EFFECT OF DIFFERENT SOURCES OF NITROGEN ON GROWTH AND YIELD OF TOMATO (*Solanum lycopersicum* L.)

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CERTIFICATE

This is to certify that the thesis entitled, ***"EFFECT OF DIFFERENT SOURCES OF NITROGEN ON GROWTH AND YIELD OF TOMATO (Solanum lycopersicum L.)"*** *submitted to the Department of Soil Science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of Master of Science in Soil Science, embodies the result of a piece of bona fide research work carried out by* ***MD. RASEL KABIR*** *Registration No.* ***14-05924*** *under my supervision and my 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.

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Place: Dhaka, Bangladesh

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Dedicated

To My

Beloved Parents

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BY

MD. RASEL KABIR

ABSTRACT

An experiment was carried out at the SAU Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2019 to March 2020 to find out the impact of different sources of nitrogen fertilizer on growth and yield of tomato under field condition. The experiment comprised of different sources and levels of nitrogen fertilizer viz. Urea Super Granule (USG), Prilled Urea (PU) and Cowdung as organic sources with three replications. Different levels of nitrogen sources had significant effects on the plant height, number of branches plant^{-1}, fruit weight plant^{-1}**,** number of fruit clusters plant^{-1},diameter of fruit, fruit weight plot^{-1}, yield, biological yield and harvest index of tomato crops. It was clearly found that, the maximum plant height was 96.64 cm observed in T_2 (100% N as USG) and the minimum was 77.27 cm found in the control treatment (T_0). Other growth and yield parameters were also significantly varied by different levels of nitrogenous fertilizer treatment. The maximum number of branches plant^{-1}(10.88), fruit weight plant^{-1} (5.23 kg), number of fruit clusters plant^{-1} (18.66), fruit diameter (6.52 cm), fruit weight plot^{-1} (52.13 kg), yield (86.53 t ha^{-1}) and biological yield (106.15 t ha^{-1}) were recorded in the T_2 (100% N as USG) treatment and the minimum number of branches plant^{-1} (6.44), fruit weight plant^{-1} (3.03 kg), number of fruits cluster plant^{-1} (8.33), fruit diameter (5.74 cm), fruit weight plot^{-1} (30.90 kg), yield (51.29 t ha^{-1}) and biological yield (57.45 t ha^{-1}) was found in the control treatment (T_0).The maximum harvest index of tomato (89.28 %) was recorded from T_0 which was statistically different from other treatments when compared among themselves. There was a significant crop yield development due to different nitrogen sources application over control. The overall result suggests that 100% Urea Super Granule (USG) at the rate 100 kg ha^{-1} proved to be the best with respect to fruit yield, quality, nutrient contents and uptake by tomato crop under the agro climate of Sher-e-Bangla Agricultural University, but it is also assumed other sources of nitrogen fertilizer seemed to have more or less same positive pronounced effect on the above characters of the crop.

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LIST OF ABBREVIATIONS

Abbreviation	=	Full word
%	=	Percent
N	=	Nitrogen
P	=	Phosphorus
RDF	=	Recommended Doses of Fertilizer
USG	=	Urea Super Granule
PU	=	Prilled Urea
DAP	=	Di-ammonium Phosphate
DAS	=	Days After Sowing
@	=	At the rate
°C	=	Degree Centigrade
Anon.	=	Anonymous
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
BBS	=	Bangladesh Bureau of Statistics
CV	=	Co-efficient of Variance
cv.	=	Cultivar (s)
DAI	=	Days After Inoculation
HSD	=	Honestly Significant Difference
e.g.	=	(For example) example gratia
et al.	=	(And Others) et alibi
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
g	=	Gram
hr	=	Hour (s)
i.e.	=	That is
IRRI	=	International Rice Research Institute
ISTA	=	International Seed Testing Agency
kg	=	Kilogram
LSD	=	Least Significant Difference
no.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
T	=	Treatment
NPK	=	Nitrogen, Phosphorus and Potassium
t/ha	=	Ton per Hectare
UNDP	=	United Nation Development Program
wt.	=	Weight
BE	=	Biological efficiency
MRR	=	Mycelium Running Rate
NMDEC	=	National Mushroom Development and Extension Center
MCC	=	Mushroom Culture Centre
mg	=	Milligram
CHO	=	Carbohydrate
Conc.	=	Concentration

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) belongs to the family Solanacea, genus *Lycopersicon*, sub family Solanoideae and tribe Solaneae. It is widely cultivated in tropical, subtropical and temperate climates and ranks third next to potato and sweet potato in terms of world vegetable production (FAOSTAT, 2019). With estimated annual area coverage and total production of 182 metrics million tons in 2017 which was harvested from 4.8 million hectares (FAO, 2014). Among vegetable crops, tomato is the most important edible and nutritious worldwide (FAOSTAT, 2019). Tomato plays an important role in human nutrition by providing essential amino acids, vitamins, minerals, sugars and dietary fibers (Kanyomeka, 2005). The fruit also contains antioxidant carotenoids that contribute to human nutrition and give the red color for most existing cultivars on the market (Rocha and Silva, 2011).

The edaphic and climatic conditions of Bangladesh are congenial for tomato cultivation. The production of tomato in our country in 2017-18 was 385 thousand metric tons whereas it was only 190 thousand metric tons in 2009-10 (BBS, 2018). Although the production of tomato in Bangladesh is increasing day by day but it is not enough to fulfill the demand of the peoples; thus, every year the country needs to import tomato. 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 (Manang *et al.*, 1982). Among different nutrients that were required for tomato cultivation nitrogen is the most important nutrients. On the other hand, soils of Bangladesh have been deficient in nitrogen fertilizer. So, it is necessary to apply these nutrient elements for satisfactory growth, development and also yield of tomato.

Nitrogen is an important plant nutrient and is the most limiting element due to its high mobility and different types of losses (Zaman *et al*., 1993). It is well documented that application of N promotes vegetative growth and fruit yield of tomato, and later application in the growing stages favors fruit development, thus nitrogen has a dramatic effect on tomato growth and development in soils with limited N supplies such as sandy soils (Hokam *et al*., 2011). It also promotes vegetative growth, flower and fruit setting of tomato. Optimum nitrogen increases fruit quality, fruit size, color, taste and acidity. It significantly increases the growth and yield of tomato (Banerjee *et al*., 1997).

Urea Super Granule (USG) is a fertilizer that can be applied in the root zone at 8-10 cm depth of soil (reduced zone of rice soil) which can save 30% nitrogen than prilled urea, increase absorption rate, improve soil health and ultimately increase the crops yield. The deep placement of large urea granules (known as Guti urea in Bangladesh) into puddle enhances the soil's nitrogen absorption capacity. To improve the N use efficiency urea super granule (USG) is one of the popular nitrogenous fertilizers and can be used for upland crops like tomato, broccoli, cabbage, cauliflower, brinjal, banana etc. like wetland rice crop (BARC, 2005).The application of USG guarantees the better utilization of N throughout the growing period and ensures high yield reducing the nitrate level by 20-30% (Wojciechowska, 2002). Hussain *et al.* (2003) showed that 20% urea could be saved by the use of USG instead of prilled urea (PU) for cabbage, cauliflower and brinjal as well as tomato. The USG technology might have agronomic importance for upland or dryland crop like tomato (Haque, 2002) and deeper placement of USG can reduce NH_3 and NOx emissions substantially compared with broadcast or mixed PU (Khalil *et al.,* 2006). Nazrul *et al.* (2007) reported that 5-8 cm deep placement of USG in cabbage cultivation could save 20% N than PU. Annual urea requirement of the country is about 28 million tons of which 50% is met by domestic production. The rest of the urea needs to be imported by spending a large amount of foreign currency. To reduce nitrogen loss, application of urea super granule (USG) is strongly considered to be an important alternative that increases the efficiency of N about 20 to 25 % and also increases the yield by 15 to 20% (BBS, 2008). The soil nitrogen content of the country is also very low due to warm climate accompanied by extensive cultivation practices with little addition of manures in the crop fields. In spite of that, the farmers use urea fertilizer by broadcast method during cultivation and most of the applied fertilizers are lost through volatilization, denitrification, run-off and leaching. The use of USG and organic manure has often been advocated to minimize nitrogen losses because organic manures act as a great source of plant nutrients especially of N, P, K and S, and also prevents leaching loss of the nutrients. Government has been trying to encourage farmers in using USG instead of prilled urea (PU) in crop production in order to reduce N loss that would in turn enhance productivity (Rahman *et al*., 2004). Virtually, there has been very scanty/minimum research works done so far in digging into farmers' interaction and efficiency differences between the USG and PU users at the end-user's level. On the other hand, DAP is produced in many locations in the world and is a widely traded fertilizer commodity. DAP fertilizer is an excellent source of P and nitrogen (N) for plant nutrition. It contains 18 per cent N and 46 per cent P_2O_5. For instance, typical compost may be 1–3% total N by weight, but the ammonium and nitrate (available forms) of N are typically less than 0.05% by weight.

Therefore, to control the loss and to improve fertilizer use efficiency USG application may be a good option to minimize production cost as well as to increase crop yield of tomato. But there is a scanty of research findings to develop a fertilizer recommendation with USG for tomato production. For years, increasing tomato yield was the main objective in the development of cultural practices and fruit quality has seldom been considered (Ferreira *et al*., 2006).

