Example
et al.	And other
etc	etcetera
FAO	Food and Agriculture Organization
Fed	feddon
gm	Gram
ha	Hectare
HCl	Hydrochloric acid
hr	Hour
HRC	Horticulture Research Centre
HYVs	High Yielding Varieties
Inst.	Institute
IRRI	International Rice Research Institute
J.	Journal
K	Potassium
kg	Kilogram

LIST OF ACRONYMS (cont'd)

ABBREVIATIONS	ELABORATION
Kg/ha	Kilogram per hectare
KSI	Potassium Supplementation Index
LSD	Least Significant Difference
m	Meter
m^2	Square meter
ml	Milliliter
mm	Millimeter
Mn	Manganese
MOP	Muriate of Potash
N	Nitrogen
NaCl	Sodium Chloride
NAR	Net Assimilation Rate
NFT	Nutrient Film Technique
NGOs	Non Government Organizations
No.	Number
NS	Non Significant
NSI	Nitrogen Supplementation Index
P	Phosphorous
pH	Hydrogen ion concentration
ppm	parts per million
PSI	Phophorous Supplementation Index
RCBD	Randomized Complete Block Design
Res.	Research
RH	Relative Humidity
RUE	Radiation Use Efficiency
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Research Development Institute
t/ha	Ton per hectare
TSP	Triple Superphosphate
TSS	Total Soluble Solid
UNDP	United Nations Development Program
USDA	United States Department of Agriculture
VAM	Vesicular Arbuscular Mycorrhiza
viz.	videlicet
Wt.	Weight

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum.* Mill) belongs to the family solanaceae, is one of the most important, popular and nutritious vegetable in Bangladesh. It is originated in tropical America (Salunkhe *et al.* 1978) and ranks third in terms of world, vegetable production (FAO, 1997). It is the top listed canned vegetables (Choudhury, 1997). It is adapted to a wide range of climate ranging from tropics to within a few degrees of the Arctic Circle. However, in spite of its broad adaptation, it is concentrated in a few area and rather dry area (Cuortero and Fernandez, 1999).

The popularity of tomato and different products of 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 and juice etc. They are extensively used in the Canning food 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 high contents of vitamins A, B and C including calcium and carotene. Tomato adds flavor to the foods and it is also rich in medicinal value. In other aspect, Bangladesh can earn huge foreign currencies to export raw tomatoes and processed tomatoes by producing more quality tomatoes using modern technologies and high yielding varieties. For this purpose we should take initiatives to make our farmers more knowledgeable and expert to grow more food from our limited lands. In addition, we should encourage the farmers and other NGOs to grow more and more vegetable like tomato. The government should take the steps to establish tomato processing plant because of our huge production in all the year.

The edaphic and climatic conditions of winter seasons 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 , 1,31000 metric tons of tomato were produced from 13,845 hectares of land with an average yield of 9.46 t/ha (BBS, 2006). Except 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 yield potentiality of this crop, but, the fact that the lower yield may be attributed to a number of reasons viz. unavailability of quality seeds of improved varieties, fertilizers management, disease infestation and improper moisture management. Among them fertilizer management is a vital factor that influence the growth and yield of tomato. Balance fertilizations in crops will act as an insurance against possible nutrient deficiencies that may be created by the respected use of a single nutrient (Manage *et al.,* 1982). Among different nutrients that were required for tomato cultivation nitrogen and phosphorous are the 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 required large quantity of readily available fertilizer nutrients (Gupta and Shukla, 1977). In indeterminate type of tomato, vegetative and reproduction stages overlap and the plants need nutrients up to 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 K (Hedge, 1997).

In Bangladesh, fertilizer especially nitrogen is the most critical input for increasing 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 induced cell division and initial meristematic activity when applies in optimum quantity (Sing and Kuer, 1969). Nitrogen had the largest effect on yield and quality of tomato (Xin *et al.,* 1997). It also promotes vegetative growth, flower and fruit setting of tomato (Lose and Som, 1971). Optimum nitrogen increases fruit quality, fruit size, 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 fertilizers dwell is 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 to the tomato has received considerable attention and appears to have had a profound influence on horticultural practices. Combined effects of nitrogen and phosphorous have also been proved quite effective in increasing growth and yield of tomato (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).

In Bangladesh, BARI (Bangladesh Agricultural Research Institute) has released at least ten HYVs (High yielding varieties) of tomato. The variety BARI Tomato-2 (Raton) is one of the high yielding varieties of indeterminate type. It may be cultivated throughout the year all over the country. Research in response of tomato to nitrogen, phosphorous, potassium and sulphur fertilization is very limited for tomato cultivation

Keeping all the above facts in view, the present experiment has been undertaken with following objectives:

1. To see the combined effect of Nitrogen and Phosphorus on yield and yield components of tomato
2. To determine the Nitrogen and Phosphorus requirement of tomato plants.
3. To evaluate the nutrient uptake behavior of tomato plants under different levels of Nitrogen and Phosphorus application.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most important vegetable crops in Bangladesh and as well as many countries of the world. It is a high yielding year round crop and fertilizer responsive crop. Among different fertilizers, 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 in relation to nitrogen and phosphorous on growth, yield and development of tomato. 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 nitrogen and phosphorous fertilizers so far been done at home and abroad on this crop and have been reviewed in this chapter under the following parameters.

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 (100gm/plant) to supply N to increase yields of tomato *(Lycopersicon esculentum)* was compared with that of N fertilization (0, 4.1, and 8.2g N/plant) in a medium containing a mixture of 3 perlite : 1 vermiculite in a greenhouse. Leaf dry weight, leaf and stem N uptake of tomato, and NH_4^+ and inorganic N concentrations in the medium at transplanting were significantly greater 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 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 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 crop of wheat, Tomato (*Lycopersicon esculentum mill.*) and snap bean (*Phaseolus vularis 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 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 autumn tomato. Yield ranged from 1900 to 2600 boxes/acre in spring tomato, and from 1300 to 2700 boxes/acre in autumn 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 autumn tomato.

A study was conducted by Ceylan *et al.* (2000) at Odemis, Izmir, Turkey to assess the effect of ammonium nitrate and urea fertilizers at 0, 12, 24, 36 kg N /ha on nitrogen uptake and accumulation in tomato plants. The total nitrogen, NO_2-N and NO_3-N contents of leaches and fruits were determined. On the first and second harvest dates, the highest NO_3^- N and NO_2-N amounts in tomato leaches and fruits were obtained upon treatment with 36 kg N/ha. Ammonium nitrate application increased nitrate and nitrite accumulation compared to urea application. The highest was recorded upon treatment with 24 kg N.

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, 40kg/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 @ 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 phosphorous 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 spacing (75cm ×50cm, 75cm ×75cm, and 75cm ×100cm) 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.

Sandoval *et al.* (2001) conducted an experiment to determine the tomato yield response to 0:100, 10:90, 20:80, 30:70, 40:60 NH_4^+ N : NO_3^- N 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_4^+ N supply nor the NH_4^+ N concentration in solution affected tomato yield. Plant height was not affected by NH_4^+ N 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_4^+ N 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 @ 0, 40, 80 and 120 kg/ha K @ 0, 30 and 60 kg/ha Gupta and Sengar (2001) conducted an experiment in Madhya Pradesh, India during rabi 1992-93 and 1993-94. 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 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 to examine the influence of legume and N fertilizer application (0, 90, and 180 kg N/ha) on short and long-term effects on soil C and N ratio 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, 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.

Chang *et al.* (2001) conducted an experiment 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 "CAUTAN" (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 seasonal 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) location and management systems are 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 then 30%. Lower RUE under N limited condition 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 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 (21g/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 nutrient film technique (NFT) were investigated for 3 months by Bellert *et al.* (1998). Growth and N uptake were not modified by 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 (at 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.

Tomato cv. Momotaro was grown using the nutrient film technique (NFT) in ½ and ¾ to full strength Enshi shoho balanced feed (Hohjo *et al.* 1995). In the first experiment, nutrient solutions were adjusted to contain NO_3^- N: NH_4^+ N 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_4^+ N, 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_4^+ N ratios of 10:0 and 8:2 and Ca concentrations of 2, 4 and 6 meq /litre were used. The higher proportion of NH_4^+ N 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 decrease in BER and leaf Mg content. The combination of 8:2, NO_3^- N: NH_4^+ N and the lowest Ca concentration reduced total yield and leaf Ca content and significantly increased blossom end rot (BER).

Trpevski *et al.*(1992) carried out in trials with 3 rates N was applied at 0, 40, 80 and 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 was conducted by Kooner and Randhaoa (1990) at Punjub Agricultural University, Ludhiana to study the interaction of rates on 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, viz. calcium ammonium nitrate (CAN) and urea, in a randomized, split plot design. PC produced significantly higher yields (222.7 kg/ha) than PK (208.9kg/ha) in the spring planting while in the winter planting OS (163.09 kg/ha) and CS (113.9 kg/ha) were the best. Yields increased linearly with increasing N rate up to 150 kg/ha and calcium ammonium nitrate(CAN) was the best source of N. Total Soluble Solid (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.* (1998) observed that increasing nitrogen rates linearly increased the number of fruits per plant. However, medium and higher nitrogen rates gave best total yield. 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 @ 70, 110 and 150 kg/ha and phosphorous (P) @ 44 or 61.6 kg/ha with basal dressing of potassium (K) @ 49.8 kg/ha and FYM @ 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 effects as any of the indices studied.

Belivhki (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 @10 meq/L N and declined at higher concentrations.

2.2 Effect of Phosphorous on the growth and yield of tomato

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.

Silva *et al.* (2001) carried out a field experiment was 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 0.6t/ha). A linear increase was observed as gypsum rates increased. Leaf 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 grown hydroponically in a controlled temperature room for 6 weeks to investigate the effectiveness of foliar application of supplementary potassium and phosphorus to 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. Concentration 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, 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(TSS) 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 average height of the seedlings decreased, while the main roots of the seedling 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 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 become more pronounced above 0.65 g 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) carried out an experiment to study the response of sulphur, phosphorus and 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 Integrated effect of nitrogen and phosphorous on the growth and yield of tomato

Garton and Widders (1990) carried out an experiment on seedlings of processing tomato cv. H 2653 grown in plug trays in a soil less growing medium. Application of nutrient solutions containing 10 or 20 mM N and 2 or 5 mM P for 10 days before transplanting altered the total ammoniacol N and P, and the soluble NO_3^-N and PO_4^+ P 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 2mM P pre-transplant treatment caused the most rapid shoot growth following early season planting in the field at Harrokw. 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 India, as a crop after potato by Taya *et al.* (1994). The preceding tomato 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 @ 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 @ 90 days after planting, fruit number and yield in the subsequent crops of tomato and okra; the F1 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 in creasing N rate; N application had an 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) @15 tones/ha + rest of the NPK (T_2); neem cake @ 3 q/ha +rest of the NPK (T_3) ; poultry manure @ 3 tonnes/ha + rest of the NPK (T4); *Azospirillum* +75% N +recommended dose of P and K (T_5); vesicular arbuscular mycorrhiza (VAM) + 50% P + recommended dose of N and K (T_6); phosphate solubilizing bacteria (PSB) +75% P + recommended dose of 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}). Incase 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 dry matter yield of tomato and fruit yields of okra and tomato.

A field experiment 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 sulphate; 150 kg ammonium sulphate/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 experiment during rabi 1994/95, 1995/1996 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); (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 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 increased yield was not due to larger fruits, but to an increase in 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) and 3 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 MPH-16 and Rupali. Application of 200 kg N /ha resulted in significantly greater fruit size and mean fruit weight, 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 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.

Cerne and Briski (1993) conducted field trials on the fertilizer and irrigation requiremint of tomato cv. Rudgers plants where 250 kg N and 725 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. rainfed 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 I 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 225 mg/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 @ 45 mg/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 III
MATERIALS AND METHODS

The experiment was conducted at the Research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during November 2010 to March 2011 to find out the effect of nitrogen (N) and phosphorous (P) on the growth and yield of BARI Tomato-2 which is one of the high yielding varieties of indeterminate type.

3.1 Experimental site

The experiment was carried out at the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar,Dhaka. The experimental site was located at $23^0 77^/$ N latitude and $90^0 3^/$ E longitude.

3.2 Characteristics of soil

The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ-28), which falls into Deep Red Brown Terrace Soil. 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	Sher-e-Bangla Agricultural University Farm, Dhaka-1207
AEZ	AEZ-28,(Modhupur Tract)
General Soil Type	Deep Red Brown Terrace Soil
Soil Series	Tejgaon
Topography	Fairly leveled
Depth of Inundation	Above flood level
Drainage condition	Well drained
Land Type	High land

Table 2. Physical and chemical properties of the experimental initial soil

Soil properties	Value
A. Physical properties	
1.Partical size analysis of soil	
Sand (%)	27.50
Silt (%)	40.30
Clay (%)	32.20
2. Soil texture	Silty-clay
3. Bulk density (g/cm^3) (0-30 cm depth)	1.39
4. Particle density (g/cm^3) (0-30 cm depth)	2.55
B. Chemical properties	
1. Soil pH	5.00
2. Organic carbon (%)	0.65
3. Organic matter (%)	1.23
4. Total Nitrogen (%)	0.109
5. C:N ratio	9.75:1
6. Available P (ppm)	0.24
7. Exchangeable K (me/100 g soil)	10.79
8. Available S (ppm)	13.2
9. Available Zn (ppm)	1.25

3.3 Climate

The experimental area has sub-tropical climate characterized by heavy rainfall during May to September and scant rainfall during rest of the year. The annual precipitation of the site is 2152 mm and potential evapotranspiration is 1297 mm. The average maximum temperature is 30.34^0 C and average minimum temperature is 21.21^0 C. The average mean temperature is 25.17^0 C. The experiment was done during the rabi season. The temperature during the cropping period ranged between 12.2^0 C to 29.20^0 C. The humidity varied from 71.52% to 81.20%. The day length was reduced to 10.50 to 11.0 hours only and there was a very little rainfall from the beginning of the experiment to harvesting.

3.4 Seeds and variety

BARI Tomato-2 (Raton), a high yielding variety of tomato (*Lycopersicon esculentum* Mill.) used in this experiment was developed by Bangladesh Agricultural Research Institute (BARI) Gazipur. The seeds were collected from Horticultural Research Centre (HRC) of BARI, Gazipur.

3.5 Raising of seedlings

The selected land for nursery bed was well drained and sandy loam type soil. The area was well prepared and converted into loose friable and dried mass to obtain fine tilth. All weeds and dead roots were removed and the soil was mixed with well rotted cow dung at the rate of 5 kg/bed. The size of the seed bed was 3m × 3m, raised 10 to 12 cm (approximately) above the ground level. The seed bed was prepared for raising the seedlings. Ten (10) grams of seeds were sown in the seed bed on 25 October, 2008. After sowing, the seeds were covered with light soil. Miral 3-GN was applied in seed bed as precautionary measures against ants and worms. Complete germination of the seeds took place with 5 days after seed sowing. Necessary shading was made by bamboo mat (chatai) from scorching sunshine or rain. No chemical fertilizer was used in the seed bed.

3.6 Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each fertilizer treatment combinations. Fertilizer treatments consisting of 4 levels of N and 4 levels of P on the growth and yield of tomato.

The study comprised the following treatments:

A. Four levels of nitrogen (N)

i. N_0: 0 kg N/ha
ii. N_{100}: 100 kg N/ha
iii. N_{150}: 150 kg N/ha
iv. N_{200}: 200 kg N/ha

B. Four levels of phosphorous (P_2O_5)

i. P_0: 0 kg P_2O_5 /ha
ii. P_{50}: 50 kg P_2O_5 /ha
iii. P_{100}: 100 kg P_2O_5 /ha
iv. P_{150}: 150 kg P_2O_5 /ha

There were 16 (4 × 4) treatment combinations. The treatment combinations were as follows

1. N_0P_0 = Control (without N and P application)
2. N_0P_{50} = 0 kg N /ha+ 50 kg P_2O_5/ha
3. N_0P_{100} = 0 kg N /ha +100 kg P_2O_5/ha
4. N_0P_{150} = 0 kg N /ha +150 kg P_2O_5/ha
5. $N_{100}P_0$ = 100 kg N /ha + 0 kg P_2O_5/ha
6. $N_{100}P_{50}$=100 kg N /ha + 50 kg P_2O_5/ha
7. $N_{100}P_{100}$ =100 kg N /ha + 100 kg P_2O_5/ha
8. $N_{100}P_{150}$ =100 kg N /ha + 150 kg P_2O_5/ha
9. $N_{150}P_0$ =150 kg N /ha + 0 kg P_2O_5/ha
10. $N_{150}P_{50}$ =150 kg N /ha + 50 kg P_2O_5/ha
11. $N_{150}P_{100}$ =150 kg N /ha + 100 kg P_2O_5/ha
12. $N_{150}P_{150}$ = 150 kg N /ha + 150 kg P_2O_5/ha
13. $N_{200}P_0$ =200 kg N /ha + 0 kg P_2O_5/ha
14. $N_{200}P_{50}$ = 200 kg N /ha + 50 kg P_2O_5/ha
15. $N_{200}P_{100}$ = 200 kg N /ha + 100 kg P_2O_5/ha
16. $N_{200}P_{150}$ = 200 kg N /ha + 150 kg P_2O_5/ha

Fertilizer treatments were randomly distributed in each block.

3.7 Design and layout of experiment

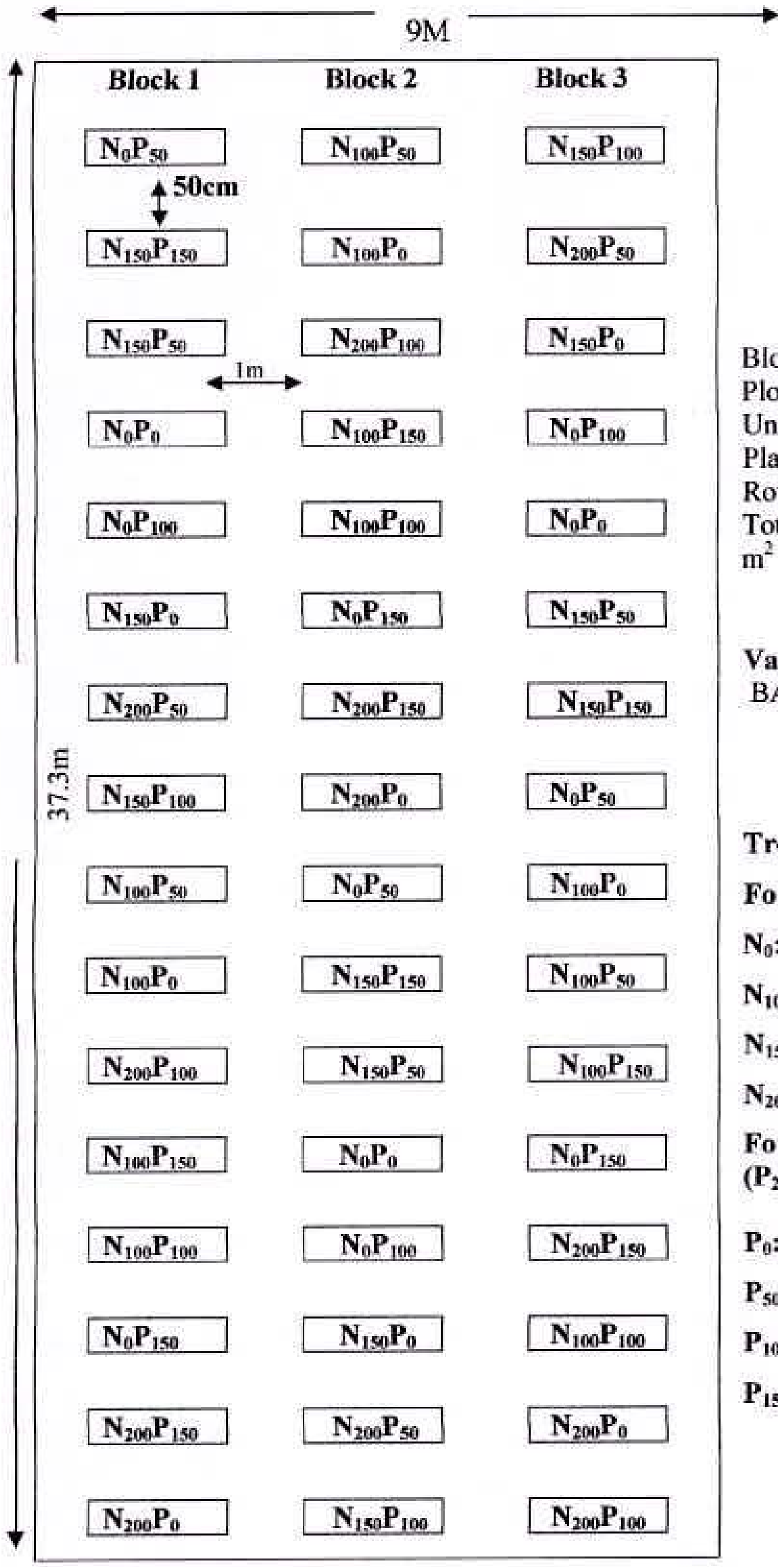
The two factors experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. An area of 335.7 m^2 (37.3 m × 9.0 m) was divided into three equal blocks. The layout of the experiment was prepared for distributing the treatment combinations into the every plot of each block. Each block was divided into 16 plots where 16 treatment combinations were allotted at random. There were 48 unit plots altogether in the experiment. Each of the plot area was 3.60 m^2 (2m × 1.8m) .The distances 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.

