GROWTH, YIELD AND SHELF LIFE OF TOMATO (*Lycopersicon esculentum*) AS INFLUENCED BY NITROGENOUS FERTILIZER

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This is to certify that the thesis entitled "[illegible] *OF TOMATO AS INFLUENCED BY* [illegible]" submitted to the Faculty of Agriculture, Department of Horticulture and Postharvest Technology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 in partial fulfillment of the requirements for the degree of ***MASTER OF SCIENCE (M.S)*** in ***HORTICULTURE*** embodies the result of a price of bona fide research work carried out by *MD.* [illegible] Registration No. ***23871/00142*** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged by him.

Dated: 16.5.06

Place: **Gazipur, Bangladesh**

Salam

(Md. Abdus Salam)
Supervisor

Dedicated to

My

Beloved

Parents & Teachers

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ABSTRACT

Field and laboratory experiments were conducted at the farm and laboratory of the Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the period from October 2004 to April 2005. The objectives of the research work were to study the growth, yield, relative cost, returns, and shelf life of BARI tomato-9 as influenced by different levels of nitrogen and stages of fruit maturity. Two experiments were laid out in a randomized complete block design (RCBD) with three replications. There were seven nitrogen levels (0, 140, 160, 180, 200, 220 and 240 Kg N/ha) in the first experiment and seven nitrogen levels (0, 140, 160, 180, 200, 220 and 240 Kg N/ha) with three stages of maturity (breaker stages, half-ripe, and full ripe) in the second experiment.

Plant height, number of leaves, days to 50% flowering, number of flower clusters, number of flowers per cluster, fruits per plant, fruit length and diameter, weight of individual fruit and fruit yield were significantly influenced by different levels of nitrogen. The highest levels of nitrogen (240 Kg N/ha) produced the highest fruit yield (85.42 ton/ha) and gave maximum (3.07) Benefit cost ratio (BCR).

Fifteen days after storage the maximum weight loss (8.93%) and shelf life (21.39days) were observed in breaker stage and the minimum in full ripe fruit (6.35%) and 15.64 days, respectively. The highest weight loss (9.5%) and shelf life (19.53 days) were recorded in 240 kg N/ha and control treatment respectively

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ABBREVIATIONS AND ACRONYMS

FULL NAME	*ABBREVIATION*
Abscisic Acid	ABA
Bangladesh Agricultural Research Council	BARC
Benefit Cost Ratio	BCR
Bangladesh Rice Research Institute	BRRI
Bangladesh Bureau of Statistics	BBS
Co-efficient of Variance	CV
Degree Centigrade	^{0}C
Days After Planting	DAP
Days After Storage	DAS
Duncan's New Multiple Range Test	DMRT
Example	e.g.
And others	*et al.*
Etcetera	etc.
Farm Yard Manure	FYM
Gram	G
Horticulture Research Center	HRC
Least Significance Difference	LSD
Maximum	Max
Minimum	Min
Number	No
Muriate of potash	MP
Randomized Completed Block Design	RCBD
Sher-e-Bangla Agriculture University	SAU
Tonnes Per Hectare	t /ha
Total Soluble Solid	TSS
Namely	Viz
Percentage	%

Chapter 1
Introduction

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) a member of the family Solanaceae is one of the most popular and important vegetables grown in Bangladesh during rabi season. It has originated in tropical America (Salunkhe *et al.* 1987), which includes Peru-Euador-Bolivia area of Andes (Kalloo, 1986). However, in spite of its broad adaptation production is concentrated in a few areas and rather in dry area (Cuortero and Fernandez, 1999). It is cultivated in almost all home gardens and in the field due to its adaptability to wide range of soil and climate (Ahmed, 1976). The soil and climatic conditions of winter season of Bangladesh are congenial for tomato cultivation. Among the winter vegetables, Crop grown in Bangladesh tomato ranks second in respect of production to potatoes and third in respect of area (BBS, 2004). It ranks next to potato and sweet potato in the world vegetable production (FAO, 1997).

The popularity of the tomato and its products continue to rise. It is a nutritious and delicious vegetable used in salad in the raw from and is made into soups, juice, ketchup, pickles, sauces conserved puree, paste powder and other products. It is extensively used in the canning industry. Nutritive value of the fruit is an important aspect of tomato. Its food value is very rich because of high content of vitamin A, B and C including calcium and carotene (Bose and Som, 1990). Tomato adds a variety of color and flavors to the foods. It is also rich in medicinal value.

In Bangladesh, recent statistic shows that tomato covered 37085 acres of land and the total production was approximately 100485 metric tons (BBS, 2004). Thus, the average yield is quite low as compared to that of other tomato producing countries such as India (15.14 t/ha), Japan (52.817 t/ha), USA (65.22 t/ha), China (30.39 t/ha), Egypt (34 ton/ha), respectively (FAO, 2002). The low yield of tomato in Bangladesh, However, is not an indication of the low yielding potentiality of this crop. This is mainly due to the use of low yielding variety and dearth of improved cultural practices including insufficient supply of required nutrient elements, water and poor disease management (Ali *et al.* 1994.) Out of these, proper fertilizer management practices may improve this situation greatly. Ali and Gupta (1978) reported that N, P and K fertilizer significantly increased the yield of tomato. Similar results were reported by Laricheva and Demkin (1980) and Ahmed and Saha (1976).

In Bangladesh, there is a great possibility of increasing tomato yield per unit area with the proper use of fertilizer. The profit from the use of commercial fertilizers has been so often demonstrated by experiment that there is no doubt about the necessity of using the right fertilizer and the economic returns resulting from them. Research results of scientists also indicated the positive response of fertilizer application in increasing yield of different species of tomato. Tomato requires large quantity of readily available fertilizer nutrient (Gupta and Shukla, 1977). In determine type of tomato, vegetative and reproductive 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 kg N, 0.2-0.3 kg P and 3-3.5 kg K (Hedge, 1997). In absence of other production constraints, nutrient uptake and yield are very closely related. Nitrogen is essential for building up protoplasm and protein, which induce cell division and initial meristematic activity when applied in optimum quantity (Singh and Kumar, 1969). Nitrogen has the largest effect on yield and quality of tomato (Xin *et al.* 1997). It also promotes vegetation growth, flower and fruit set of tomato (Bose and Som, 1990). It significantly increases the growth and yield of tomato (Banerjee *et al.* 1997).

Keeping quality of tomato during storage is degraded owing to various physio-chemical changes and decay losses caused by several microbes (Chenulu and Thakur, 1968; Bhatnagar *et al.*1980). Quality of tomato fruits during storage can be enhanced and maintained through several means including cultural practices. According to Bhatnagar and Panditu (1981), increase in nitrogen levels and spacing resulted in the production of quality fruits. Adequate nitrogen increases fruit quality, fruit size, keeping quality, color and taste (Shukla and Nair, 1993). Though effects of different fertilizers on yield of tomato were studied earlier in Bangladesh but the specific dose of nitrogen affecting yield and storage behavior of tomato fruits was not standardized so far it was reviewed.

Considering the above facts, the present study was undertaken to fulfill the following objectives

i. To find out the dose of nitrogen for optimum growth and higher yield of tomato per unit area of land

ii. To find out the relative cost and returns of tomato production at different nitrogen levels

iii. To determine the shelf life of tomato at different nitrogen levels

iv. To identify a suitable maturity stage for preservation of tomato.

Chapter 2

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most important vegetable crops grown under field and greenhouse conditions, which received much attention to the researchers throughout the world. The response of tomato the different levels of nitrogen has been investigated by numerous investigators in various parts of the world. In Bangladesh, little work (s) has been done in this respect. Besides, the reports on shelf life of tomato are scanty. However, the available research findings in this connection have been reviewed in this chapter under the following headings.

2.1 Effect of nitrogen on plant growth and fruit yield

A field experiment was conducted at the central research farm, Bangladesh Agricultural Research Institute (BARI), Joydebpur during rabi season 2003-2004 to study the effect of irrigation (EU: CPE ratio of 0.6, 0.8, 2.0 and rainfed condition) and nitrogen (0,180,160 and 240 Kg/ha) on tomato. Different nitrogen levels showed significant variations in all characters except number of fruits per plant. The highest fruit yield (49.70 t/ha) was recorded from 160 Kg N/ha that was significantly higher than other treatments (Anon., 2004).

In the field trial at Horticulture Research Center (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur tomato plants were fertilized at the rate of 550 Kg urea per hectare (Anon., 2004).

Nitrogen enhanced the growth and development, which ultimately increased the yield. While conducting an experiment in a solar greenhouse with the aid of a computer, Xin *et al.* (1997) established the relationship between N, P, K and effects on the yield and quality of tomato. Nitrogen had the largest effect on the yield and quality, while the interaction between N and K was the most significant.

Islam *et al.* (1997) studied yield contributing characters of tomato due to the effect of planting patterns and different nitrogen levels. They reported that nitrogen at the rate of 250 Kg/ ha gave the highest number of flower and fruit per plant. Such influence of nitrogen has also been reported by Midan *et al.* (1985). The maximum weight of individual fruit was obtained from 250 Kg/ha nitrogen applications. The length and diameter of individual fruit were increased nitrogen levels. Nassar (1986) also reported that the use of 250 Kg N/ha gave maximum dry weight of shoot and dry matter of fruit.

Pinto *et al.* (1997) found in a field trial where the processing tomato variety IPA-5 was grown and was supplied with 90 Kg K_2O/ha as KCl up to 75 days after transplanting and 0, 45, 90 or 135 Kg N/ha as urea up to 25,50 or 75 days after transplanting. Both were applied via dry irrigation. For comparison some plants were supplied with the conventional 30 Kg N/ha at transplanting with a further dose of 60 Kg N/ha at 30 days later. Nitrogen application increased yields by up to 308 % (compared to no nitrogen).

Banerjee *et al.* (1997) worked on the effect of N fertilizer (0.75, 100 or 125 kg/ha) and planting pattern. They found that total fruit yield per plant and ton per ha were significantly influenced by both N and planting pattern. The highest total fruit yield per plant was recorded from treatments of 125 kg N/ha and spacing of 90 x 45 cm in 1991-92 and 1995-96, 125 kg N/ha and spacing of 60 x 45 cm (single side planting) in 1990-91. The lowest yields were recorded from the treatment combination of no N and spacing of 60 x 95 cm (single side planting) in both the years.