Tomato is one of the most important horticultural crops for which a large amount of nitrogen is applied. The specific dose of nitrogen may affect yield and storage behavior of tomato fruits. Urea Super Granule (USG) technology is cost effective and environment friendly. So, the present experiment has been undertaken to investigate the effect of different nitrogen sources on nitrogen use efficiency and yield of tomato. Keeping the above stated fact in view, the present experiment was undertaken in achieving the following objectives:

Objectives:

1. To observe the growth and yield of tomato under different chemical sources of nitrogen.
2. To find out the best chemical N source with proper dose for maximum tomato production.

CHAPTER II

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the available information in home and abroad regarding the experiment on effect different sources of nitrogen on growth and yield of tomato. Many research organizations of our country has limited information about the effect of different sources of nitrogen fertilizer on tomato. But in foreign countries there are more numbers of relevant data. A review of the previous research and findings of researchers having relevance to this study which were gathered from different sources like literature, journals, thesis, reports, newspaper etc. will be represented by this chapter. However, some of the literature related to this investigation are reviewed in this chapter are given below:

Nemomsa *et al*. (2019) was conducted a field experiment in West showa zone, Toke kutaye district of Ormia region, Ethiopia with the objective to determine the optimum nitrogen fertilizer rate on different growth parameters, yield and yield component of tomato crop. To attain the objective, four level of nitrogen fertilizer Viz., 0, 50, 100, and 150 kg/ha were used as treatments. The experiment was laid out in randomized complete block design (RCBD) with three replications. Data on plant height, number of primary branches per plant, number of leaves per plants, number of cluster per plant, number of fruits per cluster and fruit yield were collected from five plants of the middle rows of each plot and subjected to statistical analysis software (SAS) version 9.3 and LSD at 5% was used for mean comparison. The statistical analysis showed that, there was the significant ($P<0.05$) difference among treatments for all parameters except for number of fruit per cluster. For growth variables, 150 kg/ha revealed the highest value but there was no significant ($P<0.05$) difference between 100 and 150 kg/ha of nitrogen except for the height of the plant. The treatment 150 kg/ha nitrogen fertilizer provided 22.41, 35.57 and 25.40% over the control treatment in height, number of leaves and number of primary branch, respectively. The treatment 150 kg/ha nitrogen fertilizer increased the number of cluster per plant and yield of tomato fruit per hectare by 34.50 and 70.79%

over the control treatment, respectively. However, there was no significant difference in both number of fruits cluster per plant and yield per hectare between 150 and 100 kg N/ha.

Application of optimum nitrogen fertilizer rate is one of the main determinant factors which significantly affect growth and yield of tomato in Ethiopia (Balemi, 2008). Also reported that as nitrogen fertilizer level increases the number of tomato leaf increased. The highest leaf number per plant was recorded from the plot treated with 150 kg N/ha (42.73)

Tomato crop is highly responsive to nitrogen fertilizer application where nitrogen availability may be limited and time of the application is critical (Fontes *et al*., 2002).

Hokam *et al*. (2011) reported that nitrogen promotes vegetative growth and fruit yield, favors fruit development (when applied at later growing stage) and application of proper amount of the fertilizer has a dramatic effect on tomato growth and development. So far, fertilizer rates for tomato crop was determined only at Melkasa Research Center which cannot represent agro-ecologically for other tomato growing regions of the country and no such study was done for tomato under vertisol condition (Kahsay *et al*., 2016).

Biswas *et al*. (2015) who revealed that the tallest plant was obtained by applying 150 kg N/ha. Also reported the heights number of leaves per plant of tomato from the plot treated by 150 kg N/ha. However, application of 100 kg N/ha was at par with 150 kg N/ha on influencing number of leaves per plants and also using 50 kg N/ha also not different from using 0 kg N/ha on number of leaves per plant. Many authors reported that supplementary application of nitrogen fertilizer increase number of leaves. And reported the highest fruit yield of tomato when the crop treated by 108.6 kg N /ha at the eastern part of Ethiopian country.

Najafvand *et al*. (2008) who reported that as the amount of nitrogen fertilizer increased the height of tomato also increased. Applying 150 Kg N/ha increased plant height by 22.41, 19.03 and 9.5% compared to 0 kg, 50, and 100 kg N/ha treatments, respectively.

Degefa *et al.* (2019) who revealed 13.6% in plant height increment compared to the control (no fertilizer application) by application of 99 kg N/ha. The increase in plant height could be due to the readily available nitrogen which promotes vegetative growth and development. Nitrogen nutrient is responsible for photosynthesis, formation of chlorophyll and nucleic acids, its absence or deficiency causes stunted growth (Tisdale *et al*., 2003), hence this nutrient responsible for accumulation of greater biomass.

Ewulo *et al*. (2015) who found that plant height in tomato increased with increased in nitrogen rate.

Iqbal *et al*. (2011) also reported that, application of 90 kg N/ha resulted in 4.33primary branches which was in par using 100 kg N/ha in this study. Application of 100 kg N/ha increased the number of branches by 24.34% compared to application of 0 kg N/ha. The number of branch per plant increased with increasing nitrogen application up to optimum level.

Degefa *et al.* (2019) also reported that, as the rate of nitrogen fertilizer increased from 0-99 kg/ha, the number of primary branches in tomato increased by 28.9% compared to the nil nitrogen fertilizer application.

Warner *et al.* (2004) who reported that, as the rate of nitrogen fertilizer increased, the yield of tomato increased.

Kamar *et al*. (2019) reported that the coastal areas cover about 20% of the geographical area of Bangladesh and comprise more than 30% of the cultivable lands of the country. Agricultural land use in these areas is very poor compared to the country's average cropping intensity of 191%. Fertilizer deep placement

(FDP) is a proven technology for nutrient supply to different crops all over the world. FDP is more effective than the traditional method (surface broadcasting) of applying fertilizer across a field. In Bangladesh, demand for vegetable production in terms of domestic and export market is increasing day by day, but soil fertility is the major constraint for agriculture especially in vegetable production. Most of the farmers in Bangladesh do not follow the judicious nutrient management strategies for vegetable production and so the farmers cannot get maximum benefit of fertilizer application. At Rahmatpur, Barishal during two seasons of 2016-17 and 2017-18, the effects of different forms of urea fertilizer deep placement were tested to quantify the fertilizer use efficiency and yield of summer tomato cultivation. The treatments were *viz*. prilled urea broadcasting (Farmers' Practice; FP), prilled urea deep placement (DPU) and urea super granules deep placement (USG). Fertilizer use efficiency was increased after application of deep placement of urea. Economic yield was higher (27.4 t ha-1) with USG followed by DPU (24.5 tha^{-1}), lowest being observed in case of FP (18.9 t ha-1). The benefit cost ratio (BCR) was greater with USG (2.01) and DPU (1.81) application than FP (1.31). Deep placement of both forms of urea was more efficient than broadcasting of prilled urea for summer tomato cultivation.

Tesfaye (2008) who reported that addition of a range of N fertilizer at 110 kg ha-1, to tomato field improved tomato fruit yield on vertisol of West Showa.

Edossa *et al*. (2013a, unpublished) also indicated that tomato growers are currently applying on the average 283 kg DAP ha^{-1}. Those growers are applying around 283 kg DAP ha^{-1}, however the quantity of N fertilizer applications are in acceptable range for tomato except that household vegetable growers use at second and third split application of DAP where plants may not use pre-plant fertilizers when applied as second and third splits.

Manjurul *et al*. (2018) reported that plant nutritional status affects yield and fruit quality. Hence it is essential to have a good knowledge of the plant's mineral requirements to ensure better growth and good yield and to avoid nutrient wastage, which will decrease production costs. This study revealed that 200 kg

N/ha performed best in terms of growth and as well as highest yield and control treatment performed lowest over all the treatments used in this study. So, from this study they were concluded that increasing the level of Nitrogen (up to 200kg N /ha), increasing the growth and yield of tomato plant.

Wahle and Masiunas (2003) and Wang *et al*. (2007) reported that the growth and yield of tomato was highest at near about 10 mm nitrogen levels but the tomato growth rate was limited with below 5 mm of nitrogen solution.

Han *et al*. (2014) reported that optimal nitrogen-treated tomato plants showed statistically similar leaf nitrogen content to those treated with high nitrogen, but the amount of tomato leaf nitrogen was statistically higher than the plants treated with low levels of nitrogen input.

Nitrogen fertilizer containing both NO_3^- and NH_4^+ are generally recommended for tomato production because vegetative growth is maximized, which is thought to increase fruit yield (Ganmore, 1980).