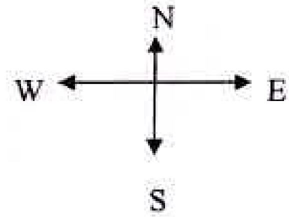
3.8 Collection and preparation of initial soil sample

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.

3.9 Land preparation

The selected land for the experiment was first opened 25 November 2008 by a tractor. The land was well prepared with the tractor followed by harrowing and laddering up to a good tilth. All weeds and stubbles were removed. Making ridges (20 cm high) around each plot to restrict the lateral run off of irrigation water. The individual plots were finally prepared through addition of the basal doses of manure and fertilizers of that respective treatment.





Block to Block distance = 1m
Plot to Plot distance = 50 cm
Unit Plot size =2m × 1.8m=3.6m^2
Plant to plant distance=50cm
Row to row distance = 60cm
Total area = 37.3m × 9m=335.7 m^2

Variety:
BARI-Tomato-2(Ratan)

Treatment:

Four levels of nitrogen (N)

N_0: 0 kg N/ha

N_{100}: 100 kg N/ha

N_{150}: 150 kg N/ha

N_{200}: 200 kg N/ha

Four levels of phosphorous (P_2O_5)

P_0: 0 kg P_2O_5 /ha

P_{50}: 50 kg P_2O_5 /ha

P_{100}: 100 kg P_2O_5 /ha

P_{150}: 150 kg P_2O_5 /ha

Figure1: Field layout of the experimental plot

3.10 Application of manure and fertilizers

The sources of N, P_2O_5, K_2O and S as urea, triple superphosphate (TSP), muriate of potash (MoP), and gypsum were applied, respectively. One third (1/3) of whole amount of urea, the entire amounts of TSP, MoP and gypsum were applied during the final land preparation. The remaining urea were top dressed in two equal installments at 20 days after transplanting (DAT) and 35 days after transplanting, respectively. Well rotten cowdung 10 t/ha also applied during final land preparation.

3.11 Transplanting of seedlings

Healthy and uniform sized 30 days old seedlings were uprooted from the seed bed and were transplanted in the experimental field on 28 November, 2010 maintaining a spacing of 60 cm and 50 cm between the rows and plants, respectively. The seed bed was watered before uprooting the seedlings so as to minimize the damage of the roots. This operation was carried out during late hours in the evening. The seedlings were watered after transplanting. Shading was provided by piece of banana leaf sheath for three days to protect the seedlings from the direct sun light. A strip of the same crop was established around the experimental field as border crop to do gap filling and to check the border effect.

3.12 Irrigation and drainage

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

3.13 Gap filling and weeding

When the seedlings were established, the soil around the base of each seedling was pulverized. A few gap filling were done by healthy plants from the border whenever it was required. 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.

3.14 Pest management

The crop was infested with cutworm, leaf hopper and others. The insects were controlled successfully by spraying Malathion 57 EC @ 2 ml/L water. The insecticide was sprayed fortnightly from one week after transplanting to one week before first harvesting. Miral 3-GN was also applied during final land preparation as soil amendments. During foggy weather precautionary measures against disease infestation especially late blight of tomato was taken by spraying Dithane M-45 fortnightly @ 2 g/L water.

3.15 Harvesting

Fruits were harvested at 5 days intervals during maturity to ripening stage. The maturity of the crop was determined on the basis of red coloring of fruits. Harvesting was started from 2 March, 2011 and completed by 22 March, 2011.

3.16 Collection of experimental data

Five (5) plants from each plot were selected randomly and were tagged for the data collection. The sample plants were uprooted and dried properly in the sun. Data were recorded on the following parameters from the sample plants during the course of experiment.

1) Plant height (cm) at 30 DAS and 60 DAS and at final harvest
2) Number of leaves per plant at 30 DAS and 60 DAS
3) Number of branches per plant at harvest
4) Number of cluster per plant
5) Number of flowers per cluster
6) Number of flowers per plant
7) Number of fruits per cluster
8) Number of fruits per plant
9) Rate of fruit setting (%)
10) Fruit size (length × diameter)
11) Weight of individual fruit (gm)
12) Fruit yield per plant (gm)
13) Fruit yield per plot (kg)
14) Fruit yield per hectare (ton)
15) Nitrogen uptake by straw
16) Phosphorous uptake by straw
17) Nitrogen uptake by fruit

18) Phosphorous uptake by fruit

19) Nitrogen content in initial and post harvest soil

20) Phosphorous content in initial and post harvest soil

1. Plant height

Plant height at 30 DAS, 60 DAS and final harvest stages was measured respectively from sample plants in centimeter from the ground level to the tip of the longest stem and mean value was calculated.

2. Number of leaves per plant at 30 DAS and 60 DAS

Number of leaves per plant at 30 DAS and 60 DAS was counted from sample plants and their average was taken as their number of total leaves per plant.

3. Number of branches per plant at harvest

Number of main branches per plant at final harvest was recorded from sample plants and the average value was taken.

4. Number of cluster per plant

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The number of clusters was counted from the sample plants and the average number of cluster produced per plant was recorded at the time of final harvest.

5. Number of flowers per plant

The number of flowers per plant was counted from the sample plant after end of flowering stage and the average number of flowers was taken.

6. Number of fruits per plant

The number of fruits per plant was counted from the sample plant after end of fruit setting and the average number of fruits was taken.

7. Number of flowers per cluster

It was calculated by the following formula

$$\text{Number of flowers} = \frac{\text{Total number of flowers of sample plants}}{\text{Total number of clusters of sample plants}}$$

8. Number of fruits per cluster

It was calculated by the following formula

$$\text{Number of fruits per cluster} = \frac{\text{Total number of flowers of sample plants}}{\text{Total number of clusters of sample plants}}$$

9. Rate of fruit setting (%)

It was calculated by the following formula

$$\text{Rate of fruit setting (\%)} = \frac{\text{Total number of fruits per plants}}{\text{Total number of flowers per plants}} \times 100$$

10. Fruit size (length × breadth)

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 5 randomly selected marketable fruits from each plot, at each harvest. Their average length was recorded. The breadth of fruit was measured at the middle position of 5 randomly selected marketable fruits from each plot at each harvest with a slide calipers.

11. Weight of individual fruit (gm)

Among the ten harvest of marketable fruits during the period from first to final harvest, the first and last two harvest were omitted and ten intermediate harvest were used for individual fruit weight in gram (gm) by the following formula

$$\text{Weight of individual fruit (gm)} = \frac{\text{Total weight of marketable fruits from10 harvested sample plant}}{\text{Total number of marketable fruits from 10 harvested of sample plant}}$$

12. Fruit yield per plant (gm)

It was calculated by the following formula

$$\text{Weight of fruits per plant (gm)} = \frac{\text{Total weight of fruits from10 samples}}{10}$$

13. Fruit yield per plot (kg)

A pan scale balance was used to take the weight of fruits during the period from first to final harvest.

14. Fruit yield per hectare (ton)

It was calculated by the following formula

$$\text{Fruit yield per hectare (ton)} = \frac{\text{Fruit yield per plot (kg)} \times 10000}{\text{Area of plot in square meter} \times 1000}$$

3.17 Analytical methods of soil and plant sample analysis

The analytical methods of physico-chemical properties of soil, nutrient content and quality of tomato are shown in the table 3

3.18 Chemical analysis of plant samples

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 65^0C for 48 hours. The dried samples were put into small paper bags and kept into desiccators till being used.

2. Digestion of plant samples with sulphuric acid

For N determination, an amount of 0.1g plant sample (plant and fruit0 was taken into a 100 ml Kjeldhal 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 plants samples.

3. Digestion of plant with nitric per chloric 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 rising 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 6 N 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.

Table 3. Different methods for determination of physico-chemical properties of soil

Physical properties of soil

Soil properties	Determination method
Soil texture (particle size analysis)	Hydrometer method
Bulk density	Core sampling method
Particle density	Pycnometer method
% Porosity	Relation between bulk density and particle density

Chemical properties of soil

Soil properties	Determination Method
Soil pH	1:2.5 soil water ratio, using glass electrode method.
Organic carbon	Wet oxidation method as outlined by Piper (1942): Through oxidation of organic matter with potassium dichromate and titrated with ammonium ferrous sulphate, using phenyl anthranalic acid indicator.
Total N	Micro-Kjeldahl method following H_2SO_4 digestion and steam distillation with NaOH. Ammonia thus collect in boric acid was determined titrimetrically.
Available P	Extracted by 0.5 M $NaHCO_3$ (pH 8.5) and determined colorimetrically using molybdate blue method (Olsen and Dean, 1965).
Available S	Extracted by Ca $(H_2PO_4)_2$, HCL and phenol and determined calorimetrically using turbidity method (Hunter, 1980).
Exchangeable K	Extracted by ammonium acetate solution determined by atomic absorption spectrophotometer (Christian and Feldman, 1970).

4. Determination of element in the digest (Table 3)

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

3.19 Soil Sample Analysis

1. Total nitrogen

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

2. Available phosphorous

Available phosphorous was extracted from soil by shaking with 0.5 M $NaHCO_3$ solution of pH 8.5 (Olsen *et al.*, 1954). The phosphorous in the extract was then determined by developing blue color using $SnCl_2$ reduction of phosphorous molybdate 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.

3.20 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 IV
RESULTS AND DISCUSSION

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-VII). The results have been presented and discussed and possible explanations have been given under the following parameters:

4.1Yield and yield contributing character of tomato

Yield contributing character such as plant height, number of leaves, number of branches, number of cluster per plant, number of flowers per cluster, number of flowers of flowers per plant, number of fruits per cluster, number of fruits per plant, rate of fruit setting (%), fruit size, weight of individual fruit, fruit yield per plant, fruit yield per hectare, yield increased over control, shoot and root dry weight etc. were recorded and have been discussed sequentially.

4.1.1 Plant height

Plant height varied significantly due to application of different doses nitrogen in tomato under the present trial (Appendix II). At 30 days after transplanting (30 DAT) the maximum plant height (60.38 cm) was recorded from N_{200} treatment consisting of 200 kg N/ha which was statistically identical (58.76 cm) (Figure 2) with N_{150} treatment as 150kg N/ha. The minimum plant height (56.16 cm) was recorded from N_0 treatment where no nitrogen was added to the soil

At 60 days after transplanting (60 DAT) the highest plant height (78.31cm) was recorded from N_{200} treatment consisting of 200 kg N/ha which was statistically identical (77.05cm) (Figure 2) with N_{150} treatment as 150 kg N/ha and the lowest plant height (70.78 cm) was recorded from N_0 treatment (Table 4)

During the harvesting period, the maximum plant height (89.58 cm), was recorded from N_{200} treatment consisting of 200 kg N/ha and the minimum plant height (56.16cm) (Figure 2) was recorded from N_0 treatment which was closely (80.17 cm) followed by N_0 treatment (Table 4)

Probably all micro and macro nutrients for 200 kg N/ha ensured the favorable condition for growth of tomato plant and the ultimate result is the tallest plant where as 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 result was reported by Chung *et al.* (1992), Grela *et al.* (1988), Sharma and Mann (1971)

Different level of phosphorous showed statistically significant differences for plant height (Appendix II). At 30 days after transplanting (30 DAT) the maximum plant height (59.43 cm), (Figure 3) was recorded from P_{100} treatment consisting of 100kg P_2O_5/ha which was statistically identical (59.15cm) with P_{150} treatment as 150kg P_2O_5//ha and (58.51cm) with P_{50} treatment as 50kg P_2O_5/ha the minimum plant height (55.46 cm) was recorded from P_0 treatment that is control condition (Table .4)

At 60 days after transplanting (60 DAT) the maximum plant height (77.61 cm), was recorded from P_{150} treatment consisting of 150kg P_2O_5/ha which was statistically identical(77.24 cm) (Figure-3) with P_{100} treatment as 100kg P_2O_5/ha and (58.51cm) withP_{50} treatment as 50kg P_2O_5/ha the minimum plant height (72.046 cm) was recorded from P_0 treatment (Table 4)

During the harvesting period, the maximum plant height (88.93 cm), was recorded from P_{150} treatment consisting of 150kg P_2O_5/ha which was statistically identical (88.08) (Figure 3) with P_{100} treatment as 100kg P_2O_5/ha and the minimum plant height (80.64 cm) was recorded from N_0 treatment (Table 4).

Table 4. Effect of nitrogen and phosphorous on plant height at 30 DAT, 60 DAT and at final harvest, number of leaves per plant at 60 DAT and number of branches per plant at harvesting period of tomato.

Treatments	Plant height at (cm)			No. of leaves / plant at	No. of branches / plant at
	30DAT	60 DAT	Harvest	60 DAT	Harvest
Nitrogen					
N_0	56.16c	70.78c	80.17d	39.72d	9.668c
N_{100}	57.25bc	75.77b	85.05c	43.08c	10.44b
N_{150}	58.76ab	77.05ab	87.47b	46.92b	10.90a
N_{200}	60.38a	78.31a	89.58a	51.72a	11.26a
$LSD_{(0.05)}$	1.636	1.765	1.747	2.073	0.3964
Phosphorous					
P_0	55.46b	72.04c	80.64c	40.10c	9.458c
P_{50}	58.51a	75.00b	84.63b	45.08b	10.29b
P_{100}	59.43a	77.24a	88.08a	47.78a	11.18a
P_{150}	59.15a	77.61a	88.93a	48.49a	11.35a
$LSD_{(0.05)}$	1.889	2.038	2.017	2.393	0.4577

In a column means having common 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_{100}: 100 kg N/ha
N_{150}: 150 kg N/ha
N_{200}: 200 kg N/ha

P_0: 0 kg P_2O_5 /ha
P_{50}: 50 kg P_2O_5 /ha
P_{100}: 100 kg P_2O_5 /ha
P_{150}: 150 kg P_2O_5 /ha

Table5.Interaction effect of nitrogen and phosphorous on plant height at 30 DAT, 60 DAT and at final harvest, number of leaves per plant at 60 DAT and number of branches per plant at harvesting period of tomato

Treatments (N×P)	Plant height at (cm)			No of leaves /plant at	No of branches / plant at
	30 DAT	60 DAT	Harvest	60 DAT	Harvest
N_0 P_0	52.77d	68.23h	75.44i	35.87e	8.39h
N_0 P_{50}	56.50bc	70.51gh	79.50h	39.52de	9.40g
N_0 P_{100}	58.55ab	72.85efg	82.80gh	41.50cd	10.32def
N_0 P_{150}	56.82bc	71.51fgh	82.95fgh	42.01cd	10.56def
N_{100} P_0	54.43cd	72.38fg	80.40h	39.53de	9.69fg
N_{100} P_{50}	58.15ab	75.35cdef	84.30efg	43.38cd	10.32def
N_{100} P_{100}	58.25ab	77.38bcd	87.51cde	44.42c	10.77cde
N_{100} P_{150}	58.17ab	77.97abcd	87.98cde	45.00c	10.99bcd
N_{150} P_0	56.71bc	73.23efg	82.20gh	41.67cd	9.82fg
N_{150} P_{50}	58.46ab	76.72bcde	86.71def	45.31c	10.57def
N_{150} P_{100}	60.03ab	78.76abc	89.82bcd	49.84b	11.57abc
N_{150} P_{150}	59.86ab	79.49ab	91.15abc	50.87b	11.66ab
N_{200} P_0	57.92abc	74.34defg	84.52efg	43.31cd	9.93efg
N_{200} P_{50}	60.94a	77.43bcd	88.00cde	52.10ab	10.87bcd
N_{200} P_{100}	60.91a	79.99ab	92.20ab	55.36a	12.05a
N_{200} P_{150}	61.74a	81.84a	93.62a	56.09a	12.19a
$LSD_{(0.05)}$	3.272	3.529	3.494	4.145	0.7927
CV(%)	3.37	2.80	2.45	5.48	4.50

In a column means having common 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_{100}: 100 kg N/ha | **P_{50}: 50 kg P_2O_5 /ha**
N_{150}: 150 kg N/ha | **P_{100}: 100 kg P_2O_5 /ha**
N_{200}: 200 kg N/ha | **P_{150}: 150 kg P_2O_5 /ha**

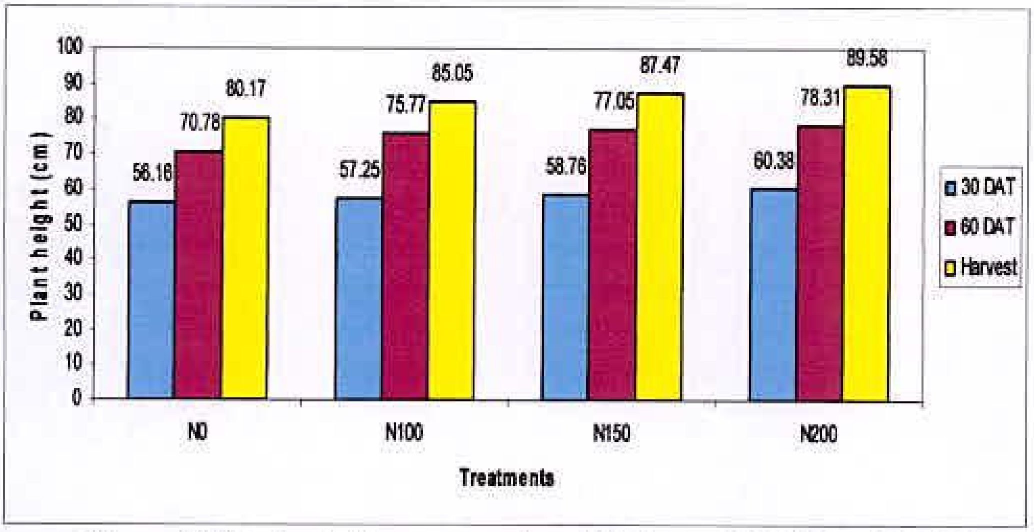


Figure 2.Effect of nitrogen on plant height at 30 DAT, 60 DAT and harvesting period of tomato.