Rhoads *et al.* (1996) stated that yield was much lower for autumn crop (the highest being 37 t/ha) as compared to spring crops (63 t/ha). Further more, yield response to N rates was much stronger for the spring crop than for the autumn crop.

Nwadukwe and Chude (1995) observed the effect of different irrigation frequencies (5, 7 and 9 day intervals) and nitrogen rate (0, 50,100 and 150 kg /ha) in N uptake by tomato variety Roma VF during three growing seasons. The application of 100 kg N / ha with irrigation schedule of 7 day intervals resulted with significantly higher nitrogen uptake and recovery rate than the other treatments. Fruit yields and water use efficiency were maximum with 100 and 150 kg N/ha and irrigation at seven-day interval.

Csizinszky (1996) conducted a field experiment with tomato cultivars Equinox and Sun bean received foliar application of bio-stimulant, Key plex-350 and Tri-Ag, at two N plus K rates, 195 kg N+324 kg/ha or times of this rate. The higher N+K rate resulted in an increased yield of medium sized fruits. Early yields of Equinox were higher than Sun beam, however, for the reason, equinox yields were higher only for the large (6.35-7.06

cm diameter) fruit size. Nicola and Basoccu (1994) noted that increasing nitrogen rate increased yield because of higher fruit number and fruit weight.

Arora *et al.* (1993) conducted an experiment to study the response of tomato variety Hisar Arun to nitrogen rate (60, 90 or 120 kg/ha) and planting method. Nitrogen at 120 kg/ha resulted in the highest contents of TSS (5.57%), fruit acidity (2.35%), ascorbic acid content (25.4 mg/100g), lockets/fruit (4.3), juice content (47.5) and per carp thickness (2.56 mm). The combination of 120 kg N/ha and spacing of 90 x 45 cm with one seedling/hill planted on both sides of the bed gave the highest fruit TSS (5.77%), ascorbic acid content (28.2 mg/100g), and pericarp thickness (2.70 mm). The combination of 120 kg N/ha and 60 x 45 cm with one seedling/hill planted on one sides of the bed increased juice content (48.2%). However, 120 kg N/ha in combination with 60 x 30 cm spacing with one seedling/hill on one side of the bed gave the highest acid content (2.5%) and number of lockets/fruit (4.5).

Chakrabarti *et al.* (1992) conducted an experiment with tomato plants (variety Pusa Early l) dwarf Perfection and Puniab Chuhara) grown in plots fertilized with 0, 30, or 60 kg N/ha. Polyacrylamide gel electrophoresis of the seed protein indicated that the number and intensity of protein bands increased as the level of N application increased.

Chung *et al.* (1992) supplied 2, 4, 8, 16 or 32 me N/liter and 2, 4, 8, or 16 me K /liter to tomato plant at the third true leaf stage and observed that the plant height increased with increasing nutrient concentrations, except at the highest concentrations where it was not significant. Top: root ratio increased with increasing nitrogen concentration and flowering response was the best at 8 me N/liter. Fruit fresh weight, fruits set per cluster increased with increasing nitrogen but fruit dry weight was influenced more by nitrogen than potassium.

Nasreen and Islam (1990) also investigated the fertilizer effect on tomato yield and found that the yield response was linear with the levels of nitrogen and nitrogen application had certain optimum range beyond which the yield of tomato would not increase.

Grela *et al.* (1988) studied the effect of different nitrogen rates and plant spacing on growth and development of commercial tomato cultivars. Nitrogen was applied at 0, 80, 160 or 240 kg / ha and found that plant height and the number of leaves, flowers and roots per plant increased with increasing rates up to 160 kg N/ha and then decreased.

Dimri and Lal (1988) studied the effect of nitrogen fertilization; spacing and method of planting on yield parameters and quality of tomato cultivar Pant Bahar. The tomato plants, received N @ 0, 60, 90 or 120 kg/ha; half was applied at planting and other half 45 days later. Fruit yield was the highest (54.9 t/ha) and the quality was best on raised bed receiving the highest nitrogen rate.

Wein and Minotti (1988) stated that nitrogen fertilizer levels up to 84 kg N/ha increased total yields compared to zero nitrogen with no further increase when nitrogen rate was doubled, whereas 168 kg N/ha of nitrogen decreased yield.

Srinivasa *et al.* (1988) observed the response of tomato varieties to different nitrogen levels and spacing geometry. They worked with the cultivars Pusa Ruby and NTDR -1, plants spaced at 75 X 60, 90 X 50, 75 X 50 or 90 X 41.6 cm that received N @ 60,120 or 180 kg/ha. The highest yields in both cultivars (60.3 and 56 t/ha, respectively) were obtained from plants spaced at 90X50 cm and receiving 120 kg N/ha.

Cholakov (1988) reported that the average requirements for producing one ton of tomato fruit were 3.82 kg N, 1.01 kg P_2O_5 and 3.65 kg K_2O.

Kaniszewski *et al.* (1987) studied the effects of nitrogen fertilization at rates from 37.5 to 300 kg N/ha and irrigation was studied under field conditions on tomato variety NewYorker. They reported that nitrogen fertilization up to the rate of 225 kg N/ha resulted in a significant increase of total and marketable yield with both irrigation whereas the yield increased up to the rate of 150 kg N/ha without irrigation. They also found that nitrogen fertilization decreased vitamin C content and increased dry matter content of fruits.

Nassar (1986) carried out a two-year investigation on the influence of planting pattern, plant population and rate of nitrogen application, on tomato variety UC 97-3 and indicated that yield can be increased considerably and quality can be improved by appropriate nitrogen application and plant population but not by planting pattern. Maximum yield was achieved at 296.4 kg N/ha associated with a plant population of

88920 plants/ha. He also reported that fruit quality was significantly increased by nitrogen rate.

Subbiah and Perumal (1986) conducted a fertilizer trial with the cultivar Co. 1 and Co. 3 and found best results with regard to yields and nutrient uptake from 50 kg K_2O/ha (for Co. 1) and 100 kg K_2O/ha (for Co.3) plus N at 120 kg/ha in each case. In a study on the effect of nitrogen fertilization and plant intensification, Midan *et al* (1985) observed that increasing nitrogen rates linearly increased number of fruit per plant. However, medium and higher nitrogen rates gave the best total yields. Three times of application improved fruit per plant, average fruit weight and total yield.

Patil and Bojappa (1984) conducted an experiment to study the effect of cultivars and graded levels of nitrogen and phosphorus on certain quality attributes of tomato. The experiment consisted of the cultivars Pusa ruby, Sioux and Sweet 72. The plant received nitrogen at 70,110 and 150 kg/ha and phosphorus at 44 or 61.6 kg/ha with basal dressing of potassium at 49.8 kg/ha and FYM at 25 ton/ha. The highest fruit content of total sugar and next highest dry matter content were in sweet 72 while juice percentage was highest in Pusa ruby. Raising nitrogen rates increased fruit total sugars and juice percentage but decreased the dry matter content. Phosphorus had no appreciable effect as any of the indices studies.

Varis and George (1985) conducted a nutritional experiment under glass house in the United Kingdom and used the tomato variety Moneymaker grown in pots of peat compost. They reported that the high nitrogen level increased flower number, fruit and seed yields and gave early flowering and ripening, when the seeds from the plants of various nitrogen treatments were sown, it was observed that seeds from the plants treated by higher nitrogen level emerged earlier than that of lower nitrogen level.

Belichki (1993) reported that nitrogen was the most important nutrient for tomato. Flower and fruit number per plant were increased by nitrogen up to 240 kg/ha and fruit size was maximum at 6. 20 cm.

Staneve *et al.* (1983) conducted an experiment to investigate the effect of nitrogen supply on photosynthesis, leaf area and total dry matter in tomato and found photosynthesis was inhibited by N deficiency. Leaf development and dry matter accumulation were greatest at 10 ml /L of N and declined at higher concentrations.

Kaniszewski and Rumpel (1983) worked on multiple harvested transplanted tomatos and found that early yield decreased with the increase of nitrogen fertilization. They further observed that nitrogen fertilization influenced dry matter and vitamin C content of fruit.

To determine the effect of nitrogen rates on the growth and yield of tomato, Doss *et al.* (1981) conducted an experiment and found that there was no consistent effect from nitrogen rate on marketable yield of tomato fruits. Average yields from the lower nitrogen rate were greater than the higher nitrogen rate in the two driest years and were similar or higher from the higher nitrogen rate in year of more average rainfall.

Rastogi *et al.* (1978) carried out a trial with the tomato variety Solar Gola. The plants were spaced at 90 x 30, 90 x 45 or 73 x 45 cm that received nitrogen at 60, 75 or 90 kg/ha. The difference between the mean three-year yields (25.56-25.89 t/ha) was very small and the 60 kg N/ha rate was considered adequate for tomatoes grown in soil of average fertility. The closest spacing (90 x 30) gave the highest yield.

Hassan (1978) reported that with the increased nitrogen levels the fruit yield increased. He also noticed that nitrogen levels and plant population were interacting. This trend reflected an edge effect on both variables, which might explain the inconsistent results obtained by different workers like Kostewicz and Locascio (1 976).

More than any other nutrient, nitrogen produced effect on vegetative growth and yield of tomato plants, while studying the influence of N, P and K fertilization on growth and yield of tomato, Han and Misra (1 976) found that nitrogen application at highest rates improved plant growth, fruit yield and fruit quality. Similar opinions were put forwarded by Kuksal *et al.* (1977) and Nedranko (1 976).

Sharma and Mann (1972) conducted a field experiment with three different nitrogen and phosphorus levels (50,100 and 150 kg N/ha) on the growth of tomato variety Pusa ruby. They reported that increasing levels of nitrogen and phosphorus application increased the plant height, number of branches and number of leaves per branch.

Brar *et al.* (1971) reported from their studies to determine the response of tomato varieties to the different fertilizer application. Early yield was not influenced by nitrogen but total yield was increased as the level of nitrogen had risen from 50 to 80 kg/ha. In contrast, Winsor and Hart (1964) found an increased early crop at a high level of nitrogen and they attributed the increased early yield to the large fruit size. In determined the effect of fertilizer and spacing on the fruit and seed yield in tomato (variety Pusa ruby). Seth and Choudhury (1970) reported that higher nitrogen level increased the fruit and seed yield.