Rebouças *et al*. (2015) reported that the use of nitrogen fertilizers contributes significantly to the proper growth and development of tomato plants, with significant gains in the production of fruit. However, incorrect use of nitrogen can change tomato fruit quality, making it undesirable for consumers. The aim of this work was to study the effect of different sources and levels of nitrogen on tomato quality to improve N management. The field experiment was conducted at the State University of Southwest Bahia - Vitória da Conquista, Bahia, Brazil. The experimental design was a randomized block with 4 replicates, with three nitrogen sources (calcium nitrate, ammonium sulfate and urea) and four levels of nitrogen (0, 140, 280 and 420 kg ha-1) in a 3×4 factorial. Fruit from the experimental treatments were evaluated for the following characteristics: firmness, pulp pH, titrate able acidity of the juice, ascorbic acid, soluble solids and the ratio of these. Increased levels of nitrogen negatively influenced the levels of ascorbic acid and titrate able acidity. The values of soluble solids and pH did not change with increasing nitrogen level, showing different effects in the sources used only. Due to effects several of different nitrogen sources on fruit quality characteristics, fertilization practices using nitrate and ammonium are recommended in order to improve quality. Li *et al.* (2003) hypothesized that soil N variability, and fertilization and cropping management affect potato (*Solanum tuberosum* L.) growth and fertilizer N efficiency. The fertilizer N treatments consisted of a control, side-dress at rates of 70, 105 and 140 kg ha^{-1}, and split applications (at seeding and bloom) at rates of 70+70, 105+70 and 140+70 kg ha^{-1}, respectively. Soil acidity was corrected with limestone following the plow down of the sod. Years of cropping, main effect of N treatment, and year and fertilizer N interaction were significant on total and marketable tuber yields and N uptake, which were significantly related to soil N, and root growth. In 2-3 years, the side-dress N (140 kg ha^{-1}) increased significantly tuber yields (11.4-19.8%) compared to the split N (70+70 kg ha^{-1}). Higher split N had no effect on tuber yield and N uptake but increased residual N at harvest. Unused fertilizer N was strongly linked (R2=0.98) to fertilizer N rates.

Ceylan *et al.* (2001) conducted a field experiment 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 under field conditions. The total nitrogen, NO2-N and NO3-N contents of leaves and fruits were determined. On the first and second harvest dates, the highest NO3-N and NO2-N amounts in tomato leaves 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 yield was recorded upon treatment with 24 kg N/ha.

Raghav (2001) conducted a field experiment evaluating two F1 hybrids of tomato (Naveen and Vaishali), three plant spacing's (75 cm x 50 cm, 75 cm x 75 cm and 75 cm x 100 cm) and four levels of nitrogen (0, 75, 150, 225 and 300 kg/ha) 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. Naveen F1 hybrids gave significantly higher yield during both years, followed by Vaishali using closer spacing (75 cm x 50 cm). Among the various levels of nitrogen, 300 kg/ha was found to be best in improving the growth and yield of both cultivars.

Sainju *et al*. (2001) stated that cover crops can influence soil properties, fruit yield, and growth of above and belowground biomass of tomato (*Lycopersicon esculentum*). The influence of legume, i.e. hairy vetch (*Vicia villosa*) and crimson clover (*Trifoliumin carnatum*), and non-legume, i.e. rye (*Secale cereale)*, cover crops and N fertilizer application (0, 90, and 180 kg N/ha) on tomato yield, root growth, and soil N and C concentrations, were examined and compared. We measured fresh market yield, biomass (dry weight of fruits, stems and leaves), N uptake and root growth by using the mini rhizotron method, and soil inorganic N, organic N and organic C concentrations on a Greenville fine sandy loam (fine-loamy, kaolinite, thermic, Rhodic Kandiudults) in 1996 and 1997 in Fort Valley, Georgia, USA. Hairy vetch, crimson clover and the application of 90 and 180 kg N/ha resulted in a greater increase in fruit yield, N uptake and biomass of tomatoes, compared with rye or 0 kg N/ha. The soil inorganic N at 48 days after transplanting (DAT) in 1996, and at 36 DAT in 1997, were greater with hairy vetch and 90 and 180 kg N/ha than with 0 kg N/ha. Rye increased tomato root growth relative to 0 kg N/ha due to higher biomass yield, and soil organic C and N levels.

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

Ravinder *et al.* (2000) found in experiments at Solan in 1996 and 1997, eight tomato hybrids (Meenakashi, Manisha, Menka, SolanSagun, FT-5XEC-174023, EC-174023XEC-174041, Rachna and Naveen) were treated with four NPK combinations (100:75:55; 150:112.5:82.5; 200:150:110; 250:187.5:137.5 kg N: P_2O_5:K_2O ha^{-1}). The number of marketable fruits per plant and yield per plant were highest in Menka followed by Manisha. Of the fertilizer's treatments, 200:150:110 kg N: P_2O_5:K_2O ha^{-1} produced the highest yields.

Faria *et al.* (2000) reported that rates and periods of application were studied for application of N via drip irrigation to processing tomatoes (cv. IPA-5) growing in sandy soil in Petrolina, Brazil, during 1993-94. The N rates tested were: a total of 45, 90 or 135 kg N/ha applied daily for up to 25, 50 or 75 days after transplanting. Application of N in irrigation water was more efficient than soil application. In 1993, yields were highest (73.43 t/ha) with N at 90 kg/ha applied daily for 75 days after transplanting, whereas in 1994, yields were highest (67.86 t/ha) with N at 90 kg/ha applied daily for 50 days after transplanting. The lower yields obtained in 1994 were attributed to soil compaction following the earlier experiment. Application of N for only 25 days after transplanting generally gave poor yields.

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

Felipe and Casanova (2000) found that the effects of N (0, 90, 180 and 270 kg/ha), P (P2O5, 0, 135, 270 and 405 kg/ha), and K (K2O, 0, 90, 180 and 270 kg/ha) on the yield and number of fruits of tomato were investigated in the field in Venezuela. The best treatment, with the highest yield and number of fruits per plant, was 180 kg N, 270 kg P2O5, and 180 kg K2O/ha. It was possible to decrease the application of nutrients, particularly P. The increased yield was not due to larger fruits, but to an increase in the number of fruits. N had a profound effect on the number of fruits.

Field studies, on PellicVertisol in Cyprus, were designed by (Papadopolos *et al.,* 2000) to investigate the response of drip-irrigated tomato to conventional soil P fertilizer application as Triple Superphosphate (TSP) and fertigation when P is applied in the form of Urea Phosphate (UP), Mono-ammonium Phosphate (MAP) or Di-ammonium Phosphate (DAP). The N and P applied in soil were 300 and 94 kg/ha. An equivalent amount of P and an amount of 70 kg P/ha in a combination with 150, 300 and 450 kg N/ha were applied with irrigation water at a total amount of 200 mm of water. The K applied was 450 kg/ha in all treatments. Irrigation was applied when the soil water potential was between 0.03 and 0.04 MPa and at full growth of plants was equivalent to 0.8 of pan evaporation from a screened USWA Class A pan. Similar treatments were tested using aubergines. The results indicated that fertigation, irrespective of the combination of fertilizers, was superior to soil application. N application was more efficient when applied with the irrigation water. UP as a source of P gave the highest yield in both tomato and aubergine. Results are discussed.

This investigation was carried out by (Hafidh, 2000) consisted of 2 experiments regarding the early growth of tomato (cv. Rio Grand), carried out during spring seasons of 1994 and 1995 in Libya. The first experiment considered the effect of early N application (0, 50, 100, 150 and 200 mg/litre) to seedlings, while the second one investigated plant response to N (100 mg/litre) applied after transplanting in relation to seedling age (1, 2, 3 or 4 weeks old). Results indicated that there were no significant effects of early N application on growth regardless of concentration. Vegetative growth characteristics were significantly lower in plants grown with N in comparison with those grown without it. In older seedlings, stem length, and fresh and dry weight of 2-week-old plants grown with N were significantly higher than those of 3- and 4-week-old transplants.

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

Current recommendations for fertilizer N rates for processing tomatoes in Bangladesh were developed (BARC, 2018). Many new tomato cultivars have been bred which have a higher yield potential, and may also have a higher fertilizer N requirement. This study was conducted to determine whether higher-than-recommended fertilizer N rates will lead to optimum fruit yield and quality in four of the new processing tomato cultivars currently grown on sandy loam soil. New experiments on tomatoes were conducting in Bangladesh Agriculture Research Institute (BARI).

Application of N-fertilizer to the soil produces high tomato fruit yield and improves fruit quality (Adams *et al*., 1978) whereas excessive application leads to luxuriant development of vegetative parts of the plant at the expense of reproductive growth. It has been reported that tomato can grow on a variety of soils except worst soils such as gravelly soils and water-logged soils (Simons and Sobulo, 1974) but better yields were obtained from some soil types than others even with the same management practices and environmental conditions (Pettygrove *et al.,* 1999). The specific dose of nitrogen may affect yield and storage behavior of tomato fruits. The experiment objective is to find out amount of nitrogen for optimum growth and higher yield of tomato per unit area of land.

Ferreira *et al.* (2010) studied that nitrogen fertilization efficiency of the tomato crop, with organic fertilization, was evaluated in two experiments conducted at two times: spring/summer and autumn/spring. The experiments were carried out at the Horticulture experimental field of the Universidade Federal de Vicosa in a Cambic Red-Yellow Argisol. In both times, the applied N doses, in the form of nitro calcium, were 0.0, 93.3, 187.0, 374.0 and 748.0 kg ha-1 and the doses of organic fertilization, in the form of cattle manure compost, were 0 and 8 t ha-1 of dry matter. The weight and the number of marketed tomatoes plant-1 increased with the increase of N level in the soil. The percentage of commercially discarded fruits was larger in the spring/summer than in the autumn/spring. The nitrogen fertilization efficiency in tomato crop was higher in the autumn/spring than in the spring/summer. In the spring/summer, the efficiency was higher without the addition of organic matter to the soil, whereas in the autumn/spring the opposite took place.