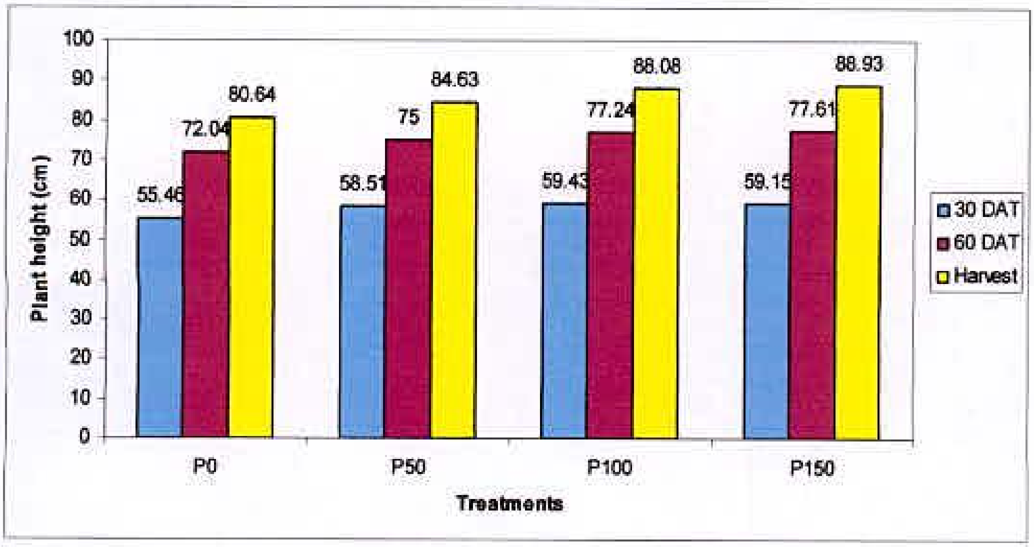


Figure 3.Effect of phosphorous on plant height at 30 DAT, 60 DAT and harvesting period of tomato.

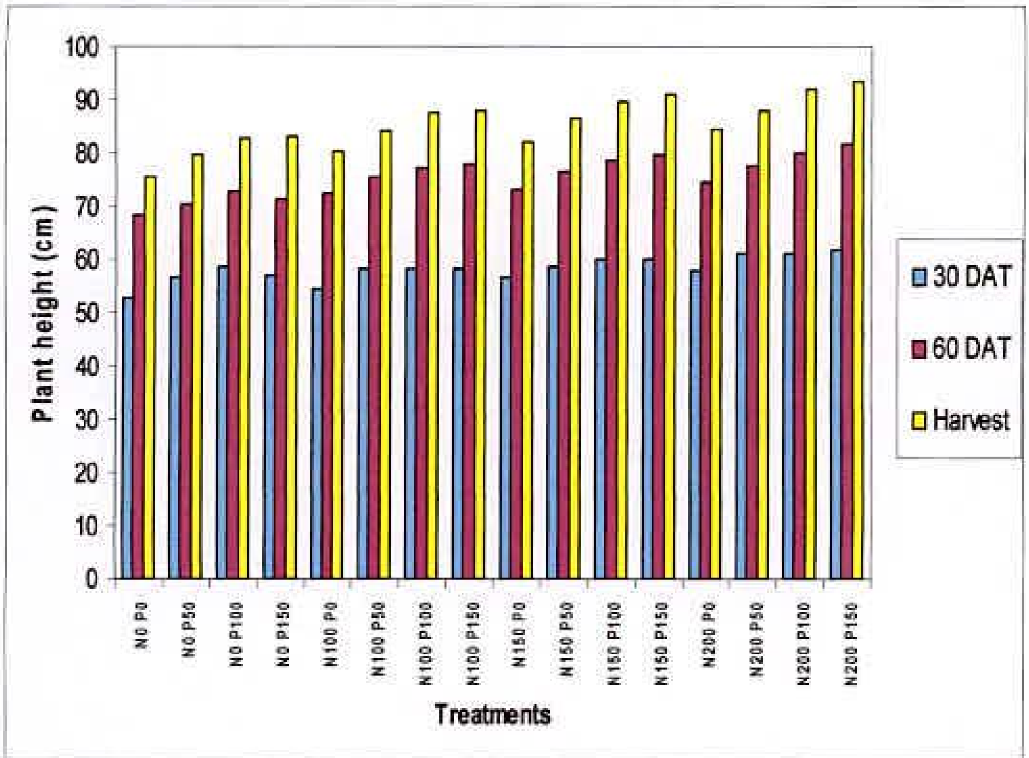


Figure 4. Interaction effect of nitrogen and phosphorous on plant height at 30 DAT, 60 DAT and harvesting period of tomato.

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). At 30 day after transplanting (30 DAT) the maximum plant height (61.74 cm), was recorded from N_{200} P_{150} treatment consisting of 200 kg N/ha +150 kg P_2O_5/ha which was statistically identical (60.94 cm) (Figure 4) with $N_{200}P_{50}$ treatment as 200 kg N/ha +50 kg P_2O_5/ha and (60.91cm) with$N_{200}P_{100}$ treatment as200 kg N/ha+ 100 kg P_2O_5/ha. The minimum plant height (52.77 cm) was recorded from N_0P_0 treatment which was statistically identical (54.43cm) by $N_{100}P_0$ treatment as 100 kg N /ha+0 kg P_2O_5/ha. (Table 5)

At 60 days after transplanting (60 DAT) the maximum plant height (81.48 cm), was recorded from N_{200} P_{150} treatment consisting of 200 kg N/ha +150 kg P_2O_5/ha which was statistically identical (79.994cm) (Figure 4) with $N_{200}P_{100}$ treatment as 200 kg N/ha +100 kg P_2O_5/ha. The minimum plant height (68.23cm) was recorded from N_0P_0 treatment which was statistically similar (70.51cm) followed by N_0P_{50} treatment as 0kgN /ha+50 kg P_2O_5/ha. (Table 5)

During the harvesting period, the maximum plant height (93.62 cm), was recorded from N_{200} P_{150} treatment consisting of 200 kg N/ha +150 kg P_2O_5/ha which was statistically identical (92.20 cm) (Figure 4) with $N_{200}P_{100}$ treatment as 200 kg N/ha +100kg P_2O_5/ha. The minimum plant height (75.44cm) was recorded fromN_0P_0 treatment that is control condition which was similar to (79.50cm) N_0P_{50} treatment as 0kgN /ha+50 kg P_2O_5/ha. (Table 5)

4.1.2 Number of leaves per plant at 60 DAT

Number of leaves per plant varied significantly due to application of nitrogen in tomato under the present trial (Appendix II). At 60 days after transplanting (60 DAT) the highest number of plant leaves (51.72), was recorded from N_{200} treatment consisting of 200 kg N/ha and the lowest number plant leaves (39.72) was recorded from N_0 treatment (Table 4) .The ranges of number of leaves per plant at 60 DAT incase of nitrogen application was 39.72 to 51.72

Different level of phosphorous showed statistically significant differences for plant leaves (Appendix II). At 60 days after transplanting (60 DAT) the number plant leaves (48.49), was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha which was statistically identical with P_{100} treatment (47.78) as 100 kg P_2O_5/ha and the minimum number of plant leaves (40.10) was recorded from P_0 treatment (Table 4). The ranges of number of leaves per plant at 60 DAT incase of phosphorous application was 40.10 to 48.49

In the interaction effect, data recorded between nitrogen and phosphorous in consideration of plant leaves under the present experiment and found statistically significant variation (Appendix II). At 60 days after transplanting (60 DAT) the maximum number of plant leaves (56.09) was recorded from N_{200} P_{150} treatment consisting of 200kg N/ha +150kg P_2O_5/ha which was statistically identical(55.36) with $N_{200}P_{100}$ treatment as 200 kg N/ha +100 kg P_2O_5/ha. The minimum number of plant leaves (35.87) was observed from N_0P_0 treatment which was statistically similar (39.52) to the N_0P_{50} treatments as 0kgN /ha+50 kg P_2O_5/ha (Table 5)

4.1.3 Number of branches per plant at final harvest

In response of number of branches per plant varied significantly due to application of nitrogen in tomato under the present trial (Appendix II). At final harvesting period, the large number of branches per plant (11.26), was observed from N_{200} treatment consisting of 200kg N/ha and which was statistically identical (10.90) with N_{150} treatment as 150 kg N/ha and the lowest number of branches per plant (9.668) was observed from N_0 treatment (Table 4). The ranges of number of branches per plant at at final harvest incase of nitrogen application was 9.66 to 11.26

Different level of phosphorous showed statistically significant differences for plant leaves (Appendix II). At final harvesting period, the large number of branches per plant (11.35), was recorded from P_{150} treatment consisting of 150kg P_2O_5/ha which was statistically identical(11.18) with P_{100} treatment as 100kg P_2O_5/ha and the minimum branches per plant (9.45) was recorded from P_0 treatment (Table .4). The ranges of number of branches per plant at final harvest incase of phosphorous application was 9.45 to 11.35

Due to interaction effect, the recorded data between nitrogen and phosphorous in consideration of number of branches per plant found statistically significant (Appendix II). At final harvesting period the maximum number of branches per plant (12.19) was recorded fromN_{200} P_{150} treatment consisting of 200 kg N/ha +150 kg P_2O_5/ha which was statistically identical (12.05) with $N_{200}P_{100}$ treatment as 200 kg N/ha +100 kg P_2O_5/ha. The minimum number of branches per plant (8.39) was recorded from N_0P_0 treatment which was statistically similar (9.40) followed by N_0P_{50} treatment as 0 kg N /ha+50 kg P_2O_5/ha (Table 5)

Table6. Effect of nitrogen and phosphorous on number of cluster / plant, number of flowers/ cluster, number of flowers/ plant, number of fruits/ cluster, number of fruits/ plant, rate of fruit setting (%) of tomato.

Treatments	Number of cluster / plant	Number of flowers/ cluster	Number of flowers/ plant	Number of fruits/ cluster	Number of fruits/ plant	Rate of fruit setting(%)
Nitrogen						
N_0	6.35d	4.520b	30.41c	3.325b	21.75c	71.27b
N_{100}	7.537c	4.813a	37.46b	3.697a	27.86b	74.63a
N_{150}	8.432b	4.932a	42.41a	3.820a	32.33a	75.60a
N_{200}	8.800a	4.943a	44.63a	3.828a	33.77a	75.71a
LSD	0.3142	0.1625	1.991	0.2059	1.687	2.556
Phosphorous						
P_0	6.365c	4.452c4.	30.01c	2.525b	22.59c	74.80a
P_{50}	7.645b	4.805b	37.88b	3.630ab	27.89b	73.50a
P_{100}	8.530a	4.947ab	43.38a	3.787a	32.49a	74.71a
P_{150}	8.580a	5.003a	44.02a	3.727ab	32.75a	74.19a
LSD	0.3628	0.1877	2.299	0.23783.	1.948	NS

In a column means having common 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_{100}: 100 kg N/ha

N_{150}: 150 kg N/ha

N_{200}: 200 kg N/ha

P_0: 0 kg P_2O_5 /ha

P_{50}: 50 kg P_2O_5 /ha

P_{100}: 100 kg P_2O_5 /ha

P_{150}: 150 kg P_2O_5 /ha

Table 7. Interaction effect of nitrogen and phosphorous number of cluster / plant, number of flowers/ cluster, number of flowers/ plant, number of fruits/ cluster, number of fruits/ plant, rate of fruit setting (%) of tomato

Treatments (N×P)	Number of cluster / plant	Number of flowers/ cluster	Number of flowers/ plant	Number of fruits/ cluster	Number of fruits/ plant	Rate of fruit setting (%)
N_0 P_0	5.01g	4.100e	23.52h	3.210d	16.08f	68.37b
N_0 P_{50}	6.41f	4.520d	29.97fg	3.330bcd	21.35e	71.24ab
N_0 P_{100}	6.98def	4.690bcd	33.74def	3.520abcd	24.57de	72.82ab
N_0 P_{150}	7.00def	4.770abcd	34.39de	3.240cd	24.99de	73.66ab
N_{100} P_0	6.32f	4.420de	28.89g	3.520abcd	22.21e	76.88a
N_{100} P_{50}	7.53cd	4.780abcd	36.99cd	3.680abc	27.71cd	74.91a
N_{100} P_{100}	8.00bc	4.910abc	40.28bc	3.750ab	30.00bc	74.48a
N_{100} P_{150}	8.30b	5.140a	43.66b	3.840a	31.54b	72.24ab
N_{150} P_0	6.75ef	4.620cd	32.19efg	3.670abcd	24.77de	76.94a
N_{150} P_{50}	8.00bc	4.910abc	40.28bc	3.770ab	30.16bc	74.88a
N_{150} P_{100}	9.54a	5.100a	49.65a	3.890a	37.11a	74.74a
N_{150} P_{150}	9.44a	5.100a	49.14a	3.950a	37.29a	75.84a
N_{200} P_0	7.38cde	4.670bcd	35.46de	3.700abc	27.31cd	77.02a
N_{200} P_{50}	8.64b	5.010ab	44.29b	3.740ab	32.32b	72.97ab
N_{200} P_{100}	9.60a	5.090a	49.86a	3.990a	38.30a	76.82a
N_{200} P_{150}	9.58a	5.00ab	48.90a	3.880a	37.17a	76.01a
$LSD_{(0.05)}$	0.6284	.3251	3.983	0.4118	3.375	5.112
CV	4.84	4.08	6.15	6.74	7.00	4.13

In a column means having common 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_{100}: 100 kg N/ha — **P_{50}: 50 kg P_2O_5 /ha**
N_{150}: 150 kg N/ha — **P_{100}: 100 kg P_2O_5 /ha**
N_{200}: 200 kg N/ha — **P_{150}: 150 kg P_2O_5 /ha**

4.1.4 Number of flower clusters per plant

Application of nitrogen in tomato under the present trial data were found statistically significant in respect of number of flower clusters per plant (Appendix III).The no of largest number flower clusters per plant (8.800), was found from N_{200} treatment consisting of 200kg N/ha and on the other hand the lowest number of flower clusters per plant (6.350) was recorded from N_0 treatment. Found the similar result that is application of 240 kg N/ha ensured the favorable condition for growth of tomato plant and the ultimate result is the number of flower cluster per plant. Grela *et al.* (1988) put forward almost similar opinion. (Table 6)

Different level of phosphorous data showed statistically significant differences for flower clusters per plant (Appendix III). The maximum number of flower clusters per plant (8.580) was found from P_{150} treatment consisting of 150 kg P_2O_5/ha which was statistically identical (8.530) with P_{100} treatment as 100 kg P_2O_5/ha whereas the minimum number of flower clusters per plant (6.365) was recorded from P_0 treatment under the present trial. With increasing level of phosphorous, plant growth increases and the number of flower clusters per plant also increases (Table 6)

In the interaction effect, data was also recorded between nitrogen and phosphorous in consideration of plant flower clusters under the present experiment and found statistically significant variation (Appendix III). The maximum flower clusters per plant (9.60) was recorded from N_{200} P_{100} treatment consisting of 200 kg N/ha +100 kg P_2O_5/ha which was statistically identical (9.580) with $N_{200}P_{150}$ treatment as 200 kg N/ha +150 kg P_2O_5/ha, (9.540) with $N_{150}P_{100}$ treatment as 150 kg N/ha +100 kg P_2O_5/ha and (9.440) with $N_{150}P_{150}$ treatment as 150 kg N/ha +150 kg P_2O_5/ha. The minimum flower clusters per plant (5.01) was recorded from N_0P_0 treatment that is control condition (Table 7)

4.1.5 Number of flowers per cluster

Number of flowers per cluster varied significantly due to application of nitrogen in tomato under the present trial (Appendix III).The highest number of flowers per cluster (4.943) was observed from N_{200} treatment consisting of 200 kg N/ha, which was statistically identical with N_{150} treatment (4.932) consisting of 150 kg N/ha, (4.813) with N_{100} treatment consisting of 100 kg N/ha and the lowest number of flowers per cluster (4.520) was found from N_0 treatment (Table 6)

Different level of phosphorous application showed statistically significant difference for flowers no. per clusters (Appendix III). The maximum number of flowers per clusters (5.003) was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha which was statistically identical with P_{100} treatment (4.947) as 100 kg P_2O_5/ha and the minimum number of flowers per cluster (4.452) was recorded from P_0 treatment (Table 6)

Due to interaction effect, data was also recorded between nitrogen and phosphorous in consideration of plant flowers no. per cluster and found statistically significant variation (Appendix III). The maximum number of flowers per cluster (5.140) was found from $N_{100}P_{150}$ treatment consisting of 100 kg N/ha +150 kg P_2O_5//ha which was statistically identical with both $N_{150}P_{100}$ and $N_{150}P_{150}$ treatment (5.100) as 150 kg N/ha +100 kg P_2O_5//ha, and as 150 kg N/ha +150 kg P_2O_5/ha, respectively and also (5.090) with $N_{200}P_{100}$treatment as 200 kg N/ha +100 kg P_2O_5/ha. The minimum number of flowers per cluster (4.100) were recorded from N_0P_0 treatment which was statistically identical with the treatment $N_{100}P_0$ (4.420) as 100 kg N/ha +0 kg P_2O_5/ha (Table 7)

4.1.6 Number of flowers per plant

Application of different doses of nitrogen fertilizer in tomato, number of flowers per plant varied significantly (Appendix III). The maximum number of flowers per plant (44.63) was recorded from N_{200} treatment consisting of 200 kg N/ha, which was statistically identical (42.81) with N_{150} treatment consisting of 150kg N/ha, and the minimum number of flowers per plant (30.41) was recorded from N_0 treatment (Table 6). The ranges of number of flowers per plant incase of nitrogen application was 30.41 to 44.63

Due to different level of phosphorous data showed statistically significant difference for flowers no. per plant (Appendix III). The highest number of flowers per plant (44.02), was observed from P_{150} treatment consisting of 150 kg P_2O_5/ha which was statistically identical with P_{100} treatment (43.38) as 100 kg P_2O_5/ha and the lowest number of flowers per plant was recorded from P_0 treatment (30.01) (Table 6) . The ranges of number of flowers per plant incase of phosphorous application was 30.01 to 44.02

In respect of interaction effect of data was recorded between nitrogen and phosphorous in consideration of flowers number per plant and observed statistically significant variation (Appendix III). The maximum number of flowers per plant (49.86) was recorded from $N_{200}P_{100}$ treatment consisting of 200 kg N/ha +100 kg P_2O_5/ha which was statistically identical, with $N_{150}P_{100}$ (49.65), $N_{150}P_{150}$ (49.14) and $N_{200}P_{150}$ (48.90) treatment as 150 kg N/ha +100 kg P_2O_5/ha, 150 kg N/ha +150 kg P_2O_5/ha, and as 200 kg N/ha +150 kg P_2O_5/ha respectively. The minimum number of flowers per plant were recorded fromN_0P_0 (23.52) treatment (Table 7)

4.1.7 Number of fruits per cluster

Number of fruits per cluster varied significantly due to application different doses of nitrogen in tomato under the present trial (Appendix III).The highest number of fruits per cluster (3.828) was recorded from N_{200} treatment consisting of 200 kg N/ha, which was statistically identical with N_{150} treatment (3.820) consisting of 150 kg N/ha, (3.697) with N_{100} treatment consisting of 100 kg N/ha and the lowest number of fruits no cluster (3.325) was recorded from N_0 treatment (Table 6). The ranges of number of fruits per cluster incase of nitrogen application was 3.325 to 3.828

Application of different levels of phosphorous showed statistically significant difference for fruits number per clusters (Appendix III). The maximum number of fruits per clusters (3.787), was recorded from P_{100} treatment consisting of 100 kg P_2O_5/ha which was statistically identical with P_{150} treatment (3.727) as 150 kg P_2O_5/ha and with P_{50} treatment (3.630) as 50 kg P_2O_5/ha. The minimum numbers of fruits per cluster (3.525) were recorded from P_0 treatment. (Table 6). The ranges of number of fruits per cluster incase of phosphorous application was 3.525 to 3.787.

In this trial, interaction effect was also recorded between nitrogen and phosphorous in consideration of fruits number per cluster and found statistically significant variation (Appendix III). The maximum number of fruits per clusters (3.990), was recorded from $N_{200}P_{100}$ treatment consisting of 200 kg N/ha +100 kg P_2O_5/ha which was statistically identical with $N_{150}P_{150}$ (3.950), $N_{150}P_{100}$ (3.890) and $N_{200}P_{150}$ (3.880) treatment as 150 kg N/ha +150 kg P_2O_5/ha, as 150 kg N/ha +100 kg P_2O_5/ha and as 200 kg N/ha +150kg P_2O_5/ha, respectively. The minimum numbers of fruits per cluster were recorded fromN_0P_0 treatment (3.210) (Table 7).