Fisher (1969) applied two levels of nitrogen before and after the initiation of the first truss and found that a high level of nitrogen (340 ppm) tended to promote earlier flowering, increased the number of flower and fruit weight on the first truss. He further observed that heavy dressings of nitrogen reduced the number of truss, the flowers per plant and the number of fruit set.

Garrison *et al.* (1967) reported that a high rate of broadcast nitrogen (208 or 280 kg/ha) increased flower formation on several clusters of processing tomato. Specially, side dressings of nitrogen increased flower formation and fruit set on late cluster only. They concluded that the yield generally increased with the increase of nitrogen level. Similar opinions were put forwarded by Anand and Muthukrishnan (1974) and Hall (1983).

Mohamedien (1983) stated that yield of tomato fruit per unit area tended to be the highest with closer spacing and fertilizer rates had been reported to influence yield of tomato.

Similar results were observed by Gupta and Shukla (1977). Sulikeri *et al* (1975) mentioned that tomato yields were higher at closer spacing with all nitrogen fertilizer levels.

Nicklow and Downess (1971) also reported that nitrogen results in a significant reduction of fruit size; but in most cases, fruit size was decreased as plant population was increased. From the fertilizer and plant population studies, Austin and Dulton (1970) observed that fertilizer application did not influence fruit size of tomato, but the size was reduced at high plant population. Side dressing with additional nitrogen increased the percentage of marketable fruit and doubling the plant population increased the yield of marketable fruit.

2. 2 Effect of maturity stages

Moura *et al.* (1999) reported that exposure of tomato to controlled atmospheres for seven days did not influence total sugar, titrable acidity and vitamin C content at the end of storage. Sharma and Dashora (1999) treated early-matured fruit with 0.0 and 0.5% $KMnO_4$ and exposed to temperature between 23.73 and 31.19 ^{0}C. They reported that weight loss (%) and decrease in TSS content were reduced by 0.5% $KMnO_4$ treatment compared with the control.

Islam *et al.* (1999) in an experiment stored vine-ripened tomato variety TMO126 at 15, 25 or 20 C and 80-90% relative humidity. In all treatment total soluble solid (TSS), ascorbic acid and organic acid concentration decreased with storage duration.

Kaynas and Surmeli (1994) in an experiment with five tomato cultivars reported that TSS content, invert sugar, and total sugar concentration increased during ripening. Ascorbic acid content increased until the red stage then decreased later.

Mallik and Biswajit (1996) reported that ascorbic acid content was lowest in mature green fruit at harvest and after storage, during which it decreased. Early harvesting increased shelf life. Islam *et al.* (1997) showed that total and L-ascorbic acid concentration were highest at pink stage, declining slightly with further maturation when they were stored in all different maturity stages.

Singh *et al.* (1993) showed that, vitamin C content of tomato decreased as the CO_2 concentration in the storage atmosphere increased. Vitamin C content increased with the storage period. Hong and Lee (1993) reported that normal tomatoes were harvested at mature green, intermediates and fully ripe stages. Ascorbic acid content in normal fruits showed a peak at the intermediate breaker stage.

Ludford and Hillman (1990) observed that, chilled fruit contained free ABA two to three times more than the amount of free ABA in unchilled fruit. Stern *et al.* (1994) reported that tomato fruits were harvested at table ripe, breaker and mature green stage. They observed that generation of volatile compound (which is related to physical changes) decreased significantly with storage and ripening temperature below 10^0 C.

Haiking and Baerdemaker (1990) reported that when tomato fruits were harvested at different stage and stored for 12 days in 20^0 C, water loss during storage was lower in chunripe fruit than ripe fruit. Upasana and Bains (1988) studied the composition and pectolytic changes in cultivars pb Chihuahua and pb Kosri, at the green, intermediate and red ripe stage. They found that lycopene content showed a spectacular increase in the ripe stage.

Whitaker (1991) in an experiment stored green tomato fruit at non-chilling or chilling temperature for 2, 4, 8 or 12 days after harvest. He reported that, fruit stored at 15^0 C had progressed to the pink stage of ripening after 12 days, whereas fruit stored at 2^0 C did not ripe properly.

2. 3 Shelf life

De Vos (1966) stated that temperature requirement of fruit for slow ripening depends upon the stage of maturity. For prolonged storage, green fruit at 15^o C, Orange green fruit at 10^o C and red fruit at 8^o C was kept. He also stated that at 20^o C the fruit quality was deteriorated and under very low temperature condition. Chilling injury was caused and such situation arose below 10^o C.

Subburamu *et al.* (1990) stated that fruit of tomato (variety Pusa-Ruby) were harvested at 4-maturity stage viz. (1) mature green (2) breaker (3) half-ripe and (4) red ripe and held under ambient condition to assess weight loss, shelf life and change of color. They observed that shelf life was longer (11.0-12.5 days) in fruits picked at the mature green stage, but their quality after storage was poor, and fruit picked at the breaker stage were of better quality and had an acceptable shelf life (8.3-10.5).

Mallik and Bhattacharya (1996) observed the shelf life of tomato (variety Roma, Pusa-Ruby, Sioux and Solangola) harvested at mature green, breaker, and half ripe and red ripe stages to observe the shelf life and storage condition. They reported that shelf life of tomato was increased at mature green stage and showed the lowest physiological weight loss (7.7-9.7 after 6 days) and longest shelf life (13.5 days). They also stated that fruit harvested at breaker or half-ripe stage exhibited good shelf life and keeping quality.

Hooda *et al.* (1994) reported that tomatoes harvested at the mature green stage and breaker or half-ripe stages were stored in ambient condition. They observed that mature green fruit showed the least physiological weight loss and decay. Fallik *et al.* (1995) stated that eggplant harvested at earlier stage were more susceptible to chilling injury during storage at 6 or 8° C (87-90 % RH) than fruits harvested later.

Kaynas and Surmeli (1995) stated that tomato cultivars (Tobol, ES-58 and Riogrande) were harvested at two maturity stages. They observed that weight loss was more severe in fruit at an early stage of maturity and increased as storage temperature increased. They stated that total weight loss over 35 days ranged from 3 to 8% depending on cultivar, maturity stage and temperature.

Thompson and Kelly (1957) divided the entire ripening period of tomato into the following color stages. Immature green turning half-ripe or pink and ripe or red ripe. Anju-kumari *et al.* (1993) also reported that the shelf life for all tomato cultivars was longest with harvesting at the mature green stage (10.9-13.5 days), but resulted in pateny color development on ripening.

Hong and Lee (1996) reported that post harvest ripening of tomato fruits was investigated for fruit harvested at the mature green stage and for fruit detached from plant at each ripening stage. They observed that post harvest ripening of normal fruit followed the same pattern of ripening (color development, respiration and ethylene production) as fruit on the plant.

Chapter 3

Materials and methods

CHAPTER III

MATERIALS AND METHODS

The present research work was carried out at the Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the period from October, 2004 – April 2005 to find out the effect of nitrogen on the growth, yield and shelf life of tomato. This chapter describes the materials and methods that were used in conducting the experiment.

3.1 Soil

The land was medium high with good drainage facilities. The soil of the experimental area belongs to the grey, terrace soil tract. The texture of the soil was silt loam having pH 6.4 and organic matter content of 1.88% (Anonymous, 2004).

The result of the chemical analysis of soil sample are shown below

Soil properties	Analytical data	Critical level
P^H	6.4	
Organic matter	1.88	
Ca	4.9 meq/100ml	2.0
Mg	1.5 meq/100ml	0.8
K	0.11 meq/100ml	0.2
Total N %	0.079	0.12
P	12µg/ml	14
S	19µg/ml	14
B	0.34µg/ml	0.2
Cu	1.2µg/ml	1.0
Fe	113µg/ml	10.0
Mn	13	5.0
Zn	1.7	2.0

3.2 Climate

The area is characterized by hot and humid climate. The average rainfall of the locality during experimental period was 209.06 mm; the minimum and maximum temperatures are 13.02°C and 32.24°C, respectively. The minimum and maximum relative humidity was 68.5% and 76.16% during October- March 2005.

3.3 Planting materials used

The tomato variety used in the experiment was BARI TOMATO-9. This is a high yielding determinate type and the seeds were collected from Horticulture Research Center (HRC), Bangladesh Agricultural Research Institute (BARI). The popular name of the variety is Lalima. Fruit is oval shaped and somewhat pointed at the end. The minimum and maximum individual fruit weight was 50.30 and 90.21gm. Each plant bears 32-35 fruit and per plant yield is 2-3 kg. The pericarp of the fruit is thick and fleshy.

3.4 Raising of seedlings

The land selected for nursery beds was well drained and was of 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 rotten cowdung at the rate of 5 kg/bed. The size of each seed bed was 3 m x 1 m raised above the ground level maintaining a spacing of 50 cm between the beds. Two seed bed were prepared for raising the seedlings. Ten grams of seeds were sown in each seedbed on 4. October 2004. After sowing, the seeds were covered with light soil. Miral 3-GN was applied in each seed bed as precautionary measurers against various soil pests. Complete germination of the seeds took place within 6 days after seed sowing. Necessary shading was made by bamboo mat (chatai) from scorching sunshine or rain. Weeding, mulching and irrigation were done as and when required. No chemical fertilizer was used in the seed bed.

3.5 Treatments and layout

The experiment consisted of seven different levels of 'nitrogen, they are mentioned below

Treatment	Dose (Kg N/ha)
T_1	140
T_2	160
T_3	180
T_4	200
T_5	220
T_6	240
T_7	0

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The whole field was divided into three blocks each containing 7 plots. In total, there were 21 unit plots. The treatments were randomly assigned to each unit plot. The size of unit plot was 4.8 m x 1 m. The distance between the blocks was 1m and that between plots was 1m.

3.6 Land preparation

The land was first opened with a tractor on l8 October, 2004.Thereafter, it was gradually ploughed and cross ploughed three times with power tiller. Laddering to break the clods and to level the soil followed each ploughing. During land preparation weeds and other stubbles of the previous crop were collected and removed from the land. These operations were done to bring the land under a good tilth condition. Irrigation channels were prepared around the plots.