Kikuchi (2009) observed that growth and nitrogen content were different among nine tomato cultivars grown under three nitrogen levels (50, 100, 150 mg N/L). Applied nitrogen efficiency to growth was the highest in Odoriko', and the lowest in 'June Pink'. It was suggested that the difference in tomato growth was influenced not only by the difference of nitrogen uptake but also the difference of nitrogen efficiency ratio (dry weight per nitrogen content). A positive correlation between the tomato growth and the content of assimilated nitrogen was observed. Therefore, it was suggested that the ability of nitrogen assimilation was different among the cultivars, and that the difference in ability of nitrogen assimilation influenced the difference in the nitrogen efficiency ratio and growth. They compared 'Odoriko' and 'June Pink' for nitrate (NO_3^-) reduction, which is the most important step in nitrogen assimilation. It was shown that there were differences of nitrate reductase (NR) activity and rate of nitrate assimilation between the two cultivars.

An investigation was carried out by (Bhadoria *et al.*, 2007) to evaluate the effect of methods of Azotobacter inoculation in combination with nitrogen rates on the flowering and fruiting behavior of tomato cv. JT-99. Treatments comprised: three methods of inoculation (no inoculation, soil inoculation and seedling inoculation) and five nitrogen rates (0, 25, 50, 75 and 100 kg ha-1). Seedling treatment with Azotobacter recorded the earliest flowering, fruit setting and picking of fruits, as well as higher number of flowers, fruits and yield ha^{-1}.

Hossain (2007) conducted a field experiment at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh during the period from October, 2006 to March, 2007 in order study the effects of nitrogen and stem pruning on the yield of tomato cv. Pusa Ruby.

A field experiment was conducted by (Basunia, 2004) to study the effect of different levels of nitrogen and pruning on the growth and yield of tomato cv. BAR1Tomato-6 at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh during the period from October 2003 to March 2004. There were four nitrogen levels, viz., 0, 100, 200, 300 kg N ha^{-1} and three pruning levels, viz., no pruning, single stem and double stem pruning. The results of the experiment revealed that plant height, total number of leaves, number of green leaves plant^{-1} at final harvest, days to first flowering, number of flower clusters, flower cluster^{-1}, flower plant^{-1}, fruits cluster^{-1}, fruits plant^{-1}, length and diameter of fruit, individual fruit weight and fruit yield were significantly influenced by the different levels of nitrogen.

A field experiment was conducted at Bhubaneswar, India by (Sahoo *et al.*, 2002) to study the effects of nitrogen (50, 100, 150 or 200 kg N ha^{-1}) and potassium (75 or 150 kg ha^{-1}) on the growth and yield of tomato var. Utkal kumara during the rabi season of 1999-2000. The wide range of variation was marked by the application of nitrogen with respect to growth, development and yield of tomato fruit. The fruit yield increased with each increase in the levels of nitrogen from 50 to 150 kg but further increased of nitrogen beyond 150 kg ha^{-1} reduced the yield considerably. They also found that the highest value relating to yield attributing characters like number of fruits plant^{-1} and single fruit weight were maximums when potassium was applied at the rate of 75 kg ha^{-1}. However, the combination of 150 kg N ha^{-1} along with 75 kg K ha^{-1} gave best result with respect to tomato from yield and other yield attributing characters.

In most cases, farmers use imbalance dose of nitrogen (N) fertilizer which causes higher insects/disease infestation resulting to lower yield. Generally, farmers are accustomed to use N fertilizer in the form of prilled urea (PU) which is very easy to apply though rice plant can receive only 25 to 30 % of applied fertilizer (BRRI, 2007).

Shahe *et al.* (2011) was carried a socio-economic study out in two rice production environments (Gazipur and Tangail) to assess the comparative advantages of using urea super granule (USG) over prilled urea (PU) in modern rice production and to examine the differences in producers' technical efficiency between USG user and nonuser in crop management. Stochastic frontier production model was employed to examine the farm specific technical efficiency difference in crop management between USG and PU users in the study areas. Analysis revealed that comparatively low amount (36%) of urea was needed in modern boro rice production using USG instead of PU. Nearly 366 % more labour was needed in the USG using plots compared to that of PU user plots, while weeding cost was a bit lower in USG using plots. Analysis also indicated that the sample farmers were able to achieve additional yield of 0.87 t/ha by using USG and this yield gain further resulted to additional benefit of Tk. 11506/ha. For the resource poor rice farms, this benefit is considered to be substantive. Farmers' contact with the technology disseminators; training on rice production and the use of USG (instead of PU) were the important factors of increasing rice farmers' technical efficiency in crop management and productivity enhancement as well. According to the farmers' opinion, there were several constraints in using USG and out of those, requirement of more labor and non-availability of USG in proper time were the dominant ones.

CHAPTER III
MATERIALS AND METHODS

This chapter briefly describes the materials and methods that are used in performing the research work. The chapter is presented under the following heads: Location, Soil characteristics, Climate and weather, Description of crop sample, Treatments, Experimental design, Land preparation, Layout of the experimental plots, Fertilizer application, Source of compost, Sowing of seedlings, Intercultural operations, Harvesting, Data collection, post-harvest soil sampling and Statistical analysis.

3.1 Location of the experiment

The field experiment was conducted at the Soil Science research field, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2019 to March 2020. Geographically the experimental field is located at 23°46' N latitude and 90° 22' E longitude at an elevation of 8.2 m above the sea level belonging to the Agro-ecological Zone "AEZ-28" of Madhupur Tract (BBS, 2011). The location of the experimental site has been shown in Appendix I.

3.2 Soil characteristics

The soil of the research field is slightly acidic in reaction with low organic matter content. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The experimental plot was also high land, having pH 6.22 and particle density 2.68 g/cc. The physicochemical property and nutrient status of soil of the experimental plots are given in Table 1 and Appendix II.

3.3 Climate and weather

The climate of experimental site is sub-tropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh

Meteorological Department, and presented in Appendix III.

Table 1: Morphological characteristics, physical and chemical properties of the soils SAU Farm of SAU.

Morphological characteristics of experimental field	
Location	SAU Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Physiological properties of the initial soil	
Particle size analysis	
Sand%	25
Silt%	45
Clay%	30
Textural Classes	Silty -Clay
pH	6.22
Particle density (g/cc)	2.68
Organic carbon (%)	0.47
Organic matter (%)	0.78
Total N (%)	0.007
Available P (ppm)	16.00
Exchangeable K (meq/100g soil)	0.11

3.4 Planting material

In the experiment planting material used as the seed of BARI Tomato-15 that was developed by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur in 2009. High yielding winter variety, thick skin and edible flesh having very good self-life, fruit oval shape, less seeded fruits with 65-70g in weight, Attractive red flesh color, 40-45 fruit/plant, life time 100-110 days. Planting season and time Rabi, and October. Medium to late variety. Within 60-70 days after transplantation fruit harvest start and harvest up to 25-30 days. Yield should be 80-85 t ha^{-1}.

3.5 Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD). All the treatments were replicated three times. There were altogether 21 = (7×3) unit's plots.

3.6 Layout of the experimental plot

Total number of plots	: 21
Individual plot size (2×3) m^2	: 6 m^2
Space between block to block	: 0.75 m
Block to border (row)	: 0.25 m
Block to border (column)	: 0.50 m
Replication	: 3
Drainage size	: 0.38 m

The layout of the experimental plots shown in figure 1

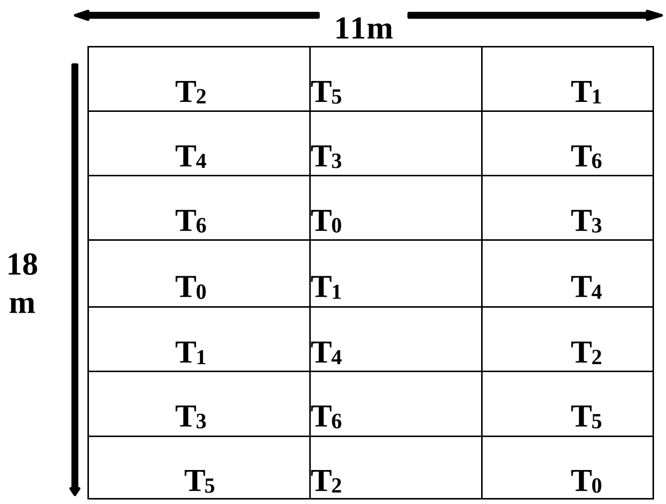

Fig. 1. Field layout of the experiment

3.7 Land preparation

Seed bed preparation was done on 29th October, 2019. The main land was irrigated before ploughing. After having 'joe' condition the land was first opened with the tractor drawn disc plough. Ploughed soil was brought into desirable fine tilth by 3 ploughing and cross-ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 23rd November and 25th November, 2019, respectively. Experimental land was divided into unit plots following the design of experiment.

