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# INFLUENCE OF NITROGEN SOURCES AND RATES ON YIELD AND NITROGEN USE EFFICIENCY OF TOMATO

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## Abstract

A study was carried out with tomato at the research field of Regional Agricultural Research Station of BARI, Cumilla during two consecutive years 2019-20 and 2020-21. The objective was to evaluate the yield response and nitrogen use efficiency (NUE) of tomato (variety BARI Tomato-15) and to suggest the source and the rate of N fertilizer recommendation for tomato. The experiment was laid out in a RCBD design with three N sources (PU, NCU and DAP) and two N rates (100% and 125% of recommendation as per FRG-2018) replicated three times. In the first year, prilled urea (PU), neem coated urea (NCU) and DAP were used but in the second year DAP was replaced by urea super granule (USG). The recommended dose of N for tomato was 120 kg $ha^{-1}$. Results revealed that between two rates of N application the yield was the maximum (77.4 t $ha^{-1}$ and 60.3 t $ha^{-1}$ in two years, respectively with 125% of RD. The highest agronomic use efficiency of nitrogen ($N_{AUE}$) was obtained from 100% RD of N as DAP (150.0 kg $kg^{-1}$) and 125% RD of N as NCU (133.3 kg $kg^{-1}$). The lowest N use efficiency was observed in 100% PU (84.2 kg $kg^{-1}$) and 100% NCU (40.8 kg $kg^{-1}$) treated plots. Due to optimal plant growth, the neem-coated urea treatment yielded little higher than PU treatment.

**Keywords:** Cowdung, DAP, DMRT, Neem coated urea, USG

## Introduction

Tomato (*Lycopersicon esculentum* Mill) is a vitamin (A, B & C) and mineral-rich vegetable crop (Olaniyi and Ajibola, 2008). It belongs to the family Solanaceae, sub family *Solanoideae* and can be grown thoughout the year. It is widely cultivated in tropical, subtropical and temperate climates and ranks second next to potato in terms of world vegetable production with a total production of 186 million metric tons which were harvested from 5.05 million hectares of land (FAOSTAT, 2020). In Bangladesh, the total area and production of tomato was about 29 thousand hactares and 4.15 lac metric tons, respectively (BBS, 2020).

Nitrogen is an essential macro nutrient element for the growth and development of plants because of its role in cell division and expansion. Nitrogen plays a major role in crop production. A non-judicial methods and sources can lead to reduced plant quality,

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economic loss and environmental pollution (Liu *et al*., 2014). Most farmers incorrectly apply excessive amounts of fertilizers as insurance against yield losses without being aware of the cost and environmental consequences (Umar *et al*., 2007). When inorganic fertilizers are applied to soils, N is rapidly released and absorbed by plants. In contrast to inorganic fertilizers, however, organic fertilizers have better efficiency of nutrient use since the nutrients they contain are delivered gradually over a longer period of time. The rate of mineralization in organic fertilizer is affected by several factors including soil properties, temperature, available water, and type of organic fertilizer (Nardi *et al*., 2018). Akanbi *et al*. (2003) reported that N fertilizer influences leaf number per plant, plant height, fruit number per plant, fruit mean weight, and total yield per plant in tomato crops.

To improve fertilizer use efficiency judicious application of different forms of N like prilled urea (PU), urea super granule (USG) and organic N sources is important. In Bangladesh, prilled urea is mostly used as nitrogenous fertilizer and farmers are widely applying it to vegetable crops. Organic manure is a valuable fertilizer for integrated nutrient management systems. Organic manure not only supplies plant nutrients but also improves physical and microbial properties of the soil. Vermicompost is an important high valued organic manure that can contribute to plants and soil. Various studies have been done on the use of nitrogenous fertilizer but, less attention has been given to NUE-based INM for tomato cultivation. Tomato is very responsive to nitrogenous fertilizers and a significant amount of supplemental N is required to maximize fruit yields. Considering all of these issues, a study was undertaken to know the yield response and NUE of tomato (variety BARI tomato-15) and to recommend the N rate and source for tomato in the Cumilla region (AEZ 16).

## Materials and Methods

### Experimental site and soil

The experiment was conducted at the research field of Regional Agricultural Research Station, BARI, Cumilla for two consecutive years 2019-20 and 2020-21. The experimental site is located at 23°28' 14.3" North latitude 91°09'20.5" East longitude with an elevation of 12 meters (39.4 ft) above sea level. This location belongs to