4.1.8 Number of fruits per plant

Number of fruits per plant varied significantly due to application of nitrogen in tomato (Appendix III).The highest amount of fruits per plant (33.77) was recorded from N_{200} treatment consisting of 200 kg N/ha, which was statistically identical with N_{150} treatment (32.33) consisting of 150 kg N/ha, and lowest amount of fruits per plant was recorded from N_0 treatment (21.75) (Table 6). Nassar (1988) found that increased nitrogen level was tended to increase average number of fruits cluster per plant.

Due to different level of phosphorous showed statistically significant difference for fruits number per plant (Appendix III). The maximum fruits number per plant (32.75) was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha which was statistically identical with P_{100} treatment (32.49) as 100 kg P_2O_5/ha and the minimum fruits number per plant was recorded from P_0 treatment (22.59) (Table 6). With increasing levels of phosphorous, plant growth increases and which ensure maximum number of flowers and fruits per cluster as well as the number of fruits per plant.

Interaction effect was also recorded between nitrogen and phosphorous in consideration of fruits number per plant and found statistically significant variation (Appendix III). The maximum number of fruits per plant was recorded from $N_{200}P_{100}$ treatment (38.30), consisting of 200 kg N/ha +100 kg P_2O_5/ha, which was statistically identical (37.29), (37.17), (37.11) with $N_{150}P_{150}$, $N_{200}P_{150}$ and $N_{150}P_{100}$ treatment as 150 kg N/ha +150 kg P_2O_5/ha, 200 kg N/ha +150 kg P_2O_5/ha, and as 150 kg N/ha +100 kg P_2O_5/ha respectively. The minimum numbers of fruits per plant (16.08) were recorded fromN_0P_0 treatment (Table 7). These result 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. Winsor *et al.* (1962) reported that increased application of nitrogen and phosphorous has the positive effect on number of fruits per plant.

4.1.9 Rate of fruit setting (%)/ Reproductive efficiency

Rate of fruit setting (%) per plant varied significantly due to the application of nitrogen in tomato (Appendix III).The maximum fruits setting per plant (75.71) was recorded from N_{200} treatment consisting of 200 kg N/ha, which was statistically identical (75.60) with N_{150} treatment consisting of 150 kg N/ha, and (74.63) with N_{100} treatment consisting of 100 kg N/ha. The minimum fruits setting per plant (71.27) were recorded from N_0 treatment that is control condition (Table 6). Nassar (1988) found that increased nitrogen level was tended to increase average number of fruits cluster per plant. The ranges of Rate of fruit setting (%) incase of nitrogen application was 71.27to 75.71

Application of different level of phosphorous did not showed statistically significant result for rate of fruit setting (%) per plant (Appendix III). The maximum Rate of fruit setting (%) per plant (74.80), was recorded from P_0 treatment, which was statistically identical with all the treatments (Table 6)

Incase of interaction effect, data was recorded between nitrogen and phosphorous in consideration of rate of fruit setting (%) per plant and found statistically significant variation (Appendix III). The maximum rate of fruit setting (%) per plant (77.02), was recorded from $N_{200}P_0$ treatment consisting of 200 kg N/ha +0 kg P_2O_5//ha, which was *statistically* identical (76.94), (76.88), (76.82) with $N_{150}P_0$, $N_{100}P_0$ and $N_{200}P_{100}$ treatment as 150 kg N/ha +0 kg P_2O_5//ha, , 100 kg N/ha +0 kg P_2O_5//ha, and as 200 kg N/ha +100 kg P_2O_5//ha respectively. The minimum rate of fruit setting (%) per plant (68.37) were recorded fromN_0P_0 treatment (Table 7)

4.1.10 Weight of individual fruit

Weight of individual fruit per plant varied significantly due to application of nitrogen in tomato under the present trial (Appendix IV). On the one hand the maximum weight of individual fruit fruits per plant (83.77 gm) was recorded from N_{200} treatment consisting of 200kg N/ha, which was statistically identical (83.27 gm) with N_{150} treatment consisting of 150 kg N/ha, and on the other hand the minimum weight of individual fruit per plant (66.22 gm) was recorded from N_0 treatment that is zero level of nitrogen. (Table 8).Incase of N the maximum fruit weight (79.25 gm) was found at 200 kg N/ha which is agreement with Ahmed and Choudhury (1990).

Different level of phosphorous showed statistically significant differences for weight of individual fruit per plant in tomato (Appendix IV). The maximum weight of individual fruit per plant (81.67 gm), was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha which was statistically identical (80.96 gm) with P_{100} treatment as 100 kg P_2O_5/ha and (79.49 gm) with P_{50} treatment as 50 kg P_2O_5/ha and the minimum weight of individual fruit per plant (71.54) was recorded from P_0 treatment that is zero level of phosphorous (Table 7). The ranges of weight of individual fruit incase of phosphorous application was 71.54 gm to 81.67 gm

Incase of interaction effect, data was also recorded between nitrogen and phosphorous in consideration of weight of individual fruit per plant and found statistically significant variation (Appendix IV). When the maximum weight of individual fruit per plant (87.59 gm) was recorded from $N_{150}P_{100}$ treatment consisting of 150 kg N/ha +100 kg P_2O_5//ha which was statistically identical (87.29) both $N_{200}P_{150}$ and $N_{150}P_{150}$ treatment consisting of 200 kg N/ha +150 kg P_2O_5/ha and 150 kg N/ha +150 kg P_2O_5/ha and (86.97 gm) from $N_{200}P_{100}$ treatment consisting of 200 kg N/ha +100 kg P_2O_5/ha, then minimum weight of individual fruit per plant (63.85 gm) was recorded fromN_0P_0 treatment (Table 9)

4.1.11Fruit size (Fruit length)

Length of fruit incase of fruit size of tomato plant varied significantly due to application of nitrogen in tomato (Appendix IV).The highest fruit length (5.320 cm) was recorded from N_{150} treatment consisting of 150 kg N/ha, which was statistically identical (5.278 cm) with N_{200} treatment consisting of 200kg N/ha, and (5.225cm) with N_{100} treatment consisting of 100 kg N/ha, the minimum fruit length (4.605cm) was recorded from N_0 treatment that zero level of nitrogen (Table 8)

Due to different level of phosphorous, data showed statistically significant difference for fruit length of plant (Appendix IV). The maximum fruit length (5.262 cm) was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha and the minimum fruit length (4.960 cm) was recorded from P_0 treatment that is zero level of phosphorous (Table 8)

Incase of interaction effect, data was recorded between nitrogen and phosphorous in consideration of fruit length under the present experiment and found statistically significant variation (Appendix IV). The maximum fruit length (5.610cm) was recorded from $N_{150}P_{150}$ treatment consisting of 150 kg N/ha +100 kg P_2O_5/ha, and the minimum fruit length per plant (4.52cm) was recorded from N_0P_0 treatment (Table 9)and founds with N_0P_{150}, N_0P_{100} and N_0P_{150} treatments. Islam *et al.* (1997) showed that the length and breadth of individual fruit increased with increasing of nitrogen level.

4.1.12 Fruit size (Fruit breadth)

Breadth of individual fruit per plant incase of fruit size varied significantly due to the application of nitrogen in tomato (Appendix IV).The highest fruit breadth (5.88cm) was found from N_{200} treatment consisting of 200 kg N/ha, which was statistically identical (5.80cm) with both N_{150} and N_{100} treatment consisting of 150kg N/ha, and 100 kg N/ha. And the lowest fruit breadth (4.283cm) was recorded from N_0 treatment (Table 8). The ranges of Fruit breadth incase of nitrogen application were 4.283cm to 5.88 cm.

In regard of different level of phosphorous data showed statistically significant difference for fruit breadth per plant (Appendix IV). The maximum fruit breadth (4.600cm) was observed from P_{150} treatment consisting of 150 kg P_2O_5/ha which was statistically identical (4.568cm) with P_{100} treatment as 100 kg P_2O_5/ha while (4.505cm) with P_{50} treatment as 50 kg P_2O_5/ha and the minimum fruit breadth

(4.358cm) was recorded from P_0 treatment (Table 8) The ranges of Fruit breadth incase of phosphorous application were 4.358 cm to 4.600 cm.

Due to interaction effect was also recorded between nitrogen and phosphorous in consideration of fruit breadth per plant and also found statistically significant variation (Appendix IV). The maximum fruit breadth per plant (4.700cm) was recorded from both $N_{100}P_{100}$ and $N_{150}P_{100}$ treatment consisting of 100 kg N/ha +100 kg P_2O_5/ha and $N_{150}P_{100}$ treatment consisting of 150 kg N/ha +100 kg P_2O_5//ha and on the other hand the minimum fruit breadth (4.11cm) was recorded from N_0P_0 treatment (Table 9) where no fertilizers were applied.

4.1.13 Fruit weight per plant (kg)

Weight of fruit per plant varied significantly due to the application of different doses of nitrogen in tomato (Appendix IV).The maximum weight fruit fruits per plant (2.125 kg) was recorded from N_{200} treatment consisting of 200 kg N/ha, while the minimum weight of fruit per plant (1.085kg) was observed from N_0 treatment (Table 8). The ranges of fruit weight per plant incase of nitrogen application were 1.085 kg to 2.125 kg. Chung *et al.* (1992) reported that increasing levels of nitrogen increased the fresh weight of tomato fruit.

Due to different level of phosphorous application data showed statistically significant difference for weight of fruit per plant (Appendix IV). The maximum weight of fruit per plant (2.033kg) was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha which was statistically identical (2.007kg) with P_{100} treatment as 100 kg P_2O_5/ha and where as the minimum weight of fruits per plant (1.225kg) was recorded from P_0 treatment (Table 8). Ahmed and Choudhury (1990) reported that with increasing the level of phosphorous, plant growth increases and which ensure maximum number of flower and fruits per cluster as well as the weight of fruits.

Table 8. Effect of nitrogen and phosphorous on fruit size, weight of individual fruit (gm), fruit weight /plant (kg), fruit yield (ton/h), yield increase over control (%) of tomato

Treatment	Fruit size		Weight of individual fruit (gm)	Fruit weight /plant (kg)	Fruit yield (ton/ha)
	Length (cm)	Breadth (cm)			
Nitrogen					
N_0	4.605b	4.289b	66.22c	1.085d	39.00d
N_{100}	5.225a	4.580a	80.40b	1.690c	60.91c
N_{150}	5.320a	4.580a	83.77a	2.050b	73.80b
N_{200}	5.278a	4.588a	83.27a	2.125a	76.52a
LSD	0.114	0.087	2.121	0.058	1.919
Phosphorous					
P_0	4.960c	4.358b	71.54b	1.225c	44.11c
P_{50}	5.080bc	4.505a	79.49a	1.685b	60.62b
P_{100}	5.125b	4.568a	80.96a	2.007a	72.24a
P_{150}	5.262a	4.600a	81.67a	2.033a	73.26a
LSD	0.132	0.101	2.449	0.068	2.216

In a column means having common 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_{100}: 100 kg N/ha
N_{150}: 150 kg N/ha
N_{200}: 200 kg N/ha

P_0: 0 kg P_2O_5 /ha
P_{50}: 50 kg P_2O_5 /ha
P_{100}: 100 kg P_2O_5 /ha
P_{150}: 150 kg P_2O_5 /ha

Table 9. Interaction effect of nitrogen and phosphorous fruit size, weight of individual fruit (gm), fruit weight /plant (kg), fruit yield (ton/h), yield increase over control (%) of tomato.

Treatments (N×P)	Fruit size		Weight of individual fruit (gm)	Fruit weight /plant (kg)	Fruit yield (ton/ha)
	Length (cm)	Breadth (cm)			
$N_0 P_0$	4.520e	4.110f	63.85d	0.7700i	27.72j
$N_0 P_{50}$	4.600e	4.300e	67.37d	1.080h	38.83i
$N_0 P_{100}$	4.650e	4.320de	65.99d	1.220g	43.78h
$N_0 P_{150}$	4.650e	4.400de	67.68d	1.270g	45.67h
$N_{100} P_0$	4.900d	4.420cde	73.03c	1.220g	43.79h
$N_{100} P_{50}$	5.200c	4.500abcd	80.86b	1.680d	60.50e
$N_{100} P_{100}$	5.300bc	4.700a	83.31ab	1.870c	67.48d
$N_{100} P_{150}$	5.500ab	4.700a	84.41ab	1.990bc	71.88bc
$N_{150} P_0$	5.200c	4.450bcde	74.87c	1.390f	50.07g
$N_{150} P_{50}$	5.220c	4.620ab	85.32ab	1.930bc	69.48cd
$N_{150} P_{100}$	5.250bc	4.600abc	87.59a	2.440a	87.76a
$N_{150} P_{150}$	5.610a	4.650ab	87.29a	2.440a	87.89a
$N_{200} P_0$	5.220c	4.450bcde	74.41c	1.520e	54.87f
$N_{200} P_{50}$	5.300bc	4.600abc	84.42ab	2.050b	73.67b
$N_{200} P_{100}$	5.300bc	4.650ab	86.97a	2.500a	89.93a
$N_{200} P_{150}$	5.290bc	4.650ab	87.29a	2.430a	87.60a
$LSD_{(0.05)}$	0.2299	0.1749	4.242	0.1179	3.839
CV(%)	2.67	2.36	3.24	3.98	3.68

In a column means having common 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_{100}: 100 kg N/ha	**P_{50}: 50 kg P_2O_5 /ha**
N_{150}: 150 kg N/ha	**P_{100}: 100 kg P_2O_5 /ha**
N_{200}: 200 kg N/ha	**P_{150}: 150 kg P_2O_5 /ha**

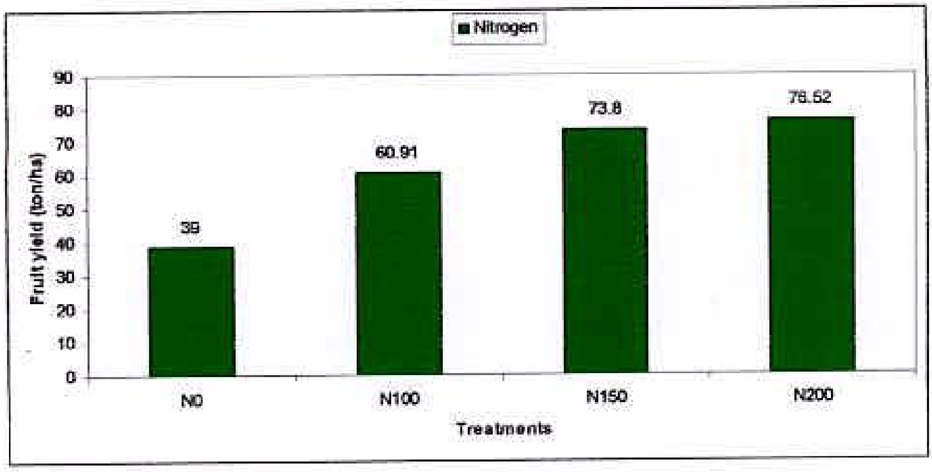
Interaction effect was also recorded between nitrogen and phosphorous in consideration of weight of fruits per plant and found statistically significant variation (Appendix IV). The highest weight of fruits per plant (2.500 kg) was recorded from $N_{200}P_{100}$ treatment consisting of 200 kg N/ha +100 kg P_2O_5/ha which was statistically identical (2.440 kg), both $N_{150}P_{100}$ and $N_{150}P_{150}$ treatment consisting of 150 kg N/ha +100 kg P_2O_5/ha and 150 kg N/ha +150 kg P_2O_5//ha and (2.430 kg) from $N_{200}P_{150}$ treatment consisting of 200 kg N/ha +150 kg P_2O_5/ha. While the lowest weight of fruits per plant (0.770 kg) was recorded fromN_0P_0 treatment (Table 9). Ahmed and Choudhury (1990) revealed that higher dose of nitrogen and phosphorous is influential nutrient for attaining better growth and ultimate results was desirable growth with maximum number of flower and fruit per cluster and highest weight of fruits per plant.

4.1.14 Fruit yield (ton/ha)

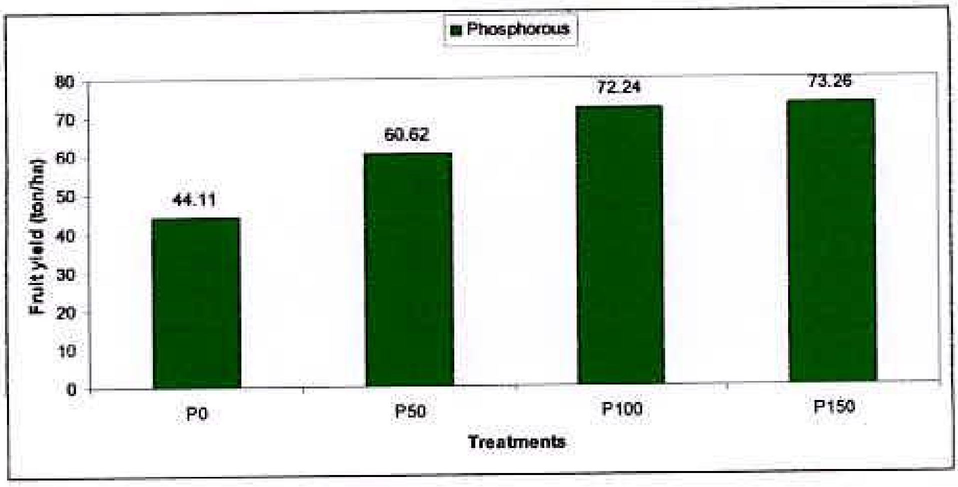
Fruit yield of tomato varied significantly due to application of nitrogen in tomato (Appendix IV).The maximum fruit yield (76.72 ton/ha) (Figure 5) was recorded from N_{200} treatment consisting of 200 kg N/ha, and the minimum fruit yield (39.00 ton/ha) was recorded from N_0 treatment (Table 8). Chung *et al.* (1992) reported that increasing levels of nitrogen increased the fresh weight of tomato fruit as well as fruit yield.

Different level of phosphorous showed statistically significant difference for fruit yield in tomato (Appendix IV). The maximum fruit yield (73.26 ton/ha) was found from P_{150} treatment consisting of 150 kg P_2O_5/ha which was statistically identical (72.24 ton/ha) (Figure 6) with P_{100} treatment as 100 kg P_2O_5/ha and while the minimum fruit yield (44.11 ton/ha) was recorded from P_0 treatment (Table 8). With increasing the level of phosphorous, plant growth increases and which ensure maximum number of flower and fruits per cluster as well as the weight of fruits and also increase the fruit yield of tomato.