3.8 Treatments under investigation

The experiment consisted of following treatments:

T_0 = Control

T_1 = 100% N as Prilled Urea (PU)

T_2 = 100% N as Urea Super Granule (USG)

T_3 = 80% as Prilled urea (PU) + 20% N as cowdung

T_4 = 80% as USG (Urea Super Granule) + 20% N as cowdung

T_5 = 120% N as Prilled urea (PU)

T_6 = 120% N as USG (Urea Super Granule)

3.9 Fertilizer application

Prilled Urea (PU), Urea Super Granule (USG) and cowdung was used as the sources of Nitrogen. Doses of Nitrogen were applied as per treatments of the experiment. MoP as source of potassium were applied in two equal installments at 15 and 30 days after transplanting (DAT) of seedlings. The fertilizers were mixed thoroughly with the soil by hand. The whole amount of TSP, gypsum, boric acid as the sources of Phosphorus, Sulphur and Boron, respectively were applied during the final land preparation. Recommended fertilizer doses (RFD) of Phosphorus, Potassium, Sulphur, Zinc and Boron was applied as Triple Super Phosphate, Muriate of Potash, Gypsum, Zinc sulphate and Boric acid at the rate of 45, 75, 15, 2 and 1 kg ha^{-1} respectively.

3.10 Sowing of seedlings in the field

Each seedling was sown in each pit at a depth of 5 cm. The seedlings were covered with pulverized soil just after sowing and gently pressed with hands. The sowing was done on 25 November, 2019 in rows and at a spacing of 50 cm x 25 cm. The seedlings were covered with loose soil.

3.11 Intercultural operations

3.11.1 Gap filling

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

3.11.2 Tagging and stalking

Tagging and stalking was done on 03 December, 2019.

3.11.3 Weeding

Weeding was done whenever it was necessary.

3.11.4 Irrigation

Light watering was given with water can immediately after transplanting the seedlings and then necessary irrigation was done as and when necessary, throughout the growing period up to before 7 days of harvesting. Ring and watering were done on 12 December, 2019.

3.12 Plant protection

3.12.1 Insect pests

Melathion 57 EC was applied @ 2 ml L-1 of water against the insect pests like cut worm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly after transplanting and stopped before second week of first harvest. Furadan lOG was also applied during final land preparation as soil insecticide.

3.12.2 Diseases

During foggy weather precautionary measure against disease attack of tomato was taken by spraying Diathane M-45 fortnightly @ 2 gm per litre of water, at the early vegetative stage. Ridomil gold was also applied @ 2 g per litre of water against blight disease of tomato.

3.13 Sampling and harvesting

Fruits were harvested at 4-5-days interval during early ripe stage when they developed slightly red color. Harvesting was started from 07th March, 2015 and was continued up to 22th March, 2020.

3.14 Data collection

Five plants in each plot were selected and tagged. All the growth data (except dry weight) were recorded from those five selected plants.

The following data were collected –

I. Plant Height (cm)
II. Number of branches plant $^{-1}$
III. Fruit weight plant^{-1} (kg)

IV. Number of fruit clusters plant^{-1}

V. Fruit Diameter (cm)

VI. Fruit weight plot^{-1} (kg)

VII. Yield (t ha^{-1})

VIII. Biological yield (t ha^{-1})

IX. Harvest Index (%)

3.15 Procedure of data collection

3.15.1 Plant height (cm)

The plant height was recorded at harvest only. The plant height was taken from the ground level to the tip of the longest leaf of the plants. Plant height was recorded from 10 randomly sampled plants, and the mean was calculated and recorded in centimeter (cm).

3.15.2 Number of branches plant $^{-1}$

Average number of branches per plant was found from 5 randomly selected plants per unit plot and the means were found out.

3.15.3 Number of fruit clusters plant^{-1}

The number of fruit clusters was counted from the sample plants and the average number of clusters born per plant was recorded at the time of final harvest. The data of cluster/plant is presented only 45 and 63 DAT.

3.15.4 Fruit weight plant^{-1} (kg)

Fruit weight plant^{-1} from 5 randomly selected plants was counted, and their mean values were found out.

3.15.5 Fruit Diameter (cm)

The diameter of fruit was measured with slide-calipers from the neck to the bottom of 5 selected marketable fruits and their average was taken in cm as the diameter of fruit.

3.15.6 Fruit weight plot^{-1} (kg)

Fruit weight plot^{-1} were counted from 5 randomly selected plants of each treatment plot and then were weighed with the help of highly sensitive electronic balance to record fruit weight plot^{-1} and was expressed in kilogram (kg).

3.15.7 Yield (t ha^{-1})

Light yellow fruits were harvested at regular interval from each unit plot and their weight was recorded. As harvesting was done at different interval, the total weight of fruits was recorded for each for each unit plot, and was expressed in tons per hectare (t ha^{-1}).

3.15.8 Biological yield (t ha^{-1})

Biological yield was calculated by using the following formula:

Biological yield (t ha^{-1}) = Fruit yield (t ha^{-1}) + Plant dry matter (t ha^{-1}).

3.15.9 Harvest Index (%)

The harvest index (%) was calculated with the following formula-

$$\text{Harvest index (\%)} = \frac{\text{Fruit yield}}{\text{Biological yield}} \times 100$$

Here, Biological yield = Fruit yield + dry matter yield

3.16 Postharvest soil analysis

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

3.16.1 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 as described by (Page *et al.*, 1982).

3.16.2 Organic matter

Organic carbon in soil sample was determined by wet oxidation method. The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_20_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_20_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

3.16.3 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated

2000C and added 3 ml H_2O_2 and then heating at 3600C was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al*., 1982). Then 20 ml digest solution was transferred into the distillation flask, then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient number of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally, the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula: % N = (T-B) × N × 0.014 × 100/S

Where, T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of

standard H_2SO_4 N = Strength of

H_2SO_4

S = Sample weight in gram

3.16.4 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wave length and readings were calibrated with the standard P curve (Page *et al*., 1982).

3.16.5 Exchangeable potassium

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

3.17 Statistical analysis

The recorded data were compiled and analyzed by single factorial design to find out the statistical significance of experimental results by using the "Analysis of variance" (ANOVA) technique with the help of statistix 10 that was an analysis software.

CHAPTER IV

RESULTS AND DISCUSSION

This experiment was conducted to determine the effect of different sources of nitrogen on growth and yield of tomato. The data have been depicted in various tables and figures. Results are discussed and possible explanations have been given under the following sub heads.

4.1 Effect of different nitrogen source on growth and yield of tomato

4.1.1 Plant height (cm)

Plant height of tomato was recorded from the ground surface to the tip of the leaf in five plants of all the treatments. The application of different nitrogen source showed a positive effect on the plant height of tomato at harvest time. The application of different nitrogen source from different nitrogen fertilizers significantly increased 1the plant height of tomato compared to that found in control showed in Figure 2. The highest plant height (96.64 cm) was recorded in the treatment T_2 which was followed by treatment T_1 and T_4. On the other hand, the lowest plant height was (77.27 cm) recorded in control treatment (T_0).

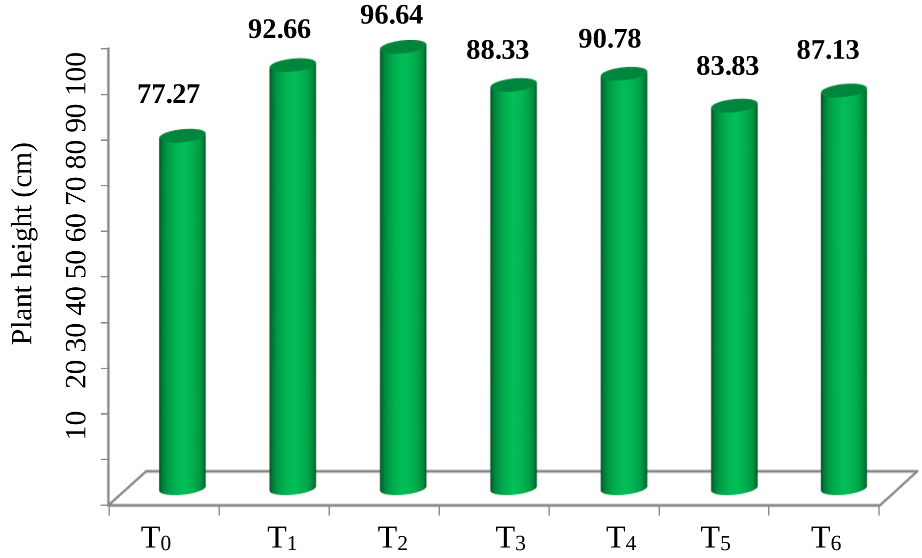

Figure 2: Effect of different sources of nitrogen on plant height (cm) of tomato

Here,
T_0 = Control
T_1 = 100% N as prilled Urea
T_2 = 100% N as USG
T_3 = 80% as prilled urea+ 20% N as cowdung
T_4 = 80% as USG+ 20% N as cowdung
T_5 = 120% N as prilled urea
T_6 = 120% N as USG

The order recorded according to the longer to the shorter plant height was $T_2 > T_1 > T_4 > T_3 > T_6 > T_5 > T_0$. Degefa *et al.* (2019) who revealed 13.6% in plant height increment compared to the control (no fertilizer application) by application of 99 kg N ha^{-1}. Some other scientists Nemomsa *et al*. (2019), Najafvand *et al*. (2008) and Gupta and Sengar (2000) also reported significant effect of nitrogen sources on plant height. Again Ewulo *et al*. (2015) who found that plant height in tomato increased with increased in nitrogen rate.

4.1.2 Number of branches plant^{-1}

The number of branches plant^{-1} is an important yield determining factor in tomato. The number of branches plant^{-1} was significantly influenced by the application of different sources of nitrogen fertilizer (Table 1). The maximum branches plant^{-1} (10.88) was found in the treatment T_2 (100% N as USG) was followed by T_1 (100% N as prilled Urea) treatment and the minimum branches plant^{-1} (6.44) was observed from treatments T_0 (Control), which differ statistically significantly when compared among themselves.