3.7 Manuring

In addition to the fertilizer under treatment, 10 tones of cowdung. 450 kg of Triple Super Phosphate (TSP) and 250 of MP per hectare were applied in the experimental plot. Half of the quantities of cowdung, the entire quantity of TSP, ½ of MP were applied during final land preparation. The remaining cowdung were applied during pit preparation. The entire urea and the rest of MP were applied in three equal installments at 10, 30, and 50 days after transplanting in the main field.

3.8 Transplanting of seedlings

Healthy and uniform sized 30 days old seedlings were taken separately from the seed bed and were transplanted in the experimental field on 4 November 2004 maintaining spacing of 60 and 40 cm between the rows, respectively. The seed beds were watered before uprooting the seedlings so as to minimize damage to the roots; this operation was carried out during late hours in the evening. The seedlings were watered after transplanting. Seedlings were also grown around the experimental area to check the border effect.

3.9 Intercultural operations

After transplanting the seedlings, various kinds of intercultural operations were accomplished for better growth and development of the plants.

3.9.1 Gap filling

When the seedlings were established, the soil around the base of the seedlings was pulverized. Healthy plants did a few gaps filling from the border whenever it was required.

3.9.2 Weeding and mulching

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

3.9.3 Staking and pruning practices

When the plants were well established, staking was given to each plant to keep them erect. Within a few days of staking, the plants were pruned uniformly having single main stem per plant.

3.9.4 Irrigation

Two irrigations were given throughout the growing period by watering cane. The first irrigation was given 40 days after planting followed by irrigation 20 days after the first irrigation. Mulching was also done after each irrigation at appropriate time by breaking the soil crust.

3.9.5 Plant protection

Insect pests: As preventive measure against the insect pests like Cut worm, Leaf hopper and others; Malathion 57 EC was applied @ 2 ml/liter. The insecticide application was done fortnightly from a week after transplanting to a week before first harvesting.

3.10 Harvesting

Fruits were harvested at 5 days intervals during ripening stage. The maturity of the crop was determined on the basis of red color development.

3.11 Data collection

Data on the following parameters were recorded from the sample plants during the course of experiment. Twenty-four plants were selected randomly from each plot.

3.11.1 Plant height (cm)

Plant height was measured from ten randomly selected plants in centimeter from the ground level to tip of the longest stem and mean value was calculated. Plant height was also recorded at 15 days interval starting from 15 days of planting up to 90 days to observe the growth of plants.

3.11.2 Total number of leaves per plant

Total number of leaves from transplant to harvest was counted from ten randomly selected plants along with the leaf scars of shed leaves and their average was taken as the number of total leaves per plant.

3.11.3 Number of green leaves at final harvest

Number of green leaves at final harvest was counted from ten randomly selected plants and their average was taken as the number of green leaves per plant.

3.11.4 Days to 50 % flowering

Different dates of 50 % flowering were recorded. Then the observation was calculated from the date of sowing. It was counted when flower was fully opened.

3.11.5 Number of flower cluster per plant

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

3.11.6 Number of flower per cluster

The number of flower per cluster was recorded as the average of ten sample plants selected from each unit plot.

3.11.7 Number of fruits per cluster

It was calculated by the following formula:

$$\text{Number of fruits per cluster} = \frac{\text{Total number fruits of sample plant}}{\text{Total number of fruit cluster of sample plant}}$$

3.11.8 Number of fruits per plant

Total number of ripe fruits was counted from selected plants and their average was taken as the number of fruits per plant.

3.11.9 Fruit length (cm)

The length of fruit was measured with a slide calipers from the neck of the fruits to the bottom of ten selected marketable fruits from each plot and the minimum and maximum fruit length (cm) was 4.52 and 6.20 centimeter.

3.11.10 Fruit diameter (cm)

Diameter of fruit was measured at the middle portion of ten selected marketable fruits from each plot with a slide calipers and was the minimum and maximum fruit diameter was 4.00 and 5.30 centimeter.

3.11.11 Weight of individual fruit (g)

Among the harvest of marketable fruits during the period from first final Harvests, first and last harvests were omitted and four intermediate harvests were taken for individual fruit weight by the following formula.

$$\text{Weight of individual fruit (g)} = \frac{\text{Total weight of marketable fruits from four harvests of sample plant}}{\text{Total number of marketable fruit from four harvests of sample plant}}$$

3.11.12 Weight of fruit per plant (kg)

It was measured by the following formula:

Weight of fruit per plant (kg) = No. of fresh fruit per plant X Wt. of individual fruit

3.11.13 Weight of fruits per plot (kg)

A pan scale balance was used to take the weight of fruits per plot. It was measured by totaling from each unit plot separately during the period from first to final harvest.

3.11.14 Dry matter (%) of fruit

For the determination of dry matter content, five fresh fruits were sliced with a fine knife. After drying in scorching sunlight, it was kept in an oven at 65°C for drying until the constant weight was reached. The percentage of fruit dry matter was calculated for each plot by the following formula:

$$\text{\% Dry matter content of fruit} = \frac{\text{Constant oven dry weight of fruit}}{\text{Fresh weight of fruit}} \text{ X100}$$

3.12 Analysis of data

The data in respect of yield and yield contributing characters were statistically analyzed to find out the statistical significance the experimental results. The means for all the treatments were calculated and analyses of variance for all the characters were performed by F test. The significance of the difference among the means was evaluated by DMRT for interpretation of the results (Gomez and Gomez, 1984).

3.13 Economic Analysis

Economic analysis was done with a view to comparing the cost and benefits under different levels of nitrogen. For this purpose, the input costs for land preparation, planting, fertilizer, irrigation, crop protection, harvesting, lease of land and manpower required were recorded against each treatment, which were then converted into cost per hectare. Farmgate price of tomato was considered for estimating the gross return.

3.14 Effect of maturity stages of harvest and different levels of nitrogen on Percent weight loss and shelf life of tomato

3.14.1 Experimental site

The present investigation was carried out in the laboratory of the Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during the period from February to April 2005. Laboratory room of the Horticulture Research Centre was used to store tomato fruits under normal condition.

3.14.2 Maturity stages of fruit

Fruits produced from different levels of nitrogen were harvested at the distinct maturity stages that were as follows:

Breaker stage: Fruits were harvested when the lower end pointing yellow color (M_1).

Half ripe: Fruits harvested at half-ripe stage (M_1)

Full ripe: Fruits harvested after attaining full red color (M_3).

3.15 Experimental details

The experiment consisted of two factors.

Factor A: Three (3) stage of maturity of tomato fruits

1) Breaker stage (M_1)
2) Half ripe (M_2)
3) Full-ripe (M_3)

Factor B: Seven (7) Nitrogen levels

Treatment	Dose (Kg N/ha)
1) T_1	140
2) T_2	160
3) T_3	180
4) T_4	200
5) T_5	220
6) T_6	240
7) T_7	0

Thus, there were 21 (3x7) treatment combinations. The combinations were as follows.

M_1T_1 = breaker stage fruits produced with 140 kg N/ha

M_1T_2 = breaker stage fruits produced with 160 kg N/ha

M_1T_3 = breaker stage fruits produced with 180 kg N/ha

M_1T_4 = breaker stage fruits produced with 200 kg N/ha

M_1T_5 = breaker stage fruits produced with 220 kg N/ha

M_1T_6 = breaker stage fruits produced with 240 kg N/ha

M_1T_7 = breaker stage fruits produced without N

M_2T_1 =Half ripe fruits produced with 140 kg N/ha

M_2T_2= Half ripe fruits produced with 160 kg N/ha

M_2T_3 = Half ripe fruits produced with 180 kg N/ha

M_1T_4 = Half ripe fruits produced with 200 kg N/ha

M_2T_5 = Half ripe fruits produced with 220 kg N/ha

M_2T_6 = Half ripe fruits produced with 240 kg N/ha

M_2T_7 = Half ripe fruits produced without N

M_3T_1 = Full ripe fruits produced with 140 kg N/ha

M_3 T_2= Full ripe fruits produced with 160 kg N/ha

M_3 T_3= Full ripe fruits produced with 180 kg N/ha

M_3 T_4= Full ripe fruits produced with 200 kg N/ha

M_3 T_5 = Full ripe fruits produced with 220 kg N/ha

M_3 T_6 = Full ripe fruits produced with 240 kg N/ha

M_3 T_7 = Full ripe fruits produced without N

3.15.1 Experimental design and layout

The experiment was laid out in a randomized complete block design with three replications. Nearly, 2 kg fresh harvested tomato was used. The skin of fruits was cleaned carefully with the help of a cloth just after harvested.

3.15.2 Collection of data

To assess the effect of maturity stage and nitrogen levels on the physical changes of the fruits during the entire storage period, the fruits used for the experiment were keenly observed and data were recorded during the storage period.

3.16 Methods of parameter studied

3.16.1 Percent weight loss

Total losses in weight of nearly 2 Kg fruits were recorded at an interval of 3 days during the storage period. Percent weight loss was measured as a reduction in weight of the fruits preserved. The percentage of loss in weight on the day of observation was calculated on the basis of the initial weight. The percent weight loss of fruit was calculated by using the following formula.

$$\text{Weight loss of fruit (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.16.2 Shelf life

Shelf life (days) of tomato varieties under each treatment was recorded during the period of study. It was calculated from the date of harvest to last edible period.

Chapter 4
Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results obtained from the present investigation. There were two separate experiments. The experiments were conducted to determine the optimum dose of nitrogen, relative cost and return and the effect of stages of maturity on weight loss and shelf life of tomato. The results of this study have been presented and expressed in tables and figures for ease of discussion, comparison and understanding, A summary of the analyses of variances in respect of all the parameters has been shown in appendices I-VIII. The results of each parameter have been discussed and possible interpretations wherever necessary have been given under the following headings.