Interaction effect was also recorded between nitrogen and phosphorous in consideration of fruit yield of tomato and found statistically significant variation (Appendix IV). The maximum fruit yield (89.93 ton/ha) was recorded from $N_{200}P_{100}$ treatment consisting of 200 kg N/ha +100 kg P_2O_5/ha (Figure 7) which was statistically identical (87.89 ton/ha),(87.76 ton/ha) and (87.60 ton/ha) with $N_{150}P_{150}$



Fugure 5.Effect of nitrogen on the yield (ton/ha) of tomato



Fugure 6.Effect of phosphorous on the yield (ton/ha) of tomato

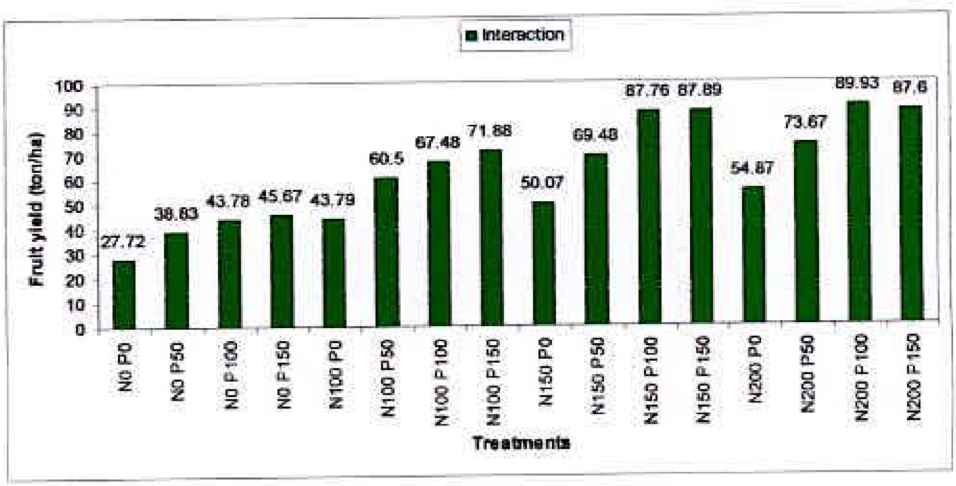


Figure 7. Interaction effect of nitrogen and phosphorous on the yield (ton/ha) of tomato

$N_{150}P_{100}$ and $N_{200}P_{150}$ treatment consisting of 150 kg N/ha +150 kg P_2O_5/ha ,150 kg N/ha +100 kg P_2O_5/ha and 200 kg N/ha +150 kg P_2O_5/ha, respectively. The minimum fruit yield (27.72 ton/ha) was recorded from N_0P_0 treatment (Table 9).

4.2Nutrient content in straw

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

4.2.1 Nitrogen content (%) in straw

Application of different level of nitrogen showed a statistically significant variation for nitrogen content in straw of tomato (Appendix VI). The maximum nitrogen content (1.742%) was recorded from N_{200} treatment consisting of 200 kg N/ha, which was closely (1.487%) followed by N_{150} treatment as 150 kg N/ha and the minimum nitrogen content (0.74%) (Figure 8) was recorded from N_0 treatment, which was closely (1.357%) followed by N_{100} treatment as 100 kg N/ha (Table 10). The ranges of Nitrogen content (%) in straw incase of nitrogen application were 0.74% to 1.742%. Highest application of nitrogen accelerated nitrogen uptake by plant and the ultimately result is the highest nitrogen content in tomato shoot or straw. Soares *et al.* (1986) reported that N fertilization increased N content in the straw and fruits. Velenzuela *et al.* (1987) also reported that straw N content was increased with increasing rates of applied N

Due to application of different level of phosphorous data showed statistically significant differences for Nitrogen content in tomato shoot or straw (Appendix VI). The maximum nitrogen content (1.497%), was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha (Figure 9) which was statistically identical (1.423%) with P_{100} treatment as 100 kg P_2O_5/ha and the minimum nitrogen content (1.115%) was recorded from P_0 treatment which was closely (1.293%) followed by P_{50} treatment as 50 kg P_2O_5/ha (Table 10). The ranges of nitrogen content (%) in straw incase of phosphorous application were 1.115% to 1.497%.

In regard to interaction effect was also recorded between nitrogen and phosphorous in consideration of nitrogen content in tomato shoot or straw and found statistically significant variation (Appendix VII). The maximum nitrogen content in tomato shoot or straw (2.040%) (Figure 10) was recorded from $N_{200}P_{150}$ treatment consisting of 200 kg N/ha +150 kgP_2O_5/ha. The minimum nitrogen content in tomato shoot or straw (0.50%) was recorded from N_0P_0 treatment (Table11).

4.2.2 Phosphorous content (ppm) in straw or shoot:

Effect of different level of nitrogen showed a statistically significant variation for phosphorous content (ppm) in straw or shoot of tomato (Appendix VI). The maximum phosphorous content (55.98 ppm) (Figure 11) was recorded from N_{200} treatment consisting of 200 kg N/ha, which was closely (50.88 ppm) followed by N_{150} treatment as 150 kg N/ha and the minimum phosphorous content (32.25 ppm) was recorded from N_0 treatment, which was closely (40.65 ppm) followed by N_{100} treatment as 100 kg N/ha (Table 10). The ranges of Phosphorous content (ppm) in straw incase of nitrogen application were 32.25 ppm to 55.98 ppm.

Application of different level of phosphorous showed statistically significant difference for phosphorous content in tomato shoot or straw (Appendix VI). The maximum phosphorous content (55.80 ppm) was observed from P_{150} treatment consisting of 150 kg P_2O_5/ha which was closely (52.48 ppm) (Figure 12) followed by P_{100} treatment as 100 kg P_2O_5/ha, and the minimum phosphorous content (28.80 ppm) was recorded from P_0 treatment (Table 10). Wateren and Coltman (1988) reported that increasing P levels increased shoot P concentrations. Dhinakaran and Savitri (1997) found that P content of tomato fruit increased with increased application of P.

Due to interaction effect, data was recorded between nitrogen and phosphorous in consideration of phosphorous content in tomato shoot or straw and found statistically significant variation (Appendix VI). The highest amount of phosphorous content in tomato shoot or straw (70.00 ppm) (Figure 13) was recorded from $N_{200}P_{150}$ treatment consisting of 200 kg N/ha +150 kgP_2O_5/ha. The lowest amount of phosphorous content in tomato shoot or straw (25.00 ppm) was recorded from N_0P_0 treatment that is control condition (Table 11).

4.2.3 Potassium content (%) in straw or shoot:

Application of different level of nitrogen, data showed a statistically significant variation for Potassium content (%) in straw or shoot of tomato (Appendix VI). The maximum potassium content (1.813%) was recorded from N_{200} treatment consisting of 200 kg N/ha, and the minimum potassium content (1.344%) was recorded from N_0

treatment that is control condition (Table.10). The ranges of potassium content (%) in straw or shoot incase of nitrogen application were 1.344%to 1.813%.

Different level of phosphorous showed statistically significant difference for potassium content (%) in tomato shoot or straw (Appendix VI). The maximum potassium content (1.719%), was recorded from P_{150} treatment consisting of 150kg P_2O_5/ha which was statistically identical (1.702%) P_{100} treatment as 100 kg P_2O_5/ha, and the minimum potassium content (1.355%) was recorded from P_0 treatment (Table 10). The ranges of potassium content (%) in straw or shoot incase of phosphorous application were 1.355% to 1.719%. Windders and Lorenz (1982) reported that tomato shoot contains 1.25% to 2.75% of potassium.

Due to interaction effect was also recorded between nitrogen and phosphorous in consideration of potassium content (%) in tomato shoot or straw and found statistically significant variation (Appendix VI). The maximum potassium content in tomato shoot or straw (2.0%) was recorded from both $N_{200}P_{150}$ and $N_{200}P_{100}$ treatment consisting of 200 kg N/ha +150 kgP_2O_5//ha and 200 kg N/ha +100 kg P_2O_5//ha. The minimum Potassium content in tomato shoot or straw (1.25%) was recorded fromN_0P_0 treatment (Table 11).

Table 10. Effect of nitrogen and phosphorous on nitrogen (%) in straw, phosphorous (P) in (ppm) in straw, potassium (K) in (%) straw, nitrogen % in fruit, phosphorous % in fruit, potassium % in fruit

Treatments	Nitrogen in straw (%)	Phosphorous (P)in straw (ppm)	Potassium (K) in straw (%)	N in fruit (%)	P in fruit (%)	K% in fruit
Nitrogen						
N_0	0.740d	32.25d	1.344d	2.852c	0.200c	3.765a
N_{100}	1.357c	40.65c	1.500c	3.257b	0.227b	3.842a
N_{150}	1.457b	50.88b	1.620b	3.600a	0.247a	3.890a
N_{200}	1.742a	55.98a	1.813a	3.662a	0.240ab	3.903a
LSD(0.05)	0.074	1.947	0.079	0.131	0.0186	0.1318
Phosphorous						
P_0	1.115c	28.80d	1.355c	3.155c	0.190c	3.745a
P_{50}	1.293b	42.67c	1.500b	3.280bc	0.225b	3.852a
P_{100}	1.423a	52.48b	1.702a	3.425ab	0.245ab	3.895a
P_{150}	1.497a	55.80a	1.719a	3.513a	0.255a	3.908a
LSD(0.05)	0.086	2.249	0.091	0.152	0.0215	0.1522

In a column means having common 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_{100}: 100 kg N/ha
N_{150}: 150 kg N/ha
N_{200}: 200 kg N/ha

P_0: 0 kg P_2O_5 /ha
P_{50}: 50 kg P_2O_5 /ha
P_{100}: 100 kg P_2O_5 /ha
P_{150}: 150 kg P_2O_5 /ha

Table 11. Interaction effect of nitrogen and phosphorous on nitrogen (%) in straw, phosphorous (P) in ppm in straw , potassium (K) in (%)straw, nitrogen % in fruit, phosphorous % in fruit, potassium % in fruit

Treatments (N×P)	Nitrogen (%) in straw	Phosphorous (P)in ppm in straw	Potassium (K) in (%) in straw	N % in fruit	P % in fruit	K % in fruit
$N_0 P_0$	0.5000i	25.00h	1.250h	2.650i	0.170f	3.610a
$N_0 P_{50}$	0.7000h	30.00g	1.300gh	2.860hi	0.200def	3.800a
$N_0 P_{100}$	0.8800g	36.00f	1.410fgh	2.900ghi	0.210def	3.820a
$N_0 P_{150}$	0.8800g	38.00f	1.415fgh	3.000fgh	0.220cde	3.830a
$N_{100} P_0$	1.260f	27.10gh	1.300gh	3.170efg	0.200def	3.760a
$N_{100} P_{50}$	1.310f	35.30f	1.450efg	3.200def	0.230bcde	3.830a
$N_{100} P_{100}$	1.370ef	50.00e	1.600cde	3.260def	0.240abcd	3.880a
$N_{100} P_{150}$	1.490ce	50.20e	1.650bcd	3.400cde	0.240abcd	3.900a
$N_{150} P_0$	1.300f	28.00gh	1.370fgh	3.370cde	0.200def	3.800a
$N_{150} P_{50}$	1.520ce	50.20e	1.500def	3.490bcd	0.240abcd	3.880a
$N_{150} P_{100}$	1.550cd	60.30c	1.800b	3.740ab	0.270ab	3.930a
$N_{150} P_{150}$	1.580c	65.00b	1.810b	3.800a	0.280a	3.950a
$N_{200} P_0$	1.400def	35.10f	1.500def	3.430cde	0.190ef	3.810a
$N_{200} P_{50}$	1.640c	55.20d	1.750bc	3.570abc	0.230bcde	3.900a
$N_{200} P_{100}$	1.890b	63.63bc	2.00a	3.800a	0.260abc	3.950a
$N_{200} P_{150}$	2.040a	70.00a	2.00a	3.850a	0.280a	3.950a
$LSD_{(0.05)}$	0.1491	3.895	0.1582	0.2637	0.0372	0.3729
CV(%)	6.86	5.20	6.05	4.72	6.72	4.10

In a column means having common 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_{100}: 100 kg N/ha
N_{150}: 150 kg N/ha
N_{200}: 200 kg N/ha

P_0: 0 kg P_2O_5 /ha
P_{50}: 50 kg P_2O_5 /ha
P_{100}: 100 kg P_2O_5 /ha
P_{150}: 150 kg P_2O_5 /ha

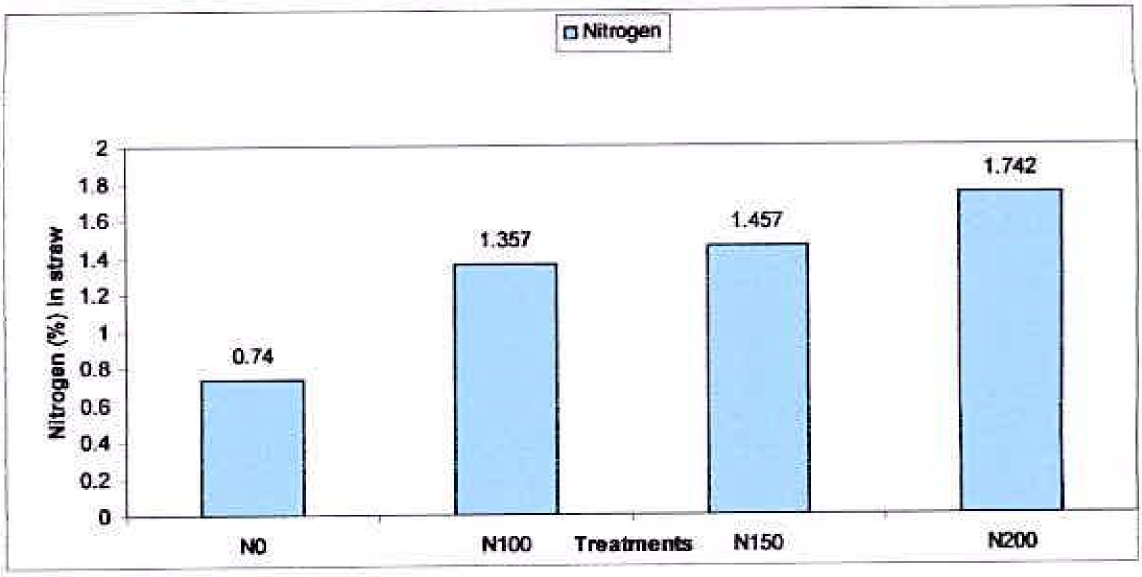


Figure 8.Effect of nitrogen on the nitrogen (%) of the straw of tomato plant

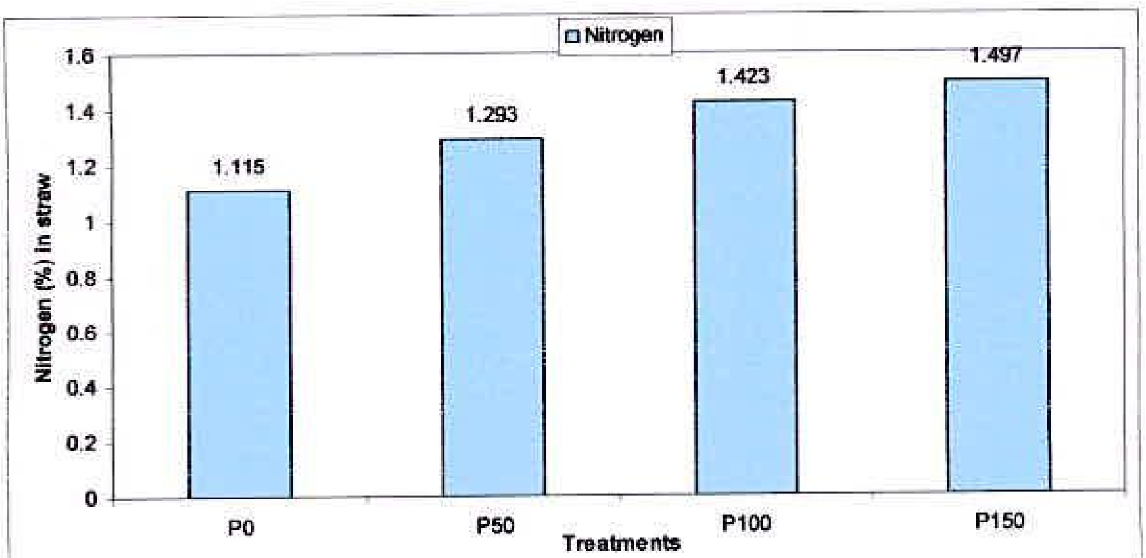


Figure 9.Effect of phosphorous on the nitrogen (%) of the straw of tomato plant

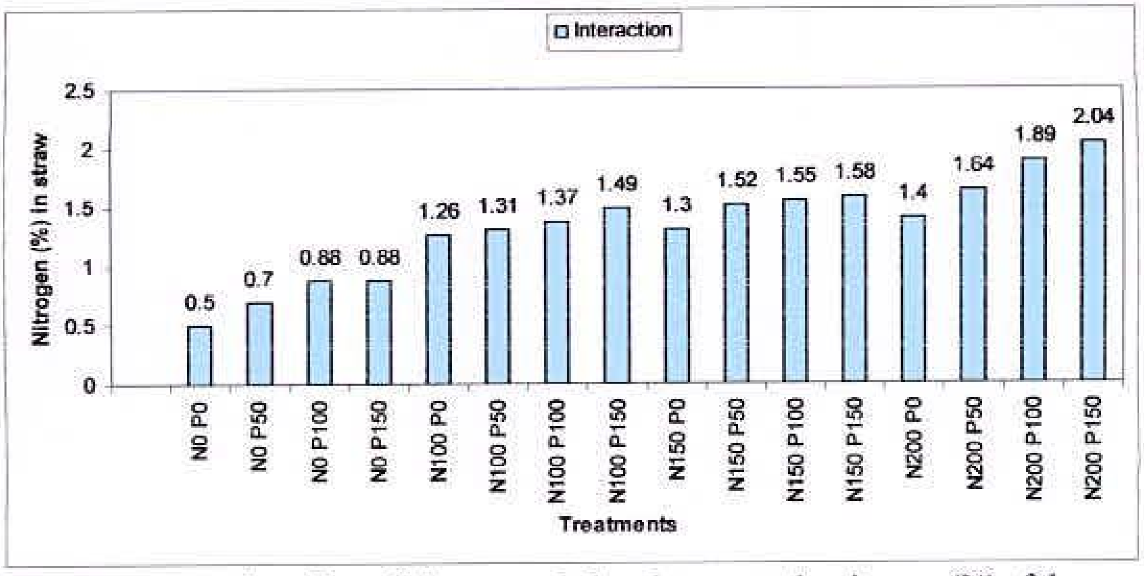


Figure 10. Interaction effect of nitrogen and phosphorous on the nitrogen (%) of the straw of tomato plant

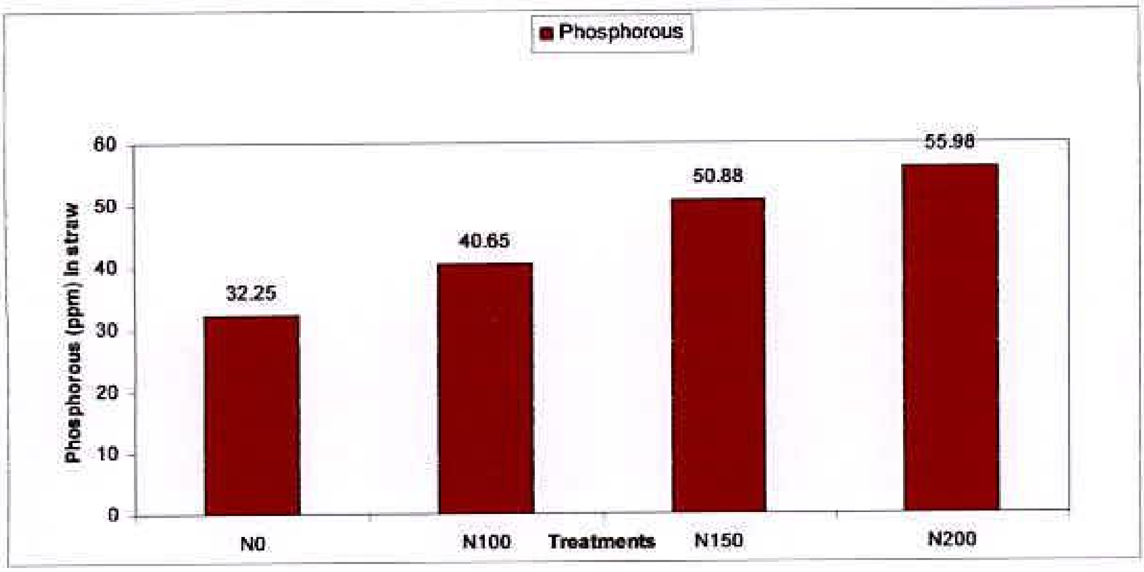


Figure11.Effect of nitrogen on the phosphorous (ppm) of the straw of tomato plant