Tables 2: Effect of different sources of nitrogen on number of branches plant^{-1} and fruit weight plant^{-1} (kg) of tomato

Treatments	Number of branches plant^{-1}	Fruit weight plant^{-1} (kg)
T_0	6.44 e	3.03 e
T_1	10.33 ab	4.73 ab
T_2	10.88 a	5.23 a
T_3	9.22 bc	4.13 bcd
T_4	9.44 bc	4.61 abc
T_5	7.89 d	3.48 de
T_6	8.44 cd	3.87 cde
LS	**	**
CV (%)	4.56	7.09

In a column, means followed by a common letter are not significantly differed of 5% level by Tukey HSD test.

Here,
T_0 = Control
T_1 = 100% N as prilled Urea
T_2 = 100% N as USG
T_3 = 80% as prilled urea+ 20% N as cowdung
T_4 = 80% as USG+ 20% N as cowdung
T_5 = 120% N as prilled urea
T_6 = 120% N as USG

Iqbal *et al*. (2011) reported that application of 100 kg N ha^{-1} increased the number of branches by 24.34% compared to application of 0 kg N/ha in tomato cultivation. Degefa *et al.* (2019) also reported that, as the rate of nitrogen fertilizer increased from 0-99 kg ha^{-1}, the number of primary branches in tomato increased by 28.9% compared to the nil nitrogen fertilizer application. Also results of experiments are in line with (Nemomsa *et al*., 2019).

4.1.3 Fruit weight plant^{-1} (kg)

Fruit weight per plant of tomato was significantly affected by different sources of N (Table 1). The highest fruit weight per plant (5.23 kg) was obtained in T_2 treatment and the lowest fruit weight per plant (3.03 kg) was obtained in control treatment that was T_0. Basunia (2004) reported that fruit weight was significantly influenced by the different levels of nitrogen. Similar findings were explained in previous research by (Gupta and Sengar, 2000) and (Sahoo *et al.*, 2002).

4.1.4 Number of fruit clusters plant^{-1}

Number of fruit clusters plant^{-1} is an important yield determining factor in tomato. It affects the number of fruits cluster plant^{-1}. The effect of different sources of nitrogen fertilizers was significant as observed on number of fruit clusters plant^{-1} (Figure 3).

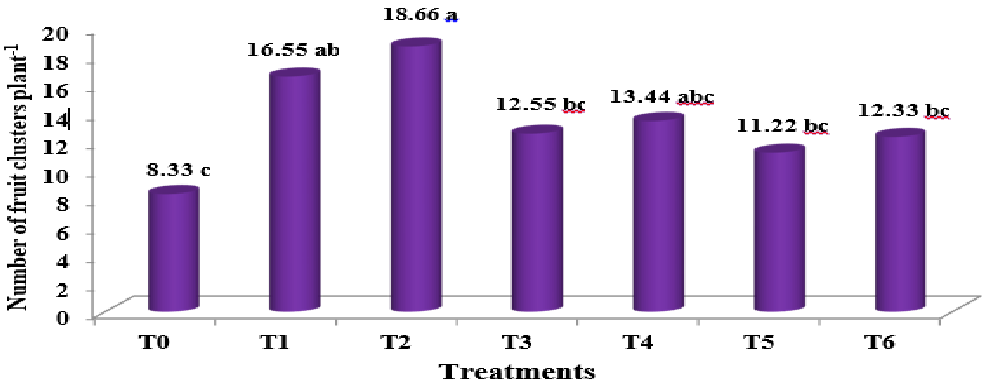

Figure 3: Effect of different sources of nitrogen on number of fruit clusters plant^{-1} of tomato

Here,
T_0 = Control
T_1 = 100% N as prilled Urea
T_2 = 100% N as USG
T_3 = 80% as prilled urea+ 20% N as cowdung
T_4 = 80% as USG+ 20% N as cowdung
T_5 = 120% N as prilled urea
T_6 = 120% N as USG

The maximum number of fruit clusters plant^{-1} (18.66) was observed at T_2 treatmentwhich treated by 100% USG as nitrogen source. The lowest number of fruit clusters plant^{-1} (8.33) was found in T_0 treatment that was control. Nemomsa *et al*. (2019) was also observed nitrogen fertilizer increased the number of clusters per plant of tomato over the control treatment.

4.1.5 Fruit Diameter (cm)

The diameter of fruit was observed significantly varied due to the different application of different sources of nitrogen fertilizers affect (Table 3). The fruit diameter varied significantly from 20.49 cm to 18.08 cm. The highest statistically superior fruit diameter was 20.49 cm recorded in the treatment T_2 where applied 100 % USG as N sources. On the other hand, the lowest fruit diameter 18.08 cm was obtained in the treatment T_0 (control).

Table 3: Effect of different sources of nitrogen on number of fruit diameter (cm), fruit weight plot^{-1} (kg) of tomato

Treatments	Fruit Diameter (cm)	Fruit weight plot^{-1} (kg)
T_0	5.74	30.90 e
T_1	6.30	49.27 ab
T_2	6.52	52.13 a
T_3	6.17	44.01 bc
T_4	6.21	47.03 ab
T_5	5.90	36.87 de
T_6	6.10	40.29 cd
LS	NS	**
CV (%)	4.18	5.33

In a column, means followed by a common letter are not significantly differed of 5% level by Tukey HSD test.

Here,
T_0 = Control
T_1 = 100% N as prilled Urea
T_2 = 100% N as USG
T_3 = 80% as prilled urea+ 20% N as cowdung
T_4 = 80% as USG+ 20% N as cowdung
T_5 = 120% N as prilled urea
T_6 = 120% N as USG

4.1.6 Fruit weight plot^{-1} (kg)

Fruit weight plot^{-1} was an important yield contributing characteristics of tomato. The weight of fruits was measured with electric balance from the weight of five selected sample plants from each plot, and their average multiply with number of plants per plot was calculated in kilogram. It was noticed that different sources of nitrogen exhibited significant effect on the weight of fruits per plot (Table 3). The maximum weight (52.13 kg) of fruits per plant was recorded in T_2 (100% N as USG*)* which followed by T_1 (100% N as prilled Urea) and T_4 (80% as USG+ 20% N as cowdung) treatment that was 49.27 kg and 47.03 kg respectively whereas the minimum weight (30.90 kg) was obtained from control treatment. These results are in accordance with the findings of (Gupta and Sengar, 2000) and (Sahoo *et al.*, 2002) that nitrogen fertilizer significantly increased the fruit weight. The treatments may be ranked in order of $T_2 > T_1 > T_4 > T_3 > T_6 > T_5 > T_{0.}$

4.1.7 Yield (t ha^{-1})

Tomato fruit yield is a function of interaction among various yield components that were affected differentially by the growing conditions and crop management practices. It is clear from the figure 4 that fruit yield was significantly affected by the application of different sources of nitrogen fertilizer. All the means of data presented clearly show that significantly highest fruit yield (86.53 t ha^{-1}) was recorded from T_2 treatment and lowest yield (51.29 t ha^{-1}) found at control treatment (T_0). Shahe *et al.* (2011) was revealed that comparatively low amount (36%) of urea was needed in modern crops production using USG instead of PU. Warner *et al.* (2004) who reported that, as the rate of nitrogen fertilizer increased, the yield of tomato increased. Kamar *et al*. (2019) also found that the effects of different forms of urea fertilizer deep placement were tested to quantify the fertilizer use efficiency and yield of summar tomato cultivation. Hokam *et al*. (2011) also reported that nitrogen promotes fruit yield. Again Biswas *et al*. (2015) reported the highest fruit yield of tomato when the crop treated by 108.6 kg N ha^{-1} at the eastern part of Ethiopian country. Addition of a range of N fertilizer at 110 kg ha^{-1}, to tomato field improved tomato fruit yield on vertisol of West Showa (Tesfaye, 2008). The order recorded according to the longer to the shorter plant height was $T_2 > T_1 > T_4 > T_3 > T_6 > T_5 > T_0$. These results are in line with the findings of (Manjurul *et al*., 2018), (Wahle and Masiunas, 2003), (Wang *et al*., 2007), (Raghav, 2001), (Sainju *et al.*, 2001), (Khalil *et al.,* 2001) and (Singh *et al.,* 2000) in tomato cultivation.