4.1 Effect of nitrogen on the growth and yield of tomato

4.1.1 Plant height

Plant height was recorded at different days after planting (DAP) and different levels of nitrogen exhibited significant variation in respect of plant height at different days after planting (Appendix II). In case of all the nitrogen doses it was observed that the plant height increased gradually with the advancement of time (Table 1). The maximum plant height was found from the plant having 240 Kg N/ha and the minimum plant height was observed in control at 15 DAP, 30 DAP, 45 DAP, 60 DAP, 75 DAP, and 90 DAP. At last, harvest plant height varied from 65.24 to 99.10 cm. The maximum (99.10 cm) plant height was recorded at 240 Kg N/ha and the minimum (65.24 cm) were recorded from the control. The plant height was increased possibly due to the readily available nitrogen, which might have encouraged more vegetative growth and development. Nitrogen also enhances the protein synthesis, which allows plant to grow faster, rate of metabolism, cell division, cell elongation and thereby stimulated apical growth (Salam, 2001). Chung *et al.* (1992) reported that plant height was increased with increasing nitrogen rate. Grela *et al.* (1988) stated that plant height increased with increasing nitrogen rates up to 160 Kg N/ha and then decreased. Kuksal *et al.* (1977) also reported that nitrogen application at higher rates improved plant height. Similar opinions were forwarded by Sharma and Mann (1972). Melton and Dufault (1991) found that plant height increased as the level of nitrogen was increased.

Table 1. Effect of nitrogen on plant height of tomato

	Plant height (cm) at different days after planting (DAP)					
Treatment	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
T_1	17.21	31.41e	59.36e	63.29f	69.78f	73.83d
T_2	17.83	33.36d	62.86d	68.75e	73.62e	78.46cd
T_3	18.00	35.92c	64.56cd	71.21d	79.21d	83.31c
T_4	18.31	36.97bc	67.00bc	76.85c	83.48c	89.56b
T_5	18.84	37.42b	69.20b	80.21b	86.00b	91.21b
T_6	19.00	39.21a	72.50a	85.21a	93.48a	99.10a
T_7	16.83	29.48f	51.00f	57.26g	62.00g	65.24e
CV%	6.3	4.34	2.96	1.58	1.45	2.28

In a column, means followed by common letter do not differ significantly at 5 % of level of probability by Duncan's New Multiple Range Test (DMRT)

Where,

T_1 = 140 Kg N/ha
T_2 = 160 Kg N/ha
T_3 = 180 Kg N/ha
T_4 = 200 Kg N/ha
T_5 = 220 Kg N/ha
T_6 = 240 Kg N/ha
T_7 = Control

4.1.2 Total number of leaves per plant

There was a significant variation among the different levels of nitrogen in respect of total number of leaves per plant (Appendix III). Total number of leaves per plant ranged from 23.62 to 35.78 (Table 2). The maximum (35.78) number of leaves was observed at 240 Kg N /ha. Whereas, the minimum (23.62) was observed in control. The plants of the treatment 140, 160, 180 Kg N /ha produced total number of leaves of 28.14, 29.00, 29.11, respectively which were statistically identical. Grela *et al.* (1988) reported that the number of leaves per plant increased with the increasing rates of nitrogen up to 160 Kg N /ha.

Table 2. Effect of nitrogen on the yield contributing characters and yield of tomato

Treatment	Total number of leaves/ Plant	Number of green leaves at final harvest	Days to 50% flowering	Number of flower cluster/ Plant	Number of flower/ Cluster	Number of fruits/ Cluster	Number of fruits/ Plant
T_1	28.14d	15.23 de	54.92a	9.02e	4.00d	2.84c	20.21d
T_2	29.00d	16.00cdc	54.84a	10.21bc	4.21.cd	2.96bc	23.56c
T_3	29.11d	17.21cd	52.95a	11.00cd	4.84bc	3.00bc	28.21b
T_4	31.00c	18.00c	52.86a	12.03bc	5.00b	3.21bc	28.32b
T_5	34.21b	22.21b	48.82b	13.26b	5.28b	3.65ab	30.00b
T_6	35.78a	24.56a	46.26b	15.00a	6.74a	4.10a	34.00a
T_7	23.62e	14.21.e	55.00a	7.21f	3.58d	2.54c	16.14e
CV%	2.50	6.23	2.89	6.81	7.86	11.86	4.40

In a column, means followed by common letter do not differ significantly at 5 % of level of probability by Duncan's New Multiple Range Test (DMRT)

4.1.3 Number of green leaves at final harvest

Nitrogen had appreciable effect on the number of leaves per plant at final harvest. The plant which were fertilized with 240 Kg N /ha produced the highest (24.56) number of green leaves and those in control treatment produced the lowest (14.21) number of green leaves (Table 2). The result clearly showed that the number of leaves per plant was gradually increased with increasing levels of nitrogen. The finding of Melton and Dufault (1991) coincided with these results. They found that leaf number was increased as the nitrogen dose was increased. Sharma and Mann (1971) also reported that increasing levels of nitrogen application increased the number of leaves per branch (240 Kg N /ha).

4.1.4 Days to 50% flowering

The different nitrogen levels showed highly significant variation in respect of days to 50% flowering (Appendix III). Days to 50% flowering decreased with the increasing nitrogen doses (Table 2). Increased nitrogen rates accelerated early flowering of the plants. The plant fertilized with 240 Kg N /ha produced early flowering (46.26) and delay flowering (55.00) of the plants occurred in control. Varis and George (1985) also found that high nitrogen level caused early flowering and ripening. Fisher (1969) found that a high level of nitrogen (240 Kg N /ha) prior to flower initiation tended to promote earlier flowering. On the other hand, Nightingale *et al.* (1982) reported that flowering of the plants was delayed consequently with increasing nitrogen rates.

4.1.5 Number of flower clusters per plant

The effect of different doses of nitrogen in respect of flower clusters per plant was highly significant (Appendix III). The maximum (15) number of flower clusters per plant was found at 240 Kg N /ha and the minimum (7.21) was found for the control treatment (Table 2). The result clearly showed that the number of flower cluster per plant gradually increased with increasing levels of nitrogen. The result is almost similar to the finding of Islam *et al.* (1997). They reported that the highest number of flowers per plant was produced from 240 Kg N /ha. Grela *et al.* (1988) put forwarded almost similar opinion. Garrison *et al.* (1967) reported that increasing levels of nitrogen increased flower formation of several clusters of processing tomato. On the other hand, Fisher (1969) observed that heavy dressing of nitrogen reduced the number of trusses.

4.1.6 Number of flower per cluster

Remarkable variation was observed as to the number of flower per cluster among the different nitrogen levels (Appendix III). The result revealed that number flower per cluster increased with the increasing nitrogen levels (Table 2). The highest (6.74) number of flower per cluster was recorded in 240 Kg N /ha, while the minimum (3.58) was found in control which was statistically similar to that of 140 Kg N /ha and 160 kg N/ha

4.1.7 Number of fruits per cluster

Application of different levels of nitrogen showed significant variation in respect of fruits per cluster (Appendix III). The maximum (4.1) number of fruits per cluster was obtained from the nitrogen level 240 Kg N /ha. The minimum (2.54) was found from the control treatment. Chung *et al.* (1992) also obtained similar result. They observed that fruit set per cluster was increased with increasing nitrogen application. Varis and George (1985) also concluded that the highest level of nitrogen was the most favorable condition for fruit setting.

4.1.8 Number of fruits per plant

Nitrogen significantly influenced the number of fruits per plant (Table 2). The highest (34.00) number of fruits per plant was produced by the application of 240 Kg N /ha and then decreased gradually with the decreasing rates of nitrogen and the lowest (16.14) number of fruit from the plants was noted from no nitrogen. Such influence of nitrogen was also been reported by Islam *et al.* (1997). They reported that the highest number of fruits per plant was produced by the application of 250 Kg N /ha nitrogen per hectare. Midan *et al.* (1985) reported that the number of fruits per plant increased as the nitrogen level was increased.

4.1.9 Fruit length

Nitrogen had significant effect on fruit length (Table 3). It ranged from 4.52 to 6.20 cm. The highest (6.20) fruit length was found in 240 Kg N /ha while the minimum (4.52) was in the control. This result showed that the fruit length was increased gradually with the increasing levels of nitrogen. Nasser (1986) had a similar report, which supports the present result. Islam *et al.* (1997) reported that the length of individual fruit was increased with the increased nitrogen levels.

4.1.10 Fruit diameter

The variation in diameter of fruit among the different doses of nitrogen was found to be statistically significant (Table 3). The maximum diameter of fruit (5.30 cm) was found from the plants grown with 240 Kg N /ha which was statistically similar to that of 140 Kg N /ha, 160 Kg N /ha, 180 Kg N /ha, 200 Kg N /ha, 220 Kg N /ha. The minimum (4.00 cm) was recorded from the control treatment. Similar opinion was put forwarded by Islam *et al.* (1997). They reported that the breadth of individual fruit was increased with the increasing nitrogen levels. Nassar (1986) also reported similar result. On the other hand, Austin and Dulton (1970) observed that fertilizer application had no effect on fruit size of tomato.

Table 3. Effect of nitrogen on the yield contributing characters and yield of tomato

Treatment	Fruit length (cm)	Fruit diameter (cm)	Weight of individual fruit (gm)	Weight of fruits/plant (Kg)	Weight of fruits/plot (Kg)	Dry matter of fruit (%)
T_1	5.78a	4.86a	61.02f	0.98bc	20.16e	3.31cd
T_2	5.80a	4.98a	69.31e	1.12abc	22.92d	3.52bcd
T_3	5.83a	5.00a	73.01d	1.36ab	28.85c	3.87abc
T_4	5.96a	5.12a	79.00c	1.43ab	30.39c	4.21ab
T_5	6.00a	5.21a	85.00b	1.59ab	34.21b	4.35a
T_6	6.20a	5.30a	90.21a	1.84a	41.00a	4.52a
T_7	4.52b	4.00b	50.30g	0.61c	9.86f	3.02d
CV %	8.92	8.45	2.08	29.63	5.65	10.34

In a column, means followed by common letter do not differ significantly at 5% of level of probability by Duncan's New Multiple Range Test (DMRT)

4.1.11 Weight of individual fruit (gm)

Different levels of nitrogen fertilization exhibited wide variation in respect of weight of individual fruit (Table 3). The result revealed that the maximum (90.21g) individual fruit weight was obtained from 240 Kg N /ha while the control treatment (0 Kg N /ha) gave the minimum (50.30) weight. Midan *et al.* (1985) and Nassar (1992) also reported that increasing levels of nitrogen significantly increased average fruit weight. Chung *et al.* (1992) also reported that increasing levels of nitrogen increased the fresh weight of tomato fruit.