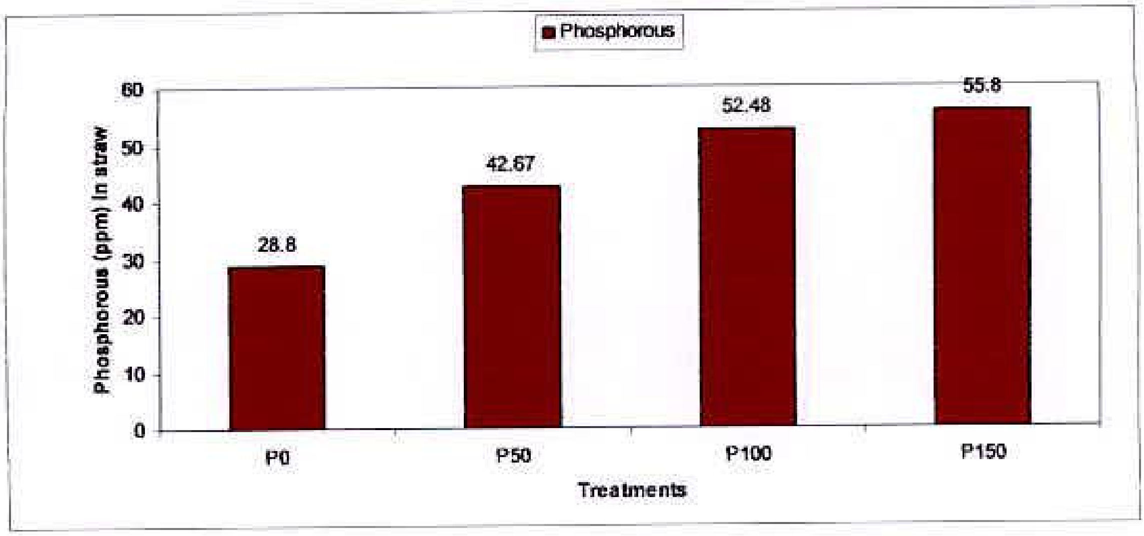


Figure 12 .Effect of phosphorous on the phosphorous (ppm) of the straw of tomato plant

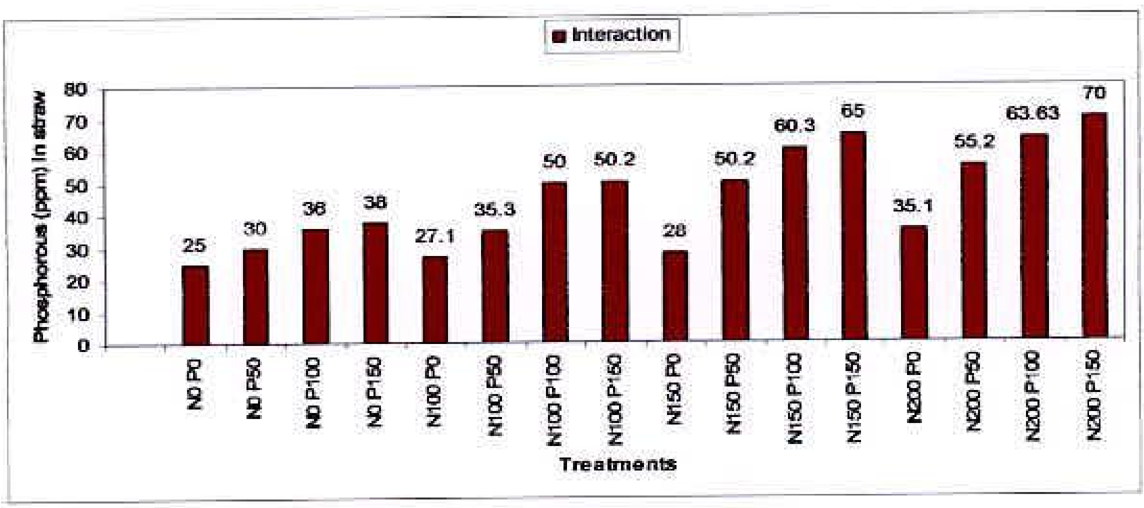


Figure 13. Interaction effect of nitrogen and phosphorous on the phosphorous (ppm) of the straw of tomato plant

4.3 Nutrient content in fruit

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

4.3.1 Nitrogen content (%) in fruit

Due to application of different level of nitrogen showed a statistically significant variation for nitrogen content in fruit of tomato (Appendix VI). The maximum nitrogen content (3.662%) (Figure 14) was recorded from N_{200} treatment consisting of 200 kg N/ha, which was statistically identical (3.600%) with N_{150} treatment as 150 kg N /ha, and the minimum nitrogen content (2.852%) was recorded from N_0 treatment (Table 10). The ranges of nitrogen content (%) in fruit incase of nitrogen application were 2.852 % to 3.662 %.

Different level of phosphorous showed statistically significant difference for nitrogen content in tomato fruit (Appendix VI). The maximum nitrogen content (3.513), (Figure 15) was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha, and the minimum nitrogen content (3.155%) was recorded from P_0 treatment (Table 10). The ranges of nitrogen content (%) in fruit incase of phosphorous application were 3.155 % to 3.513 %.

In respect of interaction effect was also recorded between nitrogen and phosphorous in consideration of nitrogen content in tomato fruit and found statistically significant variation (Appendix VI). The maximum nitrogen content in tomato fruit (3.850%) was recorded from $N_{200}P_{150}$ treatment consisting of 200 kg N/ha +150kgP_2O_5/ha, which was statistically identical (3.800%) in both $N_{200}P_{100}$ and $N_{150}P_{150}$ treatment consisting of 200 kg N/ha +100 kgP_2O_5//ha and 150 kg N/ha +150 kgP_2O_5/ha respectively (Figure 16). The minimum nitrogen content in tomato fruit (2.650%) was recorded from N_0P_0 treatment that is control condition (Table 11).

4.3.2 Phosphorous content (%) in fruit:

Effect of different level of nitrogen showed a statistically significant variation for phosphorous content (%) in fruit of tomato under the present trial (Appendix VI). The maximum phosphorous content (0.2475%) (Figure 17) was recorded from N_{150} treatment consisting of 150 kg N/ha, which was closely (0.2400%) followed by N_{200} treatment as 200 kg N/ha and the minimum phosphorous content (0.200%) was recorded from N_0 treatment (Table 10). The ranges of phosphorous content (%) in fruit incase of phosphorous application were 0.200% to 0.2475%.

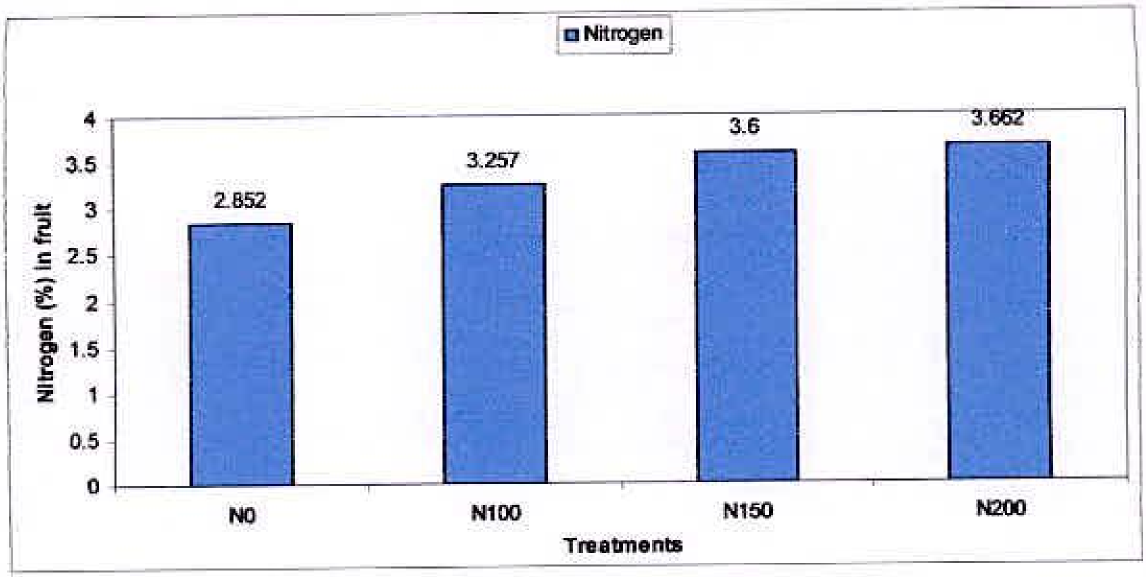


Figure 14.Effect of nitrogen on the nitrogen (%) of the fruit of tomato

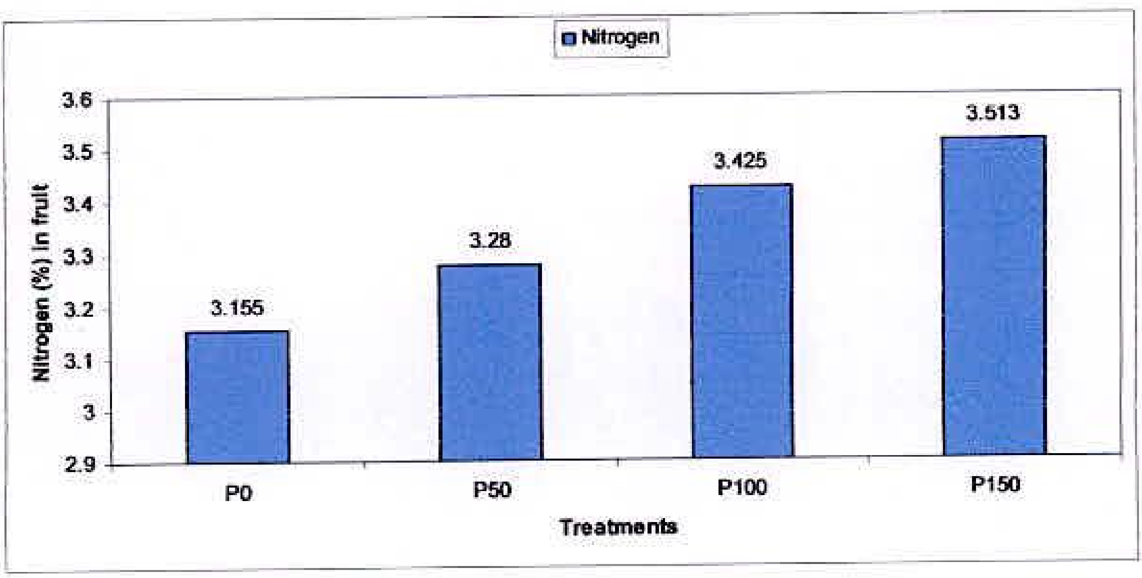


Figure 15.Effect of phosphorous on the nitrogen (%) of the fruit of tomato

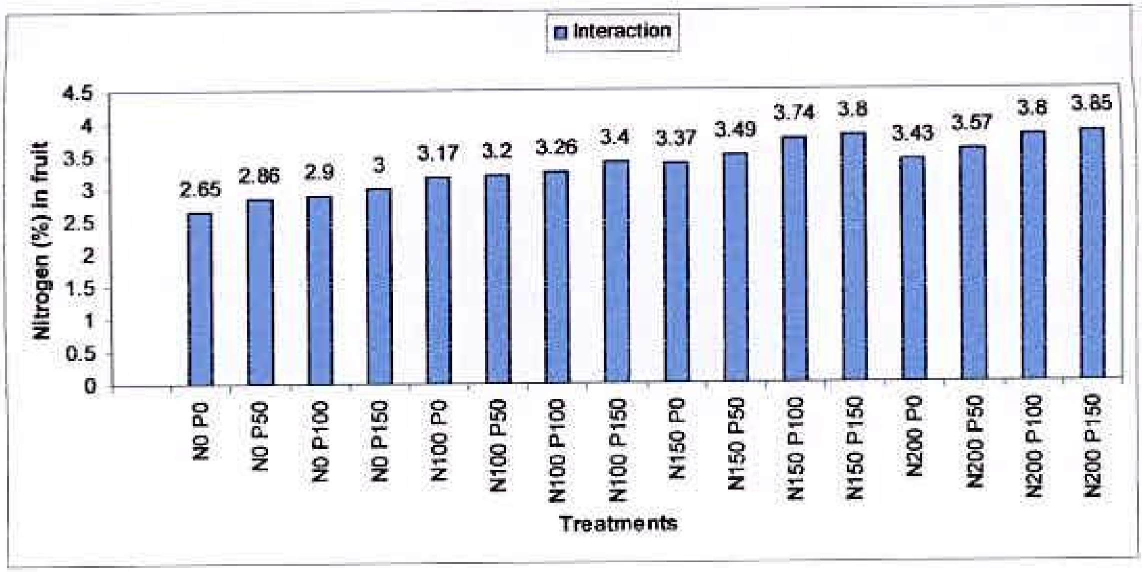


Figure 16. Interaction effect of nitrogen and phosphorous on the nitrogen (%) of the fruit of tomato

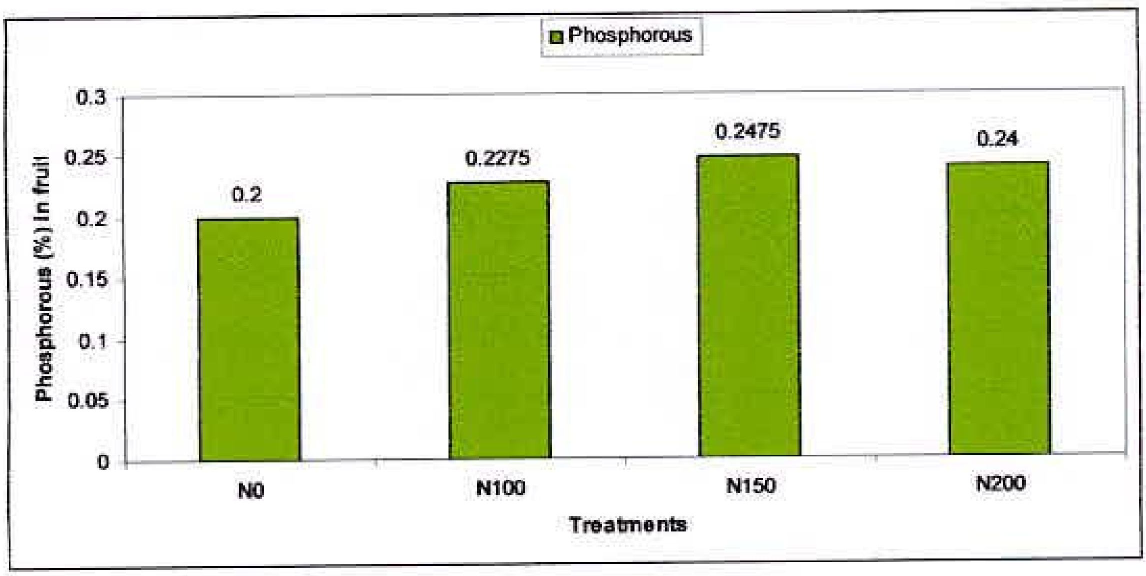


Figure 17.Effect of nitrogen on the phosphorous (%) of the fruit of tomato

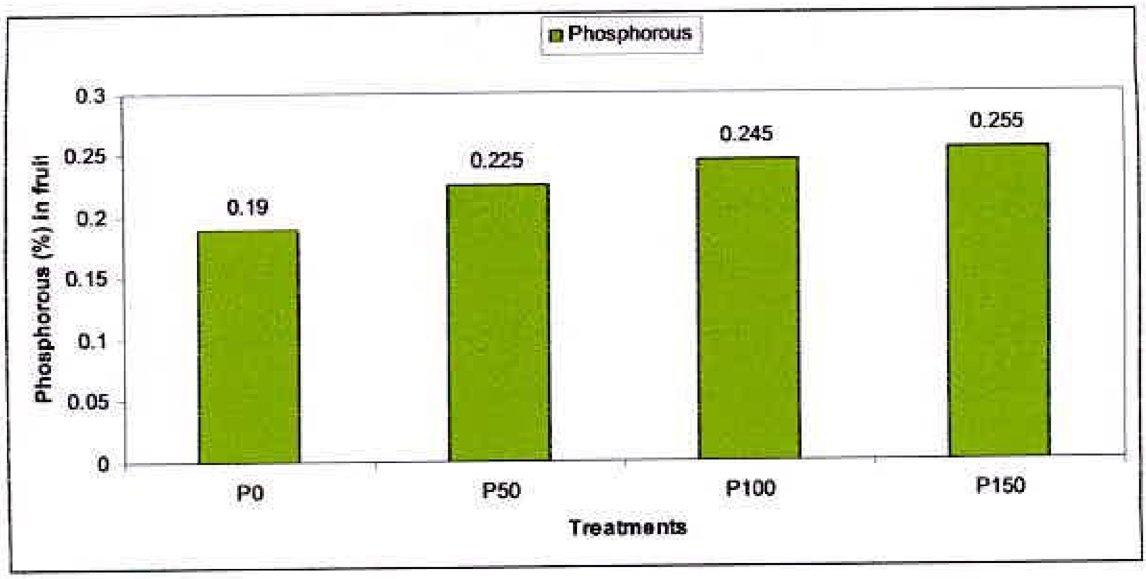


Figure 18.Effect of phosphorous on the phosphorous (%) of the fruit of tomato

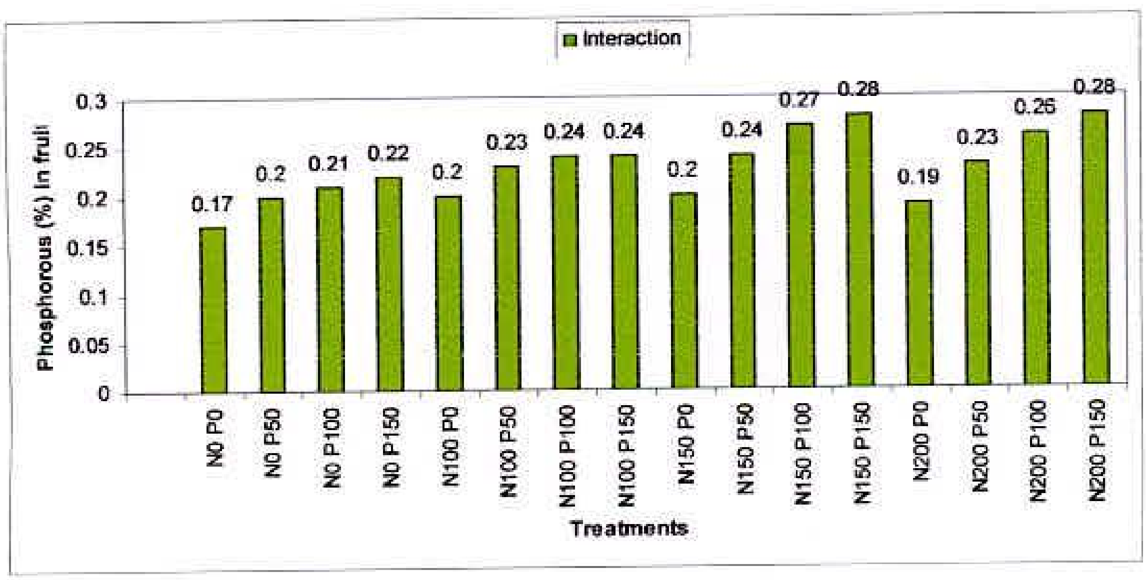


Figure 19. Interaction effect of nitrogen and phosphorous on the phosphorous (%) of the fruit of tomato

Application of different level of phosphorous showed statistically significant difference for phosphorous content in tomato fruit (Appendix VI). On the one hand, the maximum phosphorous content (0.2550%), was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha which was closely (0.2450%) (Figure 18) followed by P_{100} treatment as 100 kg P_2O_5/ha, and on the other hand, the minimum phosphorous content (0.1900%) was recorded from P_0 treatment that is control condition (Table 10).