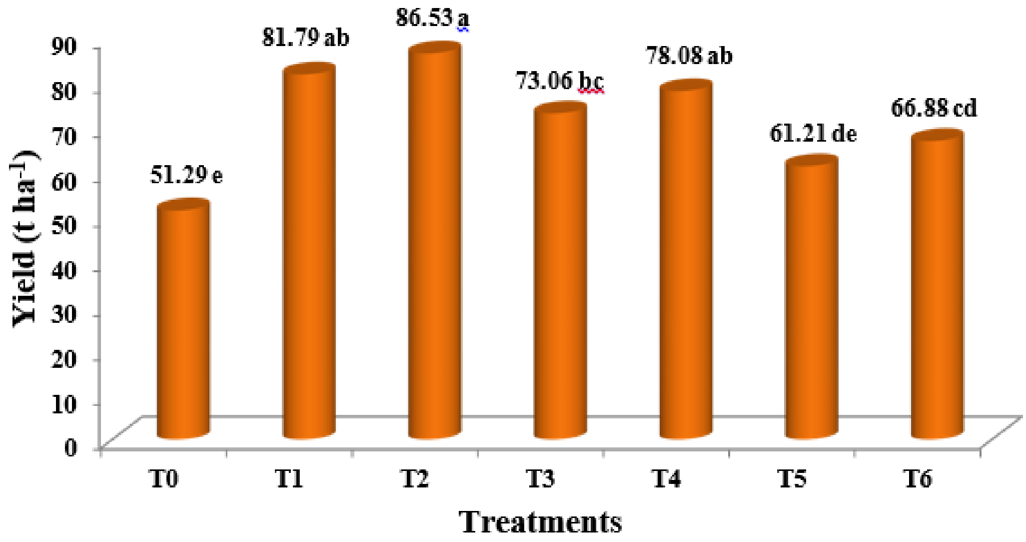

Figure 4: Effect of different sources of nitrogen on yield (t ha^{-1}) of tomato

Here,
T_0 = Control
T_1 = 100% N as prilled Urea
T_2 = 100% N as USG
T_3 = 80% as prilled urea+ 20% N as cowdung
T_4 = 80% as USG+ 20% N as cowdung
T_5 = 120% N as prilled urea
T6 = 120% N as USG

4.1.2 Biological yield (t ha^{-1})

Application of different sources of nitrogen fertilizers showed the variation for biological yield. A perusal of table 3 shows that maximum biological yield (106.15 t ha^{-1}) was obtained in T_2 treatment, which was statistically different from T_1 treatment giving biological yields of 96.65 t ha^{-1}. The lowest biological yield in T_0 (57.45 t ha^{-1}) was recorded from plot where no fertilizer was applied (control). Singh *et al.* (2000) observed the suitable rate and application of N fertilizers produced the highest yield and biomass. Increasing N rates resulted in increasing biomass and yield.

Table 4: Effect of different sources of nitrogen on number of biological yield (t ha^{-1}) and harvest Index (%) of tomato

Treatments	Biological yield (t ha^{-1})	Harvest Index (%)
T_0	57.45 e	89.28 a
T_1	96.65 b	84.67 b
T_2	106.15 a	81.52 c
T_3	85.79 c	85.24 b
T_4	92.01 bc	84.92 b
T_5	71.08 d	86.16 b
T_6	78.11 d	85.62 b
LS	**	NS
CV (%)	1.72	1.35

In a column, means followed by a common letter are not significantly differed of 5% level by Tukey HSD test.

Here,
T_0 = Control
T_1 = 100% N as prilled Urea
T_2 = 100% N as USG
T_3 = 80% as prilled urea+ 20% N as cowdung
T_4 = 80% as USG+ 20% N as cowdung
T_5 = 120% N as prilled urea
T6 = 120% N as USG
***Significant at 1% probability level.*
** Significant at 5% probability level.*
LS= Level of significance
CV= Co-efficient of variance

4.1.3 Harvest Index (%)

Harvest index of tomato significantly varied with different sources of N application (Table 4). The maximum harvest index of tomato (89.28 %) was recorded from T_0 which was statistically different from other treatments when compared among themselves.

4.2 Chemical properties of the collected soil after harvesting

Chemical Properties of soil a composite soil sample from 0 – 30cm depth was collected using augur from eight different points of the experimental area and some of its chemical properties before and after harvest were determined as presented in Table 5.

4.2.1 Soil pH

Statistically no significant variation was recorded for pH in post-harvest soil due to different sources of N fertilizer (Appendix VI B). The highest pH (6.25) was observed from T_2 treatment whereas the lowest pH (6.15) was found from T_0 treatment (Table 5).

Table 5: Effect of different sources of nitrogen of postharvest soil of soil pH and particle density (g/cc) and organic matter of tomato

Treatments	Soil pH	Particle density (g/cc)	Organic matter (%)
T_0	6.15	2.45	0.78
T_1	6.17	2.35	0.80
T_2	6.25	2.31	0.81
T_3	6.20	2.43	0.79
T_4	6.22	2.41	0.80
T_5	6.24	2.42	0.79
T_6	6.21	2.44	0.80
Initial Soil	6.22	2.68	0.78
LS	NS	NS	NS
CV%	0.58	2.16	1.22

In a column, means followed by a common letter are not significantly differed of 5% level by Tukey HSD test.

Here,
T_0 = Control
T_1 = 100% N as prilled Urea
T_2 = 100% N as USG
T_3 = 80% as prilled urea+ 20% N as cowdung
T_4 = 80% as USG+ 20% N as cowdung
T_5 = 120% N as prilled urea
T_6 = 120% N as USG
***Significant at 1% probability level.*
** Significant at 5% probability level.*
LS= Level of significance
CV= Co-efficient of variance

4.1.1 Particle density (g/cc)

Statistically non-significant variation was recorded for particle density in post-harvest soil due to different sources of N application (Appendix: IV). The highest particle density (2.45 g/cc) was observed from T_0 which followed by T_6 (120 % N as USG), whereas the lowest particle density (2.31 g/cc) was found from T_2 (control) (Table 5).

4.2.2 Organic matter (%)

Statistically significant variation was recorded for organic matter in post-harvest soil due to different sources of nutrients (Table 5, Appendix II). The highest organic matter (0.81%) was observed from T_2 treatment whereas the lowest organic matter (0.78 %) was found from T_0 treatment.

4.2.3 Total N (%)

The total N present in the post-harvest soil should be varied considerably different by plant uptake and leaching loss but here the treatments were not significantly varied in post-harvest soil due to different source of nitrogen applied (Table 6). And soil nitrogen content of the post-harvest soil was higher than the initial soil. The total nitrogen content of the post-harvest soil ranged between 0.061 % and 0.068 %. The highest nitrogen (0.068 %) was found in T_2 treatment. The lowest soil N (0.061 %) content was found in T_0 treatment. Sreelatha *et al.* (2006) reported that organic manures had a positive influence on total and available N content of soil.

Table 6: Effect of different sources of nitrogen of postharvest soil of total N (%), available P (ppm), exchangeable K (meq/100 g soil) and available S (ppm) of tomato

	Total N (%)	Available P (ppm)	Exchangeable K (meq/100 g soil)	Available S (ppm)
T_0	0.061	15.30 f	0.114	12.52 g
T_1	0.063	23.00 b	0.129	19.81 b
T_2	0.068	23.94 a	0.135	20.77 a
T_3	0.066	21.56 c	0.123	18.20 d
T_4	0.065	22.70 b	0.125	18.92 c
T_5	0.066	17.55 e	0.117	18.20 d
T_6	0.063	19.20 d	0.121	17.58 e
Initial Soil	0.007	16.00	0.11	13.58
LS	NS	**	NS	*
CV%	3.67	1.32	1.31	0.79

In a column, means followed by a common letter are not significantly differed of 5% level by Tukey HSD test.

Here,
T_0 = Control
T_1 = 100% N as prilled Urea
T_2 = 100% N as USG
T_3 = 80% as prilled urea+ 20% N as cowdung
T_4 = 80% as USG+ 20% N as cowdung
T_5 = 120% N as prilled urea
T_6 = 120% N as USG
***Significant at 1% probability level.*
** Significant at 5% probability level.*
LS= Level of significance
CV= Co-efficient of variance

4.2.4 Available P (ppm)

The available phosphorus content of the post-harvest soil not significantly varied due to similar amount of P applied in all treatments (Table 6). Available phosphorus content in soil varied from 15.30 to 23.94 ppm due to applied similar phosphorus application. The maximum phosphorus content 23.94 ppm was observed in the treatment T_2. The lowest phosphorus content (15.30 ppm) was observed in T_0.

4.2.5 Exchangeable K (meq/100 g soil)

The exchangeable potassium (K) content of the post-harvest soil not influenced considerably due to same was applied (Table 6). The exchangeable K content of initial soil was 0.10 mg 100 g^{-1} soil and the values of post-harvest soil ranged from 0.114 to 0.135 mg 100 g^{-1} soil. The highest exchangeable K (0.135 mg 100 g^{-1}) was found in the treatments of T_2. The lowest value (0.114 mg 100 g^{-1}) was found in the treatments T_0. The exchangeable K increased in soils due to the supply of nutrients from cowdung throughout the growing period. A similar observation was made by (Horuchi *et al.*, 2008) who reported that using compost of pea residues enriched soil NPK and other nutrients in soil.

4.2.6 Available S (ppm)

The available Sulphur content of the post-harvest soil not significantly varied due to similar amount of S applied in all treatments (Table 6). Available Sulphur content in soil varied from 12.52 to 20.77 ppm due to applied different sources of N fertilizer doses. The maximum Sulphur content 20.77 ppm was observed in the treatment T_2. The lowest phosphorus content (12.52 ppm) was observed in T_0.

CHAPTER V

SUMMARY AND CONCLUTION

A field experiment was conducted at the SAU Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2019 to March 2020 to evaluate the impact of different sources of nitrogen fertilizer on growth and yield of tomato under field condition.