4.1.12 Weight of fruits per plant

It was observed that different levels of nitrogen showed significant effect on the weight of fruits per plant (Appendix IV). The weight of fruits per plant ranged between 0.61 to 1.84 Kg (Table 3). The plant fertilized with 240 Kg N /ha produced the highest weight of fruit (1.84) per plant while the lowest (0.61 Kg) was found in control. Such a decreasing trend of fruit yield per plant was possible due to inadequate nitrogen supply, which caused less vegetative growth and poor yield. Islam *et al.* (1997) reported highest fruit weight per plant at 250 Kg N /ha. Varis and George (1985) have reported similar effect of different nitrogen level in respect of fruit weight per plant. Gupta and Shukla (1977) also reported that the effect of nitrogen fertilization on yield per plant was statistically significant.

4.1.13 Dry matter of fruit (%)

The variation in the percentage of dry matter content of fruit among the different doses of nitrogen was found to be significant (Appendix IV). The highest percent of dry matter of fruit (4.52 %) was obtained from the application of 240 Kg N /ha (Table 3) which was statistically identical to that of 220 Kg N /ha. On the other hand, the lowest dry matter (3.02 %) was found in the control treatment. It was observed that dry matter was increased with increasing levels of nitrogen. This is in accordance with Islam *et al.* (1997). They reported that 250 Kg N /ha gave the maximum dry matter of fruit. Dry matter content was increased with the increase in nitrogen levels, possibly due to high nitrogen, which improved the protein synthesis by increasing photosynthesis in plant leaf. This photosynthesis produced higher food materials in fruit. As a result, dry matter content of the fruit might have been increased. Chung *et al.* (1992) expressed their opinion that fruit dry weight was influenced by nitrogen. Kaniszewshi *et al.* (1987) found highest dry matter content from 150 kg N /ha and the lowest from 37.5 Kg N /ha

4.1.14 Fruit yield (ton /ha)

Analysis of variance showed that the different nitrogen levels had significant influence on yield per hectare. The maximum yield (85.42 t/ha) was achieved from 240 Kg N /ha (Table 4). The second highest yield (71.27 t/ha) was obtained from the plants having 220 Kg N /ha, while the minimum yield (20.54 t/ha) was recorded in control. This result showed that the yield of tomato fruits increased gradually with the increased doses of nitrogen fertilizer. Similarly Islam *et al.* (1997) reported that 250 Kg N /ha gave the highest fruit yield while the lowest was obtained in control. This is in conformity of the present study Profound influence of nitrogen levels to increase tomato yield was reported by many authors. (Doss *et al.* 1981, Varis and George 1985, Midan *et al.* 1985 and Kaniszewski *et al.* 1987). They found a significant increase in total yield of tomato fruit due to nitrogen fertilization up to 225 Kg N /ha and noticed no further significant increase in yield with the further application of nitrogen. Nassar (1986) reported that maximum yield was achieved at 296 Kg N / ha.

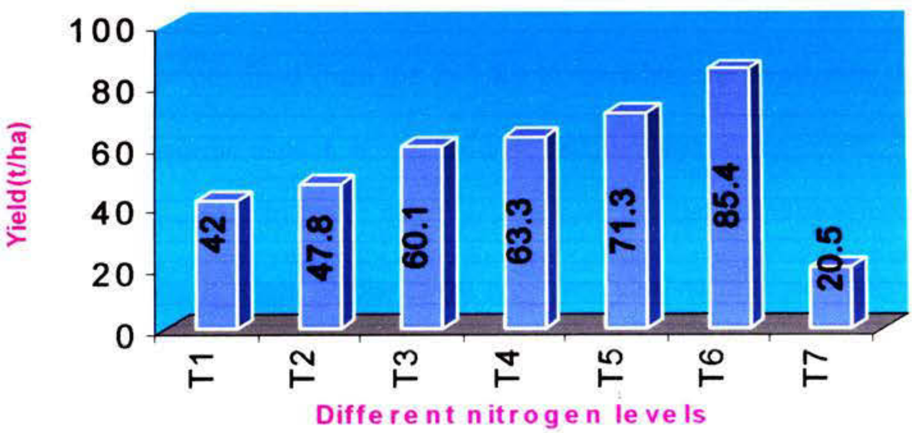

Fig 1. Effect of different nitrogen levels on fruit yield of BARI Tomato-9

4.1.15 Economic analysis

The variation in cost of production was noticed due to different levels of nitrogen. The production cost was highest (Tk.83308/ha) when 240 Kg N/ha was applied (Table 4). It might be due to use of higher level of nitrogen. The lowest cost of production (Tk.72497/ha) was found when no nitrogen was applied.

The gross return obtained through sale of harvested tomato at framgate price was found to be the lowest (Tk.61620/ha) under the control treatment .The highest gross return of Tk.256260/ha was obtained from the 240 Kg N /ha when the treatments were compared in respect of economic aspect. It was evident that the highest net return (Tk.172952/ha) was obtained from the 240 Kg N /ha. The treatment which receiving no nitrogen showed negative net return. It might be due to the crop receiving no nitrogen fertilizer the growth and development of the plant was hampered. As there was deficiency of nitrogen in the soil, the plant could not use other inputs properly. The maximum (3.07) BCR was recorded in 240 Kg N /ha while the lowest (0.85) was found in control.

Table 4. Economic analysis of tomato variety BARI TOMATO-9 production as influenced by different nitrogen levels

Treatment	Total cost of production (Tk/ha) a	Yield (ton/ha)	Gross return (Tk/ha) b	Net return (Tk/ha)	BCR
T_1	81578	42.00	126000	44422	1.544
T_2	81927	47.75	143250	61323	1.748
T_3	82268	60.10	180300	98032	2.191
T_4	82618	63.31	189930	107312	2.298
T_5	82959	71.27	213810	130851	2.57
T_6	83308	85.42	256260	172952	3.07
T_7	72497	20.54	61620	-10877	0.849

a. Details shown in (Appendix VII).

b. Considering framgate market price of Tomato- TK. 3000 per tone

4.1.15 Relationship between total number of leaves per plant and weight of fruits per plant

When data on fruit yield per plant was regressed against the total number of leaves per plant a linear relationship was observe between tem. It was observed that the equation Y= 9.5815 x +17.89 gave a good fit to the data and the co-efficient ($R^2 = 0.9411$) value showed that the fitted regression line had a significant regression co-efficient. This indicates that the fruit yield per plant increased with increase of leaves (9.59) (Fig. 6)

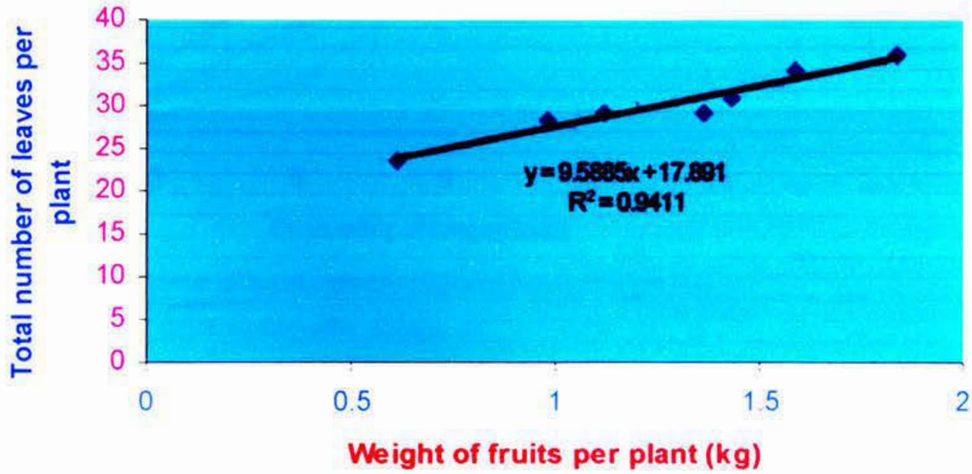

Fig 2. Relationship between total number of leaves per plant and weight of fruits per plant

4.2 Changes in physical characteristics of fruit

4.2.1 Percent weight loss

There had a highly significant variation in respect of Percent weight loss of tomato fruits among the maturity stages (Appendix V). The maximum Percent weight loss at 15 days after storage (8.93 %) was observed in breaker stage fruits. The minimum weight loss (6.35 %) was observed in fruit (Fig.2).

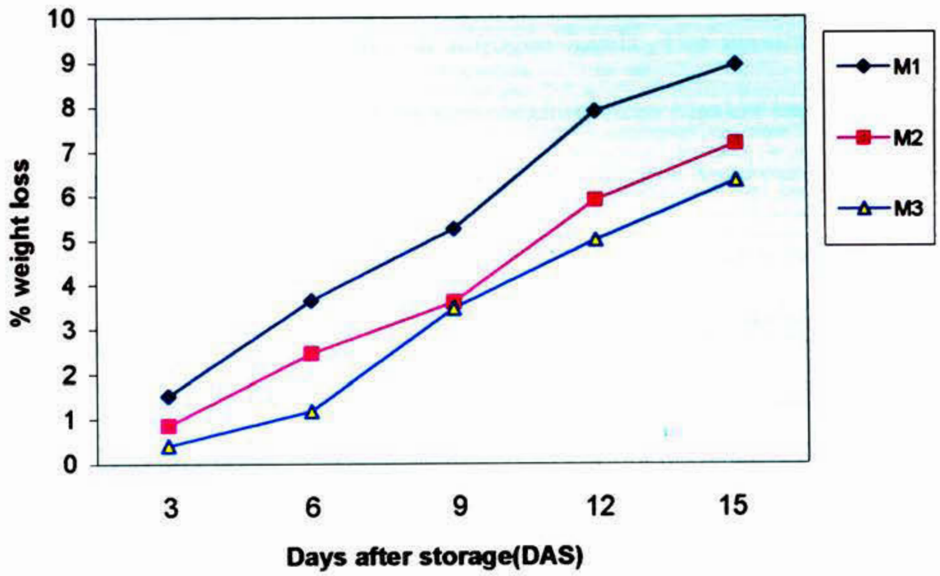

Fig 3. Main effect of maturity stages on percent weight loss at different days after storage

Different nitrogen levels also had significant effect on Percent weight loss of tomato fruit (Table 5). The highest weight loss (9.50 %) was recorded in 240 Kg N /ha. The minimum weight loss (5.34 %) was found in the fruits of control treatment. It might be due to higher transpiration was occurred in the fruits of 240 Kg N /ha. Percent weight loss due to storage condition and stage of harvest was also reported by Park *et al.* (1994) and

Artes and Escriche, (1994). Kaynas and Surmeli (1995) noticed that Percent weight loss was more severe in fruit at an early stage of maturity stage.