Due to interaction effect was also recorded between nitrogen and phosphorous in consideration of phosphorous content in tomato fruit and found statistically significant variation (Appendix VI). The highest amount of phosphorous content in tomato fruit (0.280%) (Figure 19) was recorded from both $N_{200}P_{150}$ and $N_{150}P_{150}$treatment consisting of 200 kg N/ha +150 kg P_2O_5/ha and 150 kg N/ha +150 kg P_2O_5/ha. The lowest amount of phosphorous content in tomato fruit (0.1700%) was recorded from N_0P_0 treatment that is control condition (Table 11).

4.3.3 Potassium content (%) in fruit

Application of different level of nitrogen showed a statistically significant and similar for potassium content (%) in fruit of tomato (Appendix VI). The large amount of potassium content (3.903%) was recorded from N_{200} treatment consisting of 200 kg N/ha, and the lowest amount of potassium content (3.765%) was recorded from N_0 treatment (Table 10). The ranges of potassium content (%) in fruit incase of nitrogen application were 3.765% to 3.903%.

Different level of phosphorous showed statistically significant and similar for potassium content (%) in tomato fruit (Appendix VI).While the highest amount of potassium content (3.908%), was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha, and then the lowest amount of phosphorous content (3.745%) was found from P_0 treatment (Table10)

Interaction effect was also recorded between nitrogen and phosphorous in consideration of potassium content (%) in tomato fruit under the present experiment and found statistically significant and similar (Appendix VI). The maximum potassium content in tomato fruit (3.950%) was recorded from among $N_{200}P_{150}$, $N_{200}P_{100}$ and $N_{150}P_{150}$ treatments consisting of 200 kg N/ha +150 kg P_2O_5/ha and 200 kg N/ha +100 kg P_2O_5/ha and 150 kg N/ha +150 kg P_2O_5/ha. The minimum potassium content in tomato fruit (3.610%) was recorded fromN_0P_0 treatment (Table 11)

4.4 Status of post harvest soil

4.4.1 pH at post harvest soil

Effect of different level of nitrogen showed a statistically non significant for pH at post harvest soil under the present trial (Appendix V). The highest pH content (5.42) was recorded from N_{100} treatment consisting of 100 kg N/ha, and the lowest pH content (5.250) was recorded from N_0 treatment (Table 12).

Application of different level of phosphorous also showed statistically non significant for pH at post harvest soil (Appendix V). The maximum pH content (5.425) was recorded from P_{100} treatment consisting of 100 kg P_2O_5/ha, and the minimum pH content (5.250) was recorded from P_0 treatment (Table 12)

Interaction effect was also recorded between nitrogen and phosphorous in consideration of P^H at post harvest soil under the present experiment and found statistically non significant (Appendix V). The maximum pH content (5.600) was recorded from both $N_{100}P_{100}$ and $N_{200}P_{100}$ treatments consisting of 100 kg N/ha +100 kg P_2O_5/ha and 200 kg N/ha +100 kg P_2O_5/ha and 100 kg N/ha +150 kg P_2O_5/ha. The minimum pH content (5.00) was recorded from N_0P_0 treatment (Table 13).

Comparison with initial and post harvest soil

Due to application of nitrogen and phosphorous in different doses for tomato the pH of the post harvest soil has increased slightly over the initial soil pH. The initial soil pH of the soil was 5.0 and the pH became 5.00 to 5.60 that is slightly increasing pattern.

4.4.2 Nitrogen (%) at post harvest soil

Application of different level of nitrogen showed a statistically significant variation for nitrogen content (%) at post harvest soil (Appendix V). The maximum nitrogen content (0.114%) was recorded from N_{200} treatment consisting of 200 kg N/ha, (Figure 20) which was statistically identical (0.1123%) was recorded from N_{150} treatment as 150 kg N/ha and (0.1107%) was recorded from N_{100} treatment as 100 kg N/ha, and the minimum nitrogen content (0.097%) was recorded from N_0 treatment (Table12). The ranges of nitrogen (%) at post harvest soil incase of nitrogen application were 0.097% to 0.114%. Ahmed *et al* (1992) reported that highest application of nitrogen accelerated nitrogen uptake by soil and the ultimately result is the highest nitrogen content in soil

Due to application of different level of phosphorous showed statistically non significant for nitrogen content (%) at post harvest soil (Appendix V). The maximum nitrogen content (0.1125%) was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha (Figure 21) which was statistically identical (0.1105%) with P_{100} treatment as 100 kg P_2O_5/ha and (0.1070%) with P_{50} treatment as 50 kg P_2O_5/ha, and the minimum nitrogen content (0.1042%) was recorded from P_0 treatment that is control condition (Table 12). The ranges of nitrogen (%) at post harvest soil incase of phosphorous application were 0.1042% to 0.1125%.

In regard to interaction effect was also recorded between nitrogen and phosphorous in consideration of nitrogen (%) at post harvest soil and found statistically non significant similar (Appendix V). The maximum nitrogen (%) at post harvest soil (0.119%) was recorded from $N_{200}P_{150}$ treatment consisting of 200 kg N/ha +150 kgP_2O_5/ha (Figure 22). The minimum nitrogen content (0.096%) was recorded from N_0P_0 treatment (Table 13).

4.4.3 Phosphorous content (ppm) at post harvest soil

Effect of different level of nitrogen showed a statistically significant variation for phosphorous content (ppm) at post harvest soil (Appendix V). The maximum phosphorous content (36.85 ppm) was recorded from P_{200} treatment consisting of 200 kg N/ha, (Figure 23) which was statistically identical and (36.34 ppm) was recorded from N_{150} treatment as 150 kg N/ha and the minimum phosphorous content (17.68 ppm) was recorded from N_0 treatment (Table 12). The ranges of phosphorous content (ppm) at post harvest soil incase of nitrogen application were 17.68 ppm to 36.85 ppm.

Table 12. Effect of nitrogen and phosphorous on pH of post harvest soil, nitrogen (%), phosphorous (P) in ppm, potassium (K) in meq/100 gm soil of post harvest soil

Treatments	P^H	Nitrogen (%)	Phosphorous (P) in ppm	Potassium (K)in meq/100gm soil
Nitrogen				
N_0	5.250a	0.09700b	27.68c	0.2750b
N_{100}	5.425a	0.1107a	32.24b	0.3325a
N_{150}	5.300a	0.1127a	36.34a	0.3325a
N_{200}	5.375a	0.1143a	36.85a	0.3150a
LSD	NS	0.01318	1.692	0.01749
Phosphorous				
P_0	5.250a	0.1042a	22.25d	0.2725c
P_{50}	5.275a	0.1070a	30.89c	0.3100b
P_{100}	5.425a	0.1105a	37.82b	0.3275ab
P_{150}	5.400a	0.1125a	42.15a	0.3450a
LSD	NS	NS	1.953	0.02019

In a column means having common 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_{100}: 100 kg N/ha

N_{150}: 150 kg N/ha

N_{200}: 200 kg N/ha

P_0: 0 kg P_2O_5 /ha

P_{50}: 50 kg P_2O_5 /ha

P_{100}: 100 kg P_2O_5 /ha

P_{150}: 150 kg P_2O_5 /ha

Table 13. Interaction effect of nitrogen and phosphorous on pH of post harvest soil, nitrogen (%), phosphorous (P) in ppm, potassium (K) in meq/100 gm soil of post harvest soil

Treatments	pH	Nitrogen (%)	Phosphorous (P) in ppm	Potassium (K)in meq/100g soil
$N_0 P_0$	5.000a	0.098a	13.84g	0.2400g
$N_0 P_{50}$	5.300a	0.096a	26.32ef	0.2500fg
$N_0 P_{100}$	5.200a	0.097a	34.54c	0.2900de
$N_0 P_{150}$	5.500a	0.097a	36.01c	0.3200bcd
$N_{100} P_0$	5.500a	0.104a	23.31f	0.3000cde
$N_{100} P_{50}$	5.300a	0.110a	29.07de	0.3300bc
$N_{100} P_{100}$	5.600a	0.113a	34.07c	0.3400abc
$N_{100} P_{150}$	5.300a	0.116a	42.52ab	0.3600ab
$N_{150} P_0$	5.400a	0.107a	26.00ef	0.2800ef
$N_{150} P_{50}$	5.100a	0.108a	32.39cd	0.3400abc
$N_{150} P_{100}$	5.300a	0.116a	41.67ab	0.3400abc
$N_{150} P_{150}$	5.400a	0.118a	45.30a	0.3700a
$N_{200} P_0$	5.100a	0.108a	25.84ef	0.2700efg
$N_{200} P_{50}$	5.400a	0.114a	35.77c	0.3200bcd
$N_{200} P_{100}$	5.600a	0.116a	41.01b	0.3400abc
$N_{200} P_{150}$	5.400a	0.119a	44.77a	0.3300abc
$LSD_{(0.05)}$	NS	NS	3.383	0.03498
CV	3.65	3.89	6.10	5.96

In a column means having common 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_{100}: 100 kg N/ha

N_{150}: 150 kg N/ha

N_{200}: 200 kg N/ha

P_0: 0 kg P_2O_5 /ha

P_{50}: 50 kg P_2O_5 /ha

P_{100}: 100 kg P_2O_5 /ha

P_{150}: 150 kg P_2O_5 /ha

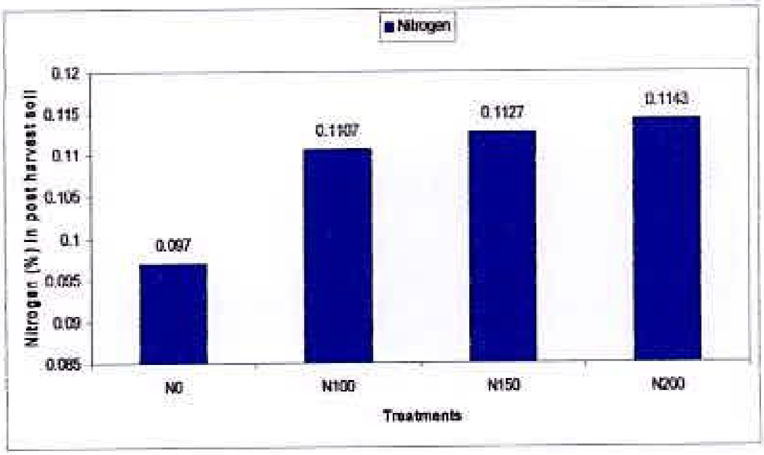


Figure 20.Effect of nitrogen on the nitrogen (%) of the post harvest soil

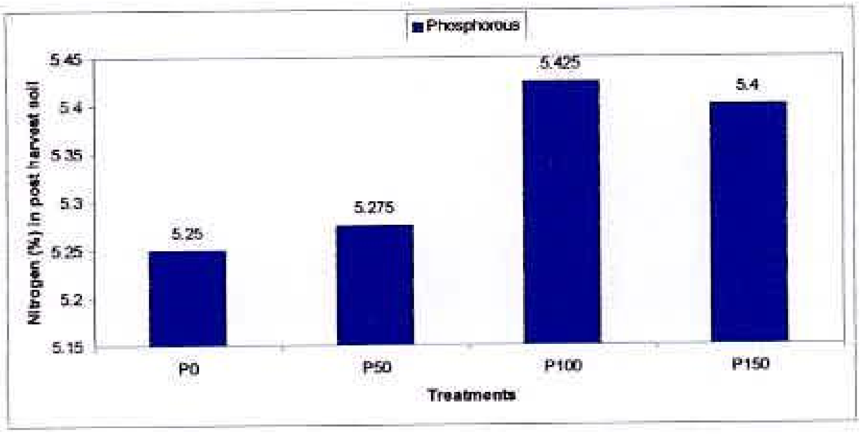


Figure 21.Effect phosphorous on the nitrogen (%) of the post harvest soil

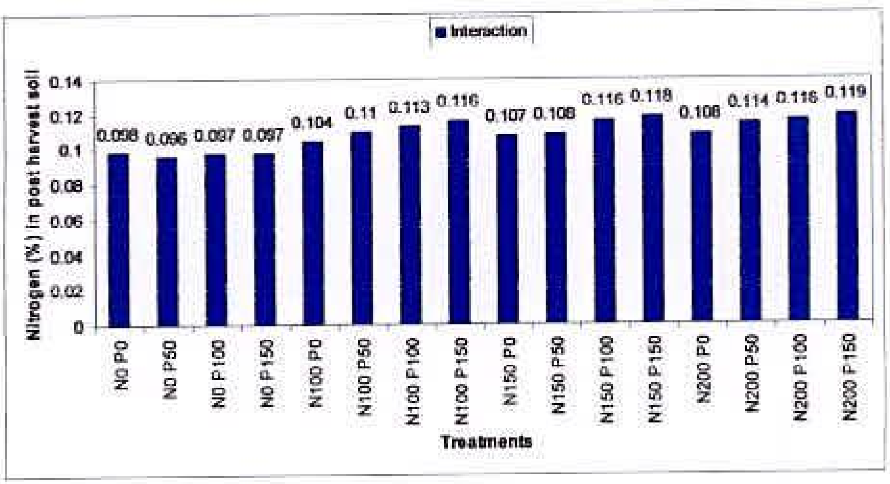


Figure 22. Interaction effect of nitrogen and phosphorous on the nitrogen (%) of the post harvest soil

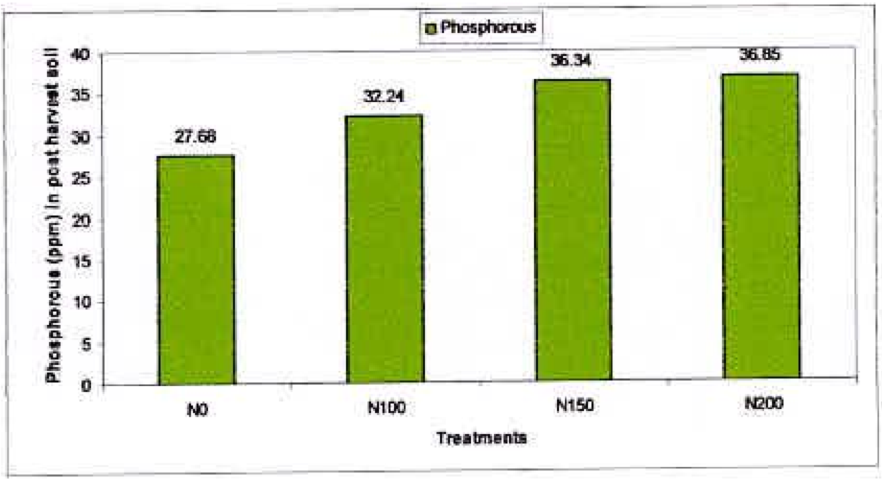


Figure 23.Effect of nitrogen on the phosphorous (ppm) on the post harvest soil

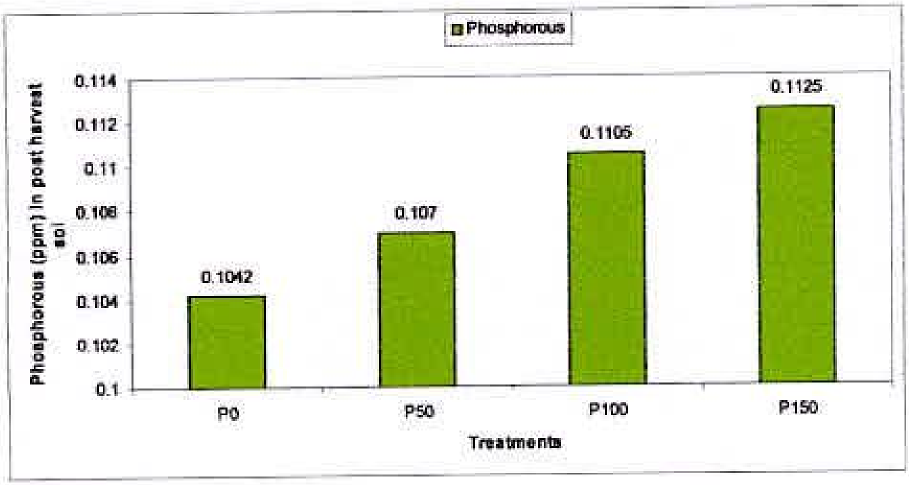


Figure 24.Effect of phosphorous on the phosphorous (ppm) on the post harvest soil

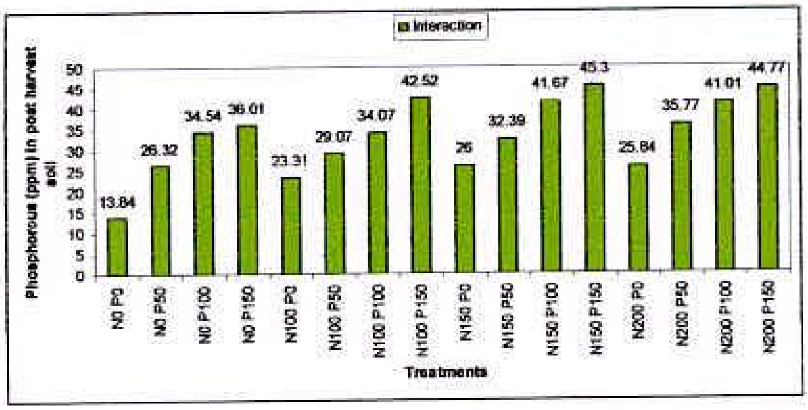


Figure 25. Interaction effect of nitrogen and phosphorous on the phosphorous (ppm) of the post harvest soil

Application of different level of phosphorous showed statistically significant variation for phosphorous content (ppm) at post harvest soil (Appendix V). The maximum phosphorous content (42.15 ppm) was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha (Figure 24) and the minimum phosphorous content (22.25 ppm) was recorded from P_0 treatment (Table 12). The ranges of phosphorous content (ppm) at post harvest soil incase of phosphorous application were 22.25 ppm to 42.15 ppm.

Due to interaction effect was also recorded between nitrogen and phosphorous in consideration of phosphorous (ppm) at post harvest soil and found statistically significant variation (Appendix V). The maximum phosphorous (45.30 ppm) at post harvest soil was recorded from $N_{150}P_{150}$ treatment consisting of 150 kg N/ha +150 kg P_2O_5/ha (Figure 25) which was statistically identical (44.77 ppm) at post harvest soil was recorded from $N_{200}P_{150}$ treatment consisting of 200 kg N/ha +150 kg P_2O_5/ha. The minimum phosphorous content (13.84 ppm) was recorded from N_0P_0 treatment (Table 13).

4.4.4 Potassium content at post harvest soil:

Effect of different level of nitrogen showed a statistically significant variation for Potassium content (meq/100gm soil) at post harvest soil (Appendix V). The maximum potassium content (0.3325 meq/100gm soil) was recorded from both N_{150} and N_{100} treatments consisting of 150 kg N/ha, and 100 kg N/ha which was statistically identical (0.3150 meq/100 gm soil) was recorded from N_{200} treatment as 200 kg N/ha and minimum potassium content (0.2750 meq/100 gm soil) was recorded from N_0 treatment (Table.12). The ranges of potassium content (meq/100 gm soil) at post harvest soil incase of nitrogen application were 0.2750 meq/100 gm soil to 0.3325 meq/100gm soil

Due to application of different level of phosphorous showed statistically significant variation for Potassium content (meq/100 gm soil) at post harvest soil (Appendix V). The maximum potassium content (0.3450 meq/100 gm soils) was recorded from P_{150} treatment consisting of 150 kg P_2O_5/ha, and the minimum potassium content (0.2725 meq/100 gm soil) was recorded from P_0 treatment (Table 12). The ranges of potassium content (meq/100 gm soil) at post harvest soil incase of phosphorous application were 0.2725 meq/100 gm soil to 0.3450 meq/100gm soil.

Interaction effect was also recorded between nitrogen and phosphorous in consideration of potassium (meq/100 gm soil) at post harvest soil and found statistically significant variation (Appendix V). The maximum potassium content (0.3700 meq/100gm soil) at post harvest soil was recorded from $N_{150}P_{150}$ treatment consisting of 150 kg N/ha +150 kg P_2O_5/ha, and the minimum potassium content (0.2400 meq/100 gm soil) was recorded from N_0P_0 treatment (Table 13).