The experiment was laid out in a Randomized Completely Block Design (RCBD) having seven treatments with three replications. The unit plot size was 6 m^2. There were six different sources of nitrogenous treatments (T_0, T_1, T_2, T_3, T_4, T_5 and T_6) they were distributed randomly in individual plots. The total number of plots was 21. Nitrogen was applied as urea super granule (USG), prilled urea (PU) and cowdung. On the other hand, Phosphorus, Potassium, Sulphur, Zinc and Boron was applied as Triple Super Phosphate, Muriate of Potash, Gypsum, Zinc Sulphate and Boric acid at the rate of 45, 75, 15, 2 and 1 kg ha^{-1} respectively. Seedlings were sown on the 25th November 2019. The crop was allowed to grow until maturity and intercultural operations such as gap filling, tagging, weeding, irrigation and general observation were done whenever required in order to support normal growth of the crop. The fruits were harvested at 07th March 2020 and was continued up to 22th March, 2020. Plot wise yield and yield components were recorded.

Different sources of nitrogen significantly increased the plant height (cm). It was clearly found that, the longest plant was 96.64 cm observed in T_2 (100% N as USG) and the shortest one was 77.27 cm found in the treatment T_0 (control). Again, the number of branches $plant^{-1}$ also varied by different treatments. The maximum number of branches $plant^{-1}$ (10.88) were observed in the T_2 (100% N as USG) was followed by T_1 (100% N as prilled Urea) treatment and the minimum branches $plant^{-1}$ (6.44) was observed from treatments T_0 (Control). The highest Fruit weight per plant (5.23 kg) was obtained in T_2 treatment and the lowest fruit weight per plant (3.03 kg) was obtained in control treatment that was T_0. The effect of different sources of nitrogen fertilizers was significant as observed on number of fruit clusters $plant^{-1}$. The maximum number of fruit clusters plant^{-1} (18.66) was observed at T_2 treatment which treated by 100% USG as nitrogen source. The lowest number of fruit clusters plant^{-1} (8.33) was found in T_0 treatment that was control. The fruit diameter varied from 5.74 cm to 6.52 cm. the highest statistically superior fruit diameter was 6.52 cm recorded in the treatment T_2 were applied 100% USG as N sources. On the other hand, the lowest fruit diameter 5.74 cm was obtained in the treatment T_0 (control). The maximum weight (52.13 kg) of fruits per plot was recorded in T_2 (100% N as USG*)* which followed by T_1 (100% N as prilled Urea) and T_4 (80% as USG+ 20% N as cowdung) treatment that was 49.27 kg and 47.03 kg respectively whereas the minimum weight (30.90 kg) was obtained from control treatment. Finally, fruit yield recorded was also significantly different in treatments of different nitrogen sources. Here, the application at the rate of 100% N as USG (T_2) produced significantly maximum fruit yield (86.53 t ha^{-1}) was obtained in T_2 treatment followed with T_1 and T_4 treatments. On the other hand, the lowest fruit yield (51.29 t ha^{-1}) was recorded in control. All the growth and yield parameters of tomato were height with 100 % N as USG while it lowest in control among them. Nitrogen always positively influenced the above-mentioned characters. Data revealed after statistical analysis that there is a significant effect of different sources of nitrogen like USG, Prilled urea and cowdung on biological yield of tomato. Plots that were treated with 100 % N as USG give maximum biological yield (106.15 t ha^{-1}). The lowest biological yield in T_0 (57.45 t ha^{-1}) was recorded from plot where no fertilizer was applied. And the maximum harvest index of tomato (89.28 %) was recorded from T_0 which was statistically different from other treatments when compared among themselves.

The results of the present investigation revealed that tomato can be grown successfully with the use of N as USG, where tomato gave more yield. The findings of the present investigation clearly indicated that the use of nitrogen as USG doses and growing tomato is a viable option for increasing income of farmers.

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APPENDICES

Appendix I: Map showing the experimental site under area

Appendix II: Characteristics of soil of experimental field

A. Morphological characteristics of experimental field

Morphological features	Characteristics
Location	SAU Farm, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physiological properties of the initial soil

Characteristics	Value
Particle size analysis	
Sand%	25
Silt%	45
Clay%	30
Textural Classes	Silty -Clay
pH	6.22
Particle density (g/cc)	2.68
Organic carbon (%)	0.47
Organic matter (%)	0.78
Total N (%)	0.007
Available P (ppm)	16.00
Exchangeable K (meq/100g soil)	0.11

Appendix III. Monthly average of relative humidity, air temperature and total rainfall of experimental site during the period from October 2019 to April 2020

Month	Average RH%	Average temperature (C^0)		Total Average Rainfall (mm)
		Min.	Max.	
October, 2019	48.54	10.65	26.54	00
November, 2019	50.45	8.56	24.87	00
December, 2019	52.41	6.04	23.35	00
January, 2020	59.13	12.45	21.32	00
February, 2020	53.66	16.34	24.12	4.34
March, 2020	46.37	19.41	28.54	1.22
April, 2020	49.16	23.21	31.42	2.17

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka - 1212

Appendix IV: Schedule of cultural operation in the experiment

Serial No.	Cultural Operations	Date
01	Seedbed preparation	29.10.2019
02	Sowing of seed on seedbed	03.11.2019
03	Opening of the main land	20.11.2019
04	Ploughing and cross ploughing	21.11.2019
05	Breaking of clods, laddering and weeding	22.11.2019
06	Layout of the experimental pit and plot	23.11.2019
07	Transplanting of seedlings to main field	24,11.2019
08	Gap fillings	30.11.2019
09	1st Irrigation	01.12.2019
10	Tagging and stalking	03.12.2019
11	1st Weeding	08.12.2019
12	2nd Irrigation	8.12.2019
13	Applications of complete USG and 1/3rd PU	10.12.2019
14	Ring and watering	12.12.2019
15	2nd Weeding	26.12.2019
16	Attach bamboo stick with plant	27.12.2019
17	2nd Treatment done	31.12.2019
18	1st Harvesting	07.03.2020
19	2nd Harvesting	12.03.2020
20	3rd Harvesting	17.03.2020
21	Final Harvesting	22.03.2020
22	Collection post-harvest soil	30.03.2020
24	Analysis of soil sample	20.04.2020

Appendix V. Factorial ANOVA tables.

Source	DF	SS	MS	F-Value	P (>F)
		1. Plant height (cm)			
Replication	2	50.784	25.392		
Treatment	6	712.175	118.696	24.43	0.0000
Error	12	58.313	4.859		
Total	20	821.272			
		2. Number of branches plant^{-1}			
Replication	2	2.9140	1.45701		
Treatment	6	40.9604	6.82673	40.93	).0000
Error	12	2.0016	0.16680		
Total	20	45.8761			
		3. Fruit weight plant^{-1} (kg)			
Replication	2	0.09350	0.04675		
Treatment	6	2.61038	0.43506	20.07	).0000
Error	12	0.26010	0.02168		
Total	20	2.96398			
		4. Number of fruit clusters plant^{-1}			
Replication	2	42.608	21.3042		
Treatment	6	209.643	34.9405	9.88	0.0005
Error	12	42.442	3.5368		
Total	20	294.693			
		5. Fruit weight plot^{-1} (kg)			
Replication	2	11.470	5.7351		
Treatment	6	248.414	41.4024	31.60	0.0000
Error	12	15.720	1.3100		
Total	20	275.605			

Source	DF	SS	MS	F-Value	P (>F)
			7. Yield (t ha^{-1})		
Replication	2	31.608	15.804		
Treatment	6	684.530	114.088	31.60	0.0000
Error	12	43.319	3.610		
Total	20	759.456			
			8. Biological yield (t ha^{-1})		
Replication	2	279.15	139.575		
Treatment	6	4873.19	812.199	51.75	0.0000
Error	12	188.35	15.696		
Total	20	5340.69			
			9. Harvest index (%)		
Replication	2	20.387	10.1935		
Treatment	6	94.567	15.7612	7.30	0.0018
Error	12	25.893	2.1578		
Total	20	140.847			
			10. Soil pH		
Replication	2	0.04095	0.02048		
Treatment	6	0.13905	0.02317	8.59	0.0009
Error	12	0.03238	0.00270		
Total	20	0.21238			
			11. Particle density (g/cc)		
Replication	2	0.00087	0.00043		
Treatment	6	0.11311	0.01885	28.28	0.0000
Error	12	0.00800	0.00067		
Total	20	0.12198			
			12. Organic matter (%)		
Replication	2	0.15287	0.07643		
Treatment	6	0.30979	0.05163	202.04	0.0000
Error	12	0.00307	0.00026		
Total	20	0.46572			
			13. Total N (%)		
Replication	2	5.321e-04	2.660e-04		
Treatment	6	8.271e-03	1.379e-03	156.20	0.0000
Error	12	1.059e-04	8.825e-06		
Total	20	8.909e-03			

Source	DF	SS	MS	F-Value	P (>F)
14. Available P (ppm)					
Replication	2	9.988	4.9938		
Treatment	6	184.468	30.7447	420.34	0.0000
Error	12	0.878	0.0731		
Total	20	195.334			
15. Exchangeable K (meq/100 g soil)					
Replication	2	3.098e-04	1.549e-04		
Treatment	6	9.039e-04	1.507e-04	57.35	0.0000
Error	12	3.152e-05	2.627e-06		
Total	20	1.245e-03			
16. Available S (ppm)					
Replication	2	16.093	8.0467		
Treatment	6	128.750	21.4583	1074.11	0.0000
Error	12	0.240	0.0200		
Total	20	145.083			

Appendix VI. Some photos document during experiment