Combined effect of maturity stages and different levels of nitrogen were highly significant. The result revealed that the Percent weight loss were higher at breaker stage with the increasing levels of nitrogen. On the other hand, at 15 days after storage Percent weight loss ranged from 5.02 to 11.10. Minimum Percent weight loss was found in the fruit of full ripe stage with the all nitrogen levels. The maximum (11.10 %) Percent weight loss at 15 days after storage was obtained from breaker stage fruits produced with 240 Kg N /ha. The minimum Percent weight loss was (5.02 %) found in the full ripe fruit produced without nitrogen. The Percent weight loss of breaker stage fruit was relatively higher probably because of higher rate of respiration and transpiration through a particular mechanism. Stage of maturity on Percent weight loss was also reported by Subburamu *et al.* (1990).

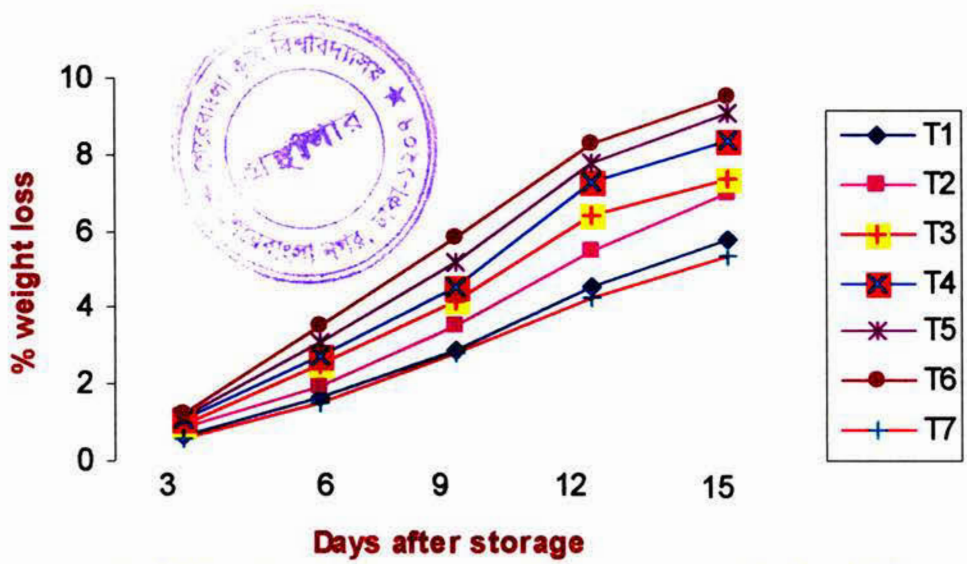

Fig 4. Main effect of different nitrogen levels on percent weight loss at different days after storage

4.2.2 Shelf life

There was a significant variation as to the main effect of maturity stages in the shelf life of tomato (Appendix V). The shelf life was higher (21.39 days) in the breaker stage fruit than the full-ripe fruits (15.64 days) (Fig.4).

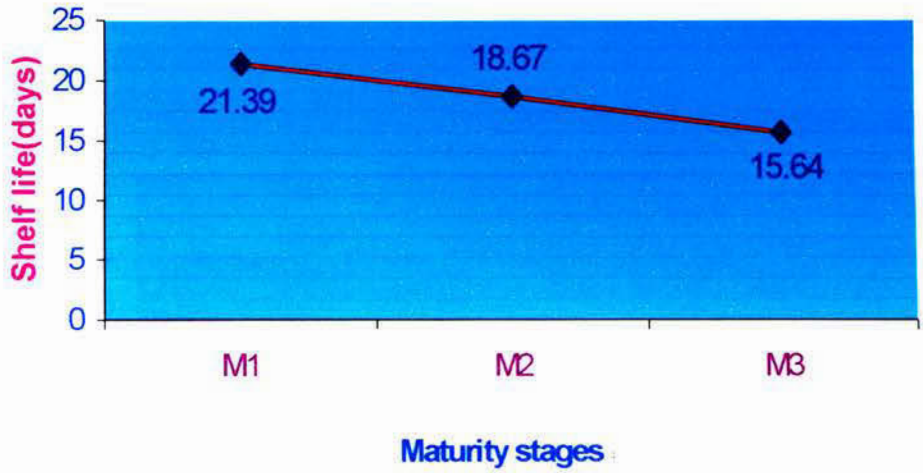

Fig 5. Main effect of maturity stages on shelf life of BARI tomato-9

There was a highly significant variation due to the main effect of nitrogen level as to the shelf life of tomato (Appendix IV). The highest shelf life (19.53) was obtained from control. The shortest shelf life (17.73) was obtained from the fruit, produced with 240 Kg N /ha (Fig 5). It may be due to the fact that, the pericarp of the control fruits had reduced transpiration and infestation of microorganism. Mallik and Bhattacharya (1996) reported that shelf life of tomato was increased at mature green stage.

The combined effect of maturity stages and nitrogen levels had significant effect as to the shelf life. It varied from 15.00 to 23.12 days. The maximum (22.12 days) shelf life was recorded in the breaker stage fruit, which was produced with 240 Kg N /ha (Table 5) the minimum (15 days) shelf life was observed in the full ripe fruit, which was produced with 240 Kg N /ha and was statistically at that produced with 220 Kg N /ha. Anjukumari *et al* (1993) and Subbramu *et al* (1990) also obtained the highest shelf life when harvested at mature stage.

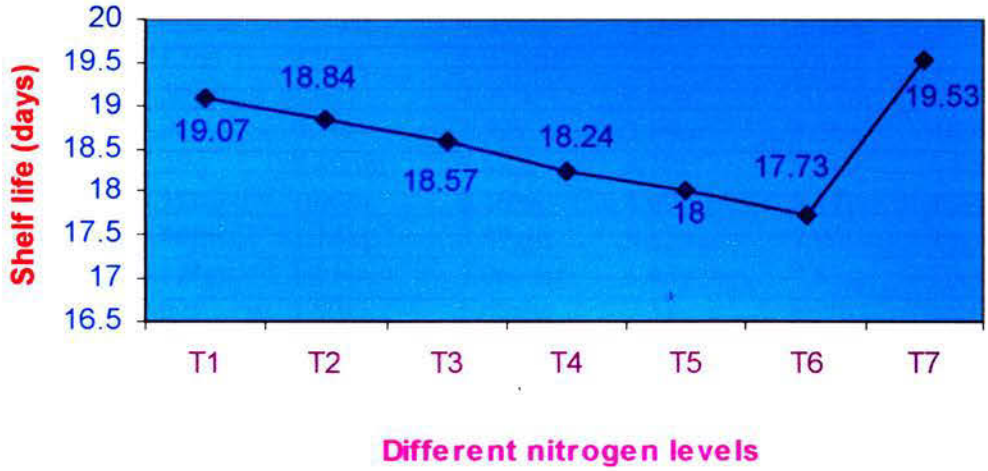

Fig 6. Main effect of different nitrogen levels on shelf life of BARI tomato-9

Table 5. Combined effect of maturity stages and nitrogen levels on Percent weight loss and shelf life

	Percent weight Loss					
Treatment	3 DAS	6 DAS	9 DAS	12 DAS	15 DAS	Shelf life
$M_1 T_1$	1.16c	2.85g	4.26eg	6.18g	7.36h	21.96a
$M_1 T_2$	1.45b	3.26e	4.85def	7.22ef	8.78e	21.80ab
$M_1 T_3$	1.56b	3.79d	5.62abcd	8.32c	9.11d	21.46bc
$M_1 T_4$	1.75a	4.10c	5.82abc	9.31b	9.82c	21.21cd
$M_1 T_5$	1.88a	4.35b	5.98ab	9.82a	10.50b	20.90d
$M_1 T_6$	1.92a	4.89a	6.35a	9.64a	11.10a	20.30e
$M_1 T_7$	0.98d	2.31h	3.96gh	4.87ij	5.89k	22.12a
$M_2 T_1$	0.60fg	1.32gk	2.43jk	4.32k	5.46l	19.26fg
$M_2 T_2$	0.85e	1.78i	3.10ij	5.10i	6.32j	19.00fg
$M_2 T_3$	0.93e	2.86g	3.72ghi	6.29g	6.87i	18.84h
$M_2 T_4$	0.98de	2.98fg	3.92ghi	6.86f	8.21f	18.25i
$M_2 T_5$	1.00cde	3.10ef	4.45efg	7.00ef	8.76e	18.00i
$M_2 T_6$	1.12cd	3.80d	5.27bcdf	7.82d	9.15d	17.89i
$M_2 T_7$	0.55fgh	1.47j	2.49jk	4.00kl	5.12m	19.46f
$M_3 T_1$	0.28j	0.70n	1.99k	3.04m	4.36n	16.00k
$M_3 T_2$	0.30ij	0.89mn	2.62jk	4.18kl	5.76k	15.72kl
$M_3 T_3$	0.39hij	1.00m	3.16hij	4.69j	6.12j	15.41lm
$M_3 T_4$	0.46jhi	1.14kl	3.89ghi	5.55h	7.00i	15.26mn
$M_3 T_5$	0.52fgh	1.81i	5.06cdef	6.48g	7.88g	15.10mn
$M_3 T_6$	0.67f	1.93i	5.80abc	7.32e	8.26f	15.00n
$M_3 T_7$	0.26j	0.82mn	1.89k	3.87l	5.02m	17.00j
CV %	10.52	4.52	10.58	3.13	4.51	1.46

In a column, means followed by common letter do not differ significantly at 5% of level of probability by Duncan's New Multiple Range Test (DMRT)

Where,

M_1T_1 = Breaker stage fruit which produce with 140 Kg N/ha
M_1T_2 = Breaker stage fruit which produce with 160 Kg N/ha
M_1T_3 = Breaker stage fruit which produce with 180 Kg N/ha
M_1T_4 = Breaker stage fruit which produce with 200 Kg N/ha
M_1T_5 = Breaker stage fruit which produce with 220 Kg N/ha
M_1T_6 = Breaker stage fruit which produce with 240 Kg N/ha
M_1T_7 = Control