CHAPTER-V

SUMMARY AND CONCLUSION

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Sher-e Bangla Nagar, Dhaka, during November 2010 to March 2011 to find out the effect of nitrogen (N) and phosphorous (P) on the growth and yield of BARI Tomato-2 which is one of the high yielding varieties of indeterminate type. BARI Tomato-2 (Raton), a high yielding variety of tomato (*Lycopersicon esculentum* Mill.) developed by Bangladesh Agricultural Research Institute (BARI),Gazipur. The seeds were collected from Horticultural Research Centre (HRC) of BARI, Gazipur. Healthy and uniform sized 30 days old seedlings were uprooted from the seed bed and were transplanted in the experimental field on 28 November, 2010 maintaining a spacing of 60 cm and 50 cm between the rows and plants, respectively. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each fertilizer treatment combinations. Fertilizer treatments consisting of 4 levels of N and 4 levels of P on the growth and yield of tomato. The study comprised the following treatments: Four levels of nitrogen N_0: 0 kg N/ha, N_{100}: 100 kg N/ha, N_{150}: 150 kg N/ha and N_{200}: 200 kg N/ha and Four levels of phosphorous: P_0: 0 kg P_2O_5 /ha, P_{50}: 50 kg P_2O_5 /ha, P_{100}: 100 kg P_2O_5 /ha and P_{150}: 150 kg P_2O_5 /ha. There were 16 (4×4) treatment combinations. Data were recorded on yield and yield contributing characters and yield of tomato and nitrogen and phosphorus uptake by plant and their availability on soil.

Incase of single effect of nitrogen, at 30 day after transplanting (30DAT) the maximum plant height (60.38 cm), was recorded from N_{200} treatment and where as the minimum plant height (56.16cm) was recorded from N_0 treatment that is control condition. At 60 day after transplanting (60DAT) the highest plant height (78.31 cm) was recorded from N_{200} treatment and the lowest plant height (56.16cm) was recorded from N_0 treatment that is control condition. During the harvesting period, the maximum plant height (89.58 cm) was recorded from N_{200} treatment and the minimum plant height (56.16cm) was recorded from N_0 treatment. At 60 day after transplanting (60 DAT) when the maximum plant leaves (51.72 cm), was recorded from N_{200} treatment, then the minimum plant leaves (39.72cm) was recorded from N_0 treatment. At final harvesting period, the maximum branches per plant (11.26), was recorded from N_{200} treatment and the minimum branches per plant (9.668) was recorded from N_0 treatment. The number of maximum flower clusters per plant (8.800), was observed from N_{200} treatment and the minimum flower clusters per plant (6.350) was observed from N_0 treatment that is zero level of nitrogen application. The highest number of flowers per cluster (4.943) was found from N_{200} treatment and the lowest number of flowers per cluster (4.520) was found from N_0 treatment. The maximum number or flowers per plant (44.63) was recorded from N_{200} treatment where as the minimum number of flowers per plant (30.41) was recorded from N_0 treatment .In the one hand, the maximum number of fruits per cluster (3.828), was recorded from N_{200} treatment and on the other hand, the minimum fruits number per cluster (3.325) was recorded from N_0 treatment. The highest numbers of fruits per plant (33.77) were observed from N_{200} treatment and the lowest numbers of fruits per plant (21.75) were observed from N_0 treatment. The maximum fruits setting (%) per plant (75.71) was recorded from N_{200} treatment, the minimum fruits setting per plant (71.27) was recorded from N_0 treatment. The maximum weight of individual fruit fruits per plant (83.27gm) was recorded from N_{200} treatment and the minimum weight of individual fruit per plant (66.22 gm) was recorded from N_0 treatment. The maximum fruit length (5.320 cm) was recorded from N_{150} treatment and the minimum fruit length (4.605 cm) was recorded from N_0 treatment. The maximum fruit breadth (5.88cm) was recorded from N_{200} treatment and the minimum fruit breadth (4.283cm) was recorded from N_0 treatment. When the maximum weight of fruits per plant (2.125kg) were recorded from N_{200} treatment, then the minimum weight of fruits per plant (1.085kg) was recorded from N_0 treatment. The maximum fruit yield (76.72 ton/ha) was recorded from N_{200} treatment and the minimum fruit yield (39.00 ton/ha) was recorded from N_0 treatment .

Incase of straw, the highest nitrogen content (1.742%) was recorded from N_{200} treatment and the lowest nitrogen content (0.74%) was recorded from N_0 treatment. The maximum phosphorous content (55.98 ppm) was recorded from N_{200} treatment and the minimum phosphorous content (32.25 ppm) was recorded from N_0 treatment. The maximum Potassium content (1.813%) was recorded from N_{200} treatment and the minimum Potassium content (1.344%) was recorded from N_0 treatment.

In case of fruit, the maximum nitrogen content (3.662%) was recorded from N_{200} treatment the minimum nitrogen content (2.852%) was recorded from N_0 treatment. The maximum Phosphorous content (0.2475%) was recorded from N_{150} treatment and the minimum Phosphorous content (0.200%) was recorded from N_0 treatment. The maximum potassium content (3.903%) was recorded from N_{200} treatment and the minimum potassium content (3.765%) was recorded from N_0 treatment.

Incase of post harvest soil, the maximum pH content (5.425) was recorded from N_{100} treatment and the minimum pH content (5.250) was recorded from N_0 treatment. The maximum nitrogen content (0.1143%) was recorded from N_{200} treatment and the minimum nitrogen content (0.09700%) was recorded from N_0 treatment .The maximum phosphorous content (36.85ppm) was recorded from P_{200} treatment and minimum phosphorous content (17.68ppm) was recorded from N_0 treatment. The maximum potassium content (0.3325meq/100gm soil) was recorded from both N_{150} and N_{100} treatments and minimum potassium content (0.2750 meq/100 gm soils) was recorded from N_0 treatment.

Incase of single effect of phosphorous, at 30 day after transplanting (30 DAT) the maximum plant height (59.43 cm), was recorded from P_{100} treatment and the minimum plant height (55.46 cm) was recorded from P_0 treatment. At 60 day after transplanting (60 DAT) the maximum plant height (77.61 cm), was recorded from P_{150} treatment and the minimum plant height (72.046 cm) was recorded from P_0 treatment. During the harvesting period, the maximum plant height (88.93 cm) was recorded from P_{150} treatment and the minimum plant height (80.64cm) was recorded from P_0 treatment. At 60 days after transplanting (60 DAT) the maximum plant leaves (48.49 cm), was recorded from P_{150} treatment and the minimum plant leaves (55.46cm) was recorded from P_0 treatment. At final harvesting period, the maximum branches per plant (11.35) were recorded from P_{150} treatment and the minimum branches per plant (9.58) were recorded from P_0 treatment. The maximum flower clusters per plant (8.580), was recorded from P_{150} treatment and the minimum flower clusters per plant (6.365) was recorded from P_0 treatment. The maximum flowers no. per clusters (5.003), was recorded from P_{150} treatment and the minimum flowers no. per clusters (4.452) was recorded from P_0 treatment. The maximum flowers no per plant (44.02), was recorded from P_{150} treatment and the minimum flowers no per plant (30.01) was recorded from P_0 treatment. The maximum fruits no. per clusters (3.87) was recorded from P_{100} treatment and minimum fruits no. per clusters (3.525) were recorded from P_0 treatment. The maximum fruits numbers per plant (32.75) were recorded from P_{150} treatment and the minimum fruits no. per plant per plant (22.59) was recorded from P_0 treatment. The maximum rate of fruit setting (%)/ per plant (74.80), was recorded from P_0 treatment and the minimum rate of fruit setting (%)/ plant (73.50) was recorded from P_{50} treatment. The maximum weight of individual fruit per plant (81.67) was recorded from P_{150} treatment and the minimum weight of individual fruit per plant (71.54) was recorded from P_0 treatment. The maximum fruit length (5.262cm), was recorded from P_{150} treatment. And the minimum fruit length (4.960cm) was recorded from P_0 treatment. The maximum fruit breadth (4.600cm), was recorded from P_{150} treatment and the minimum fruit breadth (4.358cm) was recorded from P_0 treatment. The maximum weight of fruit per plant (2.033kg), was recorded from P_{150} treatment and the minimum weight of fruits per plant (1.225kg) was recorded from P_0 treatment. The maximum fruit yield (73.26 ton/ha), was recorded from P_{150} treatment and the minimum fruit yield (44.11 ton/ha) was recorded from P_0 treatment.

In case of straw, the maximum nitrogen content (1.497%) was recorded from P_{150} treatment and the minimum nitrogen content (1.115%) was recorded from P_0 treatment. The maximum phosphorous content (55.80 ppm) was recorded from P_{150} treatment and the minimum phosphorous content (28. 80ppm) was recorded from P_0 treatment. The maximum potassium content (1.719%) was recorded from P_{150} treatment and the minimum potassium content (1.355%) was recorded from P_0 treatment.

Incase of fruit, the maximum nitrogen content (3.513%) was recorded from P_{150} treatment and the minimum nitrogen content (3.155%) was recorded from P_0 treatment. The maximum phosphorous content (0.2550%) was recorded from P_{150} treatment and the minimum phosphorous content (0.1900%) was recorded from P_0 treatment. The maximum potassium content (3.908%) was recorded from P_{150} treatment and the minimum phosphorous content (3.745%) was recorded from P_0 treatment.

Incase of post harvest soil, the maximum pH content (5.425) was recorded from P_{100} treatment, and the minimum pH content (5.250) was recorded from P_0 treatment. The maximum nitrogen content (0.1125%), was recorded from P_{150} treatment and the minimum nitrogen content 0.1042%) was recorded from P_0 treatment. The maximum phosphorous content (42.15 ppm) was recorded from P_{150} treatment and the minimum phosphorous content (22.25 ppm) was recorded from P_0 treatment. The maximum potassium content (0.3450 meq/100 gm soil), was recorded from P_{150} treatment and the minimum potassium content (0.2725 meq/100 gm soil) was recorded from P_0 treatment.

Incase of combined effect of nitrogen and phosphorous, at 30 day after transplanting (30 DAT) the maximum plant height (61.74 cm) was recorded from N_{200} P_{150} treatment and the minimum plant height (52.77 cm) was recorded from N_0P_0 treatment. At 60 days after transplanting (60 DAT) the maximum plant height (81.48 cm) was recorded from N_{200} P_{150} treatment and the minimum plant height (68.23 cm) was recorded from N_0P_0 treatment. During the harvesting period, the maximum plant height (93.62 cm) was recorded from $N_{200}P_{150}$ treatment and the minimum plant height (75.44 cm) was recorded from N_0P_0 treatment. At 60 days after transplanting (60 DAT) the highest number of leaves (56.09 cm) was recorded from $N_{200}P_{150}$ treatment and the lowest number of plant leaves (35.87) was recorded from N_0P_0 treatment. At final harvesting period the highest number of branches per plant (12.19) was recorded from $N_{200}P_{150}$ treatment and the lowest number of branches per plant (8.930) was recorded from N_0P_0 treatment. The highest amount of flower clusters per plant (9.600) was recorded from $N_{200}P_{100}$ treatment and the lowest amount of flower clusters per plant (5.010) was recorded from N_0P_0 treatment. The maximum flowers no. per clusters (5.140) was observed from $N_{100}P_{150}$ treatment and the minimum flowers no per cluster (4.100) were observed from N_0P_0 treatment. The highest amounts of flowers no. per plant (49.86) were found from $N_{200}P_{100}$ treatment and the lowest amounts of flowers no. per plant (23.52) were found from N_0P_0 treatment. The highest amounts of fruits per clusters (3.990) were recorded from $N_{200}P_{100}$ treatment and the lowest amounts of fruits per cluster (3.210) were recorded from N_0P_0 treatment. The maximum numbers of fruits per plant (38.30) were recorded from $N_{200}P_{100}$ treatment and the minimum numbers of fruits per plant (16.08) were recorded from N_0P_0 treatment. The highest rate of fruit setting (%) per plant (77.02), was recorded from $N_{200}P_0$ treatment and the lowest rate of fruit setting (%)/ per plant (68.37) were recorded from N_0P_0 treatment. The maximum weight of individual fruit per plant (87.59) was recorded from $N_{150}P_{100}$ treatment and the minimum weight of individual fruit per plant (63.85) was recorded fromN_0P_0 treatment. The maximum fruit length (5.610 cm) was recorded from $N_{150}P_{150}$ treatment the minimum fruit length per plant (4.52 cm) was recorded from N_0P_0 treatment. The highest fruit breadth per plant (4.700 cm) was recorded from both $N_{100}P_{100}$ and $N_{150}P_{100}$ treatment and the lowest fruit breadth (4.11cm) was recorded from N_0P_0 treatment. The maximum weight of fruits per plant (2.500 kg) was recorded from $N_{200}P_{100}$ treatment and the minimum weight of fruits per plant (0.7700kg) was recorded from N_0P_0 treatment. The maximum fruit yield (89.93 ton/ha) was observed from $N_{200}P_{100}$ treatment and the minimum fruit yield (27.72ton/ha) was observed from N_0P_0 treatment.

The higher amount of nitrogen content in tomato shoot or straw (2.040%) was recorded from $N_{200}P_{150}$ treatment and the lower amount of nitrogen content in tomato shoot or straw (0.50%) was recorded from N_0P_0 treatment. The maximum phosphorous content in tomato shoot or straw (70 ppm) was found from $N_{200}P_{150}$ treatment. The minimum phosphorous content in tomato shoot or straw (25 ppm) was found from N_0P_0 treatment. The maximum potassium content in tomato shoot or straw (2.0%) was recorded from both $N_{200}P_{150}$ and $N_{200}P_{100}$ treatment and the minimum potassium content in tomato shoot or straw (1.25%) was recorded from N_0P_0 treatment. The highest amount of nitrogen content in tomato fruit (3.850%) was recorded from $N_{200}P_{150}$ treatment and the lowest amount of nitrogen content in tomato fruit (2.650%) was recorded from N_0P_0 treatment. The maximum phosphorous content in tomato fruit (0.2800%) was observed from both $N_{200}P_{150}$ and $N_{150}P_{150}$ treatment and the minimum phosphorous content in tomato fruit (0.1700%) was observed from N_0P_0 treatment. The maximum potassium content in tomato fruit (3.950%) was recorded from among $N_{200}P_{150}$, $N_{200}P_{100}$ and $N_{150}P_{150}$ treatments and the minimum potassium content in tomato fruit (3.610%) was recorded from N_0P_0 treatment. The highest pH content (5.600) was observed from both $N_{100}P_{100}$ and $N_{200}P_{100}$ treatments and the lowest pH content (5.00) was observed from N_0P_0 treatment. The maximum nitrogen (%) at post harvest soil (0.1190%) was recorded from $N_{200}P_{150}$ treatment and the minimum nitrogen content (0.09600%) was recorded from N_0P_0 treatment. The maximum phosphorous content (45.30 ppm) at post harvest soil was recorded from $N_{150}P_{150}$ treatment and the minimum phosphorous content (13.84 ppm) was recorded fromN_0P_0 treatment. The maximum potassium content (0.3700 meq/100gm soil) at post harvest soil was observed from $N_{150}P_{150}$ treatment and the minimum potassium content (0.2400 meq/100 gm soils) was observed from N_0P_0 treatment.

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 different level of nitrogen and phosphorous fertilizer, time and application method may be included in this experimental protocol.
3. It is needed to conduct further trial other varieties of tomato with the same treatment.

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APPENDICES

Appendix I: Monthly record of air temperature, relative humidity and sunshine of the experimental site during the period from November 2010 to February 2011

Year	Month	Air Temperature (^{o}C)		Relative Humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum			
2008	October	30.4	15.6	81	0	7.3
	November	32.3	16.3	79	0	7.9
	December	29.0	13.0	72	1	3.9
2009	January	28.1	11.1	55	1	5.7
	February	33.9	12.2	67	45	8.7
	March	34.6	16.5	65	88	7.3

Source: Bangladesh Meteorological Department (Climate & water division) Agargoan, Dhaka- 1207

Appendix II: Analysis of variance of the data on plant height at 30, 60 DAT, at harvest, number of leaves per plant and 60 DAT and number of branches per plant at harvesting period as influenced by nitrogen and phosphorous

Source of variation	Degrees of freedom	Mean square				
		Plant height at			No. of leaves per plant at	No. of branches per plant at
		30 DAT	60 DAT	Harvest	60 DAT	Harvest
Replication	2	0.250	0.813	1.188	2.313	0.015
Nitrogen(A)	3	40.438**	130.779**	196.545**	319.071**	5.676**
Phosphorous (B)	3	40.107**	78.760**	171.048**	173.876**	9.174**
Interaction (A×B)	9	1.290	1.573	0.647	8.359	0.151
Error	30	3.850	4.479	1.388	6.179	0.226

Appendix III: Analysis of variance of the data on number of cluster / plant, number of flowers/ cluster , number of flowers/ plant, number of fruits/ cluster, number of fruits/ plant and rate of fruit setting(%) as influenced by nitrogen and phosphorous

Source of variation	Degrees of freedom	Mean square					
		Number of cluster / plant	Number of flowers/ cluster	Number of flowers/ plant	Number of fruits/ cluster	Number of fruits/ plant	Rate of fruit setting (%)
Replication	2	0.010	0.174	0.348	0.021	7.563	0.063
Nitrogen (A)	3	14.279**	0.466**	489.450**	0.668**	351.094**	51.748**
Phosphorous (B)	3	12.892**	0.734**	505.157**	0.159^{NS}	274.154**	4.310^{NS}
Interaction (A×B)	9	0.185	0.021	8.442	0.018	3.966	10.989
Error	30	0.142	0.038	5.704	0.061	4.096	9.396

Appendix IV: Analysis of variance of the data on fruit size, weight of individual fruit (gm), fruit weight /plant (kg) and fruit yield (ton/ha) as influenced by nitrogen and phosphorous

Source of variation	Degrees of freedom	Mean square				
		Fruit size		Weight of individual fruit (gm)	Fruit weight /plant (kg)	Fruit yield (ton/ha)
		Length (cm)	Breadth (cm)			
Replication	2	0.006	0.010	4.938	0.011	1.563
Nitrogen (A)	3	1.361**	0.270**	819.407**	2.703**	3515.749**
Phosphorous (B)	3	0.781**	0.139**	262.031**	1.701**	2208.871**
Interaction (A×B)	9	0.043	0.006	14.812	0.051	65.709
Error	30	0.019	0.011	6.471	0.005	5.296

Appendix V: Analysis of variance of the data on pH of post harvest soil, nitrogen (%), phosphorous (P) in ppm and potassium (K) in meq/100 gm soil of post harvest soil as influenced by nitrogen and phosphorous

Source of variation	Degrees of freedom	Mean square			
		P^H	Nitrogen (%)	Phosphorous (P) in ppm	Potassium (K)in meq/100gm soil
Replication	2	0.010	0.000	5.290	0.000
Nitrogen (A)	3	0.072^{NS}	0.001*	218.220**	0.009**
Phosphorous (B)	3	0.092^{NS}	0.000*	907.005**	0.012**
Interaction (A×B)	9	0.097	0.000	11.762	0.001
Error	30	0.038	0.000	4.117	0.000

Appendix VI: Analysis of variance of the data on nitrogen (%) in straw, phosphorous (P) in ppm in straw , potassium (K) in (%) straw, N % in fruit, P % in fruit and K % in fruit as influenced by nitrogen and phosphorous

Source of variation	Degrees of freedom	Mean square					
		Nitrogen (%) in straw	Phosphorous (P) in ppm in straw	Potassium (K) in (%) straw	N in fruit (%)	P in fruit (%)	K in fruit (%)
Replication	2	0.001	3.755	0.038	0.109	0.000	0.031
Nitrogen (A)	3	2.175**	1346.497**	0.470**	1.664**	0.005**	0.047^{NS}
Phosphorous (B)	3	0.337**	1761.885**	0.363**	0.299**	0.010**	0.065^{NS}
Interaction (A×B)	9	0.026	79.166	0.013	0.013	0.000	0.002
Error	30	0.008	5.455	0.009	0.025	0.000	0.025