M_2T_1 = Half ripe fruit which produce with 140 Kg N/ha
M_2T_2 = Half ripe fruit which produce with 160 Kg N/ha

M_2T_3 = Half ripe fruit which produce with 180 Kg N/ha
M_2T_4 = Half ripe fruit which produce with 200 Kg N/ha
M_2T_5 = Half ripe fruit which produce with 220 Kg N/ha
M_2T_6 = Half ripe fruit which produce with 240 Kg N/ha
$M_2 T_7$ = Control

M_3T_1 = Full ripe fruit which produced with 140 Kg N/ha
M_3T_2 = Full ripe fruit which produced with 160 Kg N/ha
M_3T_3 = Full ripe fruit which produced with 180 Kg N/ha
M_3T_4 = Full ripe fruit which produced with 200 Kg N/ha
M_3T_5 = Full ripe fruit which produced with 220 Kg N/ha
M_3T_6 = Full ripe fruit which produced with 240 Kg N/ha
M_3T_7 = Control

Chapter 5

Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

Field and laboratory experiments were conducted at the farm and laboratory of the Horticulture Research Center (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur and Gazipur during the period from October 2004 to April 2005. The objectives of the research work were to study the growth, yield, relative cost and returns and shelf life of BARI Tomato-9 as influenced by different levels of nitrogen and stage of maturity. Two experiments were conducted and both were laid out in a randomized complete block design (RCBD). The field experiment and the laboratory experiment had three replications. For the field experiment, the size of unit plot was 4.8 x 1 m and 24 plants were accommodated in each plot with a spacing of 60 x 40 cm. Seedling were planted in the field on 4 November, 2004. From each plot, 10 plants were randomly selected for collection of data on yield contributing characters and yield. The treatment of the laboratory experiment comprised of two factors, namely (A) Seven (7) nitrogen level (B) Maturity stage viz., breaker stage, half ripe stage and full-ripe. Thus, there were all together (21) treatment combinations. Fruits were kept in a laboratory room under ordinary room conditions. Observations were made on total Percent weight loss and shelf life. Data were collected at 3 days interval, and were statistically analyzed following F-test and Duncan's New Multiple Range Test (DMRT).

Regarding the vegetative characters, it was observed that nitrogen has a significant effect on plant height. Nitrogen applied at 240 Kg N/ha produced the tallest plants while the shortest plants were produced by 0 Kg N/ha (control). Different levels of nitrogen significantly influenced total number of leaves and number of green leaves per plant at harvest time. The maximum values of these characters were found at the highest level of nitrogen (240 Kg N/ha) and minimum values were obtained from 0 Kg N/ha (control). The days required to produce 50 % flowering was earlier at 240 Kg N/ha and was delayed at 0 Kg N/ha.

The highest number of flower clusters; fruit per cluster and fruits per plant were significantly influenced by different levels of nitrogen. The maximum values of these characters were found from the highest level of nitrogen (240 Kg N/ha). It was evident that there was an increasing response of all the parameters due to the increasing levels of nitrogen. However, the plants showed minimum response to the plots where no nitrogen was applied. On the other hand, the number of flower clusters, number of fruits per cluster, the maximum fruit length, diameter and weight of individual fruit were obtained from the highest level of nitrogen 240 Kg N/ha.

Different levels of nitrogen exhibited marked influence on the fruit yield of tomato. The plants receiving 240 Kg N/ha produced the highest fruit yields per plant and per plot. 240 Kg N/ha produced the highest total yield 85.42 ton/ha. The maximum (4.52 %) Percent dry matter content was also recorded from 240 Kg N/ha. The highest (3.07) BCR was recorded in 240 Kg N/ha while the lowest (0.85) was found in control. In experiment 2, marked variations were found in relation to Percentage weight loss and shelf life. The effect of stage of maturity was highly significant in relation to Percent weight loss. The Percent weight loss was higher in breaker stage (8.93 %) than in full-ripe fruit (6.34 %).

The effect of nitrogen treatment was highly significant in respect of Percent weight loss. The maximum weight loss (9.50 %) over 15 days after storage was recorded in the fruits produced with 240 Kg N/ha. The combined effect of stage of maturity and different levels of nitrogen was highly significant in respect of Percent weight loss. The maximum weight loss (11.10 %) was recorded in breaker stage fruit of BARI Tomato-9, produced with 240 Kg N/ha, and the minimum in full-ripe fruit, and produced without nitrogen. The maturity stages of fruits showed highly significant variation in respect of shelf life. The shelf life was higher in breaker stage fruits (21.39) than in full-ripe fruits (15.64 days). The effect of different levels of nitrogen was highly significant in respect of shelf life. Among the nitrogen levels, the longest shelf life (19.53 days) was obtained from the fruits, produced without nitrogen. The combination of maturity stage and different levels of nitrogen demonstrated highly significant variation as to the shelf life. The breaker stage fruits produced without nitrogen showed the longest shelf life (22.12 days).

Considering the findings in connection with growth, yield and BCR of tomato; 240 Kg N/ha showed better performance. For better production, 240 Kg N/ha can be recommended for cultivation under Joydebpur and similar agro-ecological conditions. The findings in respect of storage behavior suggested that breaker stage fruits were the best for extending the shelf life.

RECOMMANDATION

Taking into account the limitations of the study, the following suggestion may be considered for further studies.

(1) By taking further increased levels of nitrogen to find out the peak point of maximum nitrogen level corresponding to maximum fruit yield.

(2) The number of days from flowering could be a better indicator for considering the stage of maturity.

(3) Vegetables are nutrient rich food items. Lack of nutrient status during storage could be an important area of study.

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Appendix I. Monthly temperature, relative humidity and rainfall during the period October 2004 to March 2005

Month	** Air temperature (^{O}C)			**Humidity (%)	* Rainfall (mm)
	Maximum	Minimum	Average		
October' 04	31.45	23.12	27.28	75.25	17.4
November' 04	29.60	17.68	23.63	68.5	0.00
December' 04	27.14	14.93	21.03	73.41	0.00
January' 05	24.91	13.02	18.96	72.87	0.08
February' 05	29.15	16.96	23.06	69.07	0.01
March' 05	32.24	21.22	26.73	76.16	17.52

* = Monthly total

** = Monthly Average

Source: Plant Physiology Division. Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur-1701.

Appendix II. Analysis of variance of plant highest of tomato at different days after planting

Sources of variation	Degrees of freedom	Plant height at different days after transplanting (DAT)					
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Replication	2	1.28	2.28	3.57	1.28	1.28	3.57
Treatment	6	1.91 **	37.07 **	150.05 **	284.76 **	338.76 **	394.92 **
Error	12	1.28	2.28	3.57	1.28	1.28	3.57

Appendix III. Analysis of variance of different yield attributes of tomato

Sources of variation	Degree of freedom	Total Number of leaves/ plant	Number of green leaves at final harvest	Days to 50% flowering	Number of flower cluster/ plant	Number of flower/ cluster	Number of fruits/ cluster	Number of fruits/ plant
Replication	2	0.59	1.28	2.28	0.57	0.14	0.14	1.28
Treatment	6	48.91 **	43.56 **	34.95 **	20.50 **	3.25 **	0.83 **	113.30 **
Error	12	0.56	1.28	2.28	0.57	0.14	0.14	1.28

Appendix IV. Analysis of variance of different yield attribute of tomato

Sources of variation	Degrees of freedom	Fruit length (cm)	Fruit breath (cm)	Weight of individual fruit	Weight of fruits/ plant	Weight of fruits/plot	Dry matter (%)
Replication	2	0.42	0.57	2.28	0.14	2.28	0.33
Treatment	6	0.94 **	0.56 **	573.59 **	0.50 **	309.47 **	0.95 **
Error	12	0.26	0.40	2.28	0.14	2.28	0.15

Appendix V. Analysis of variance for weight loss of tomato fruit at different days After Storage

Sources of variation	Degrees of freedom	3 DAS	6 DAS	9 DAS	12 DAS	15 DAS	Shelf life
Replication	2	0.01	0.01	0.19	0.004	0.015	0.18
Maturity(A)	2	6.63 **	31.19 **	20.48 **	6.02 **	37.51 **	171.07 **
Nitrogen dose(B)	6	0.46 **	5.15 **	11.65 **	22.43 **	22.90 **	2.38 **
A x B	12	0.04 **	0.33 **	0.45 **	0.78 **	0.51 **	0.24 **
Error	40	0.01	0.01	0.19	0.03	0.013	0.07

Appendix VI. Labours requirements per hectare for various operations to produce Tomato variety BARI Tomato-9

Heads for use of labours	No. of labours
Bed preparation	128
Planting and watering	43
Irrigation	42
Weeding	84
Insecticide application	23
Harvesting (4 times)	48
Cowdung, TSP and MP application	82

Appendix VII. Cost of nitrogen and labour for topdressing and soil mixture to produce tomato variety BARI TOMATO-9

Treatment	Cost of fertilizer(Tk/ton) [a]	Number of labours	Tk/ha	Total cost of fertilizer and labour(Tk/ha)
T_1	2128	84	58801	8008
T_2	2436	84	58801	8316
T_3	2732	84	58801	8617
T_4	3045	84	58801	8925
T_5	3346	84	58801	9226
T_6	3654	84	58801	9534
T_7	-	-	-	-

a: Calculated on the basis of October 2004 market price of

Urea: Taka 7.00 per kg including carrying cost.

Appendix VIII. Cost and return in tomato variety BARI TOMATO-9 production as influenced by different nitrogen level

SL. No.	**Cost per hectare**	**Taka**
1	Labour 45 man days @ Tk.70 (Details shown in appendix)	31500
2	Ploughing (Three times)	3000
3	Cost for lease land Tk.1200 for season (6 month)	6000
4	Cost of cowdung, TSP and MP	63930
5	Cost for insecticide @ Tk 70 /50ml	1630
6	Cost of seedling @ Tk.300 per 1000 seeding	7800
7	Cost of urea and labour for top dressing and soil mixture (Appendix VI).	Variable
8	Miscellaneous cost 5% of the total from 1-7	Variable
9	Total input cost (From 1-7)	Variable
10	Interest on running capital 8 % for 6 months of the total input cost	Variable
11	Total cost of production (From 1-10)	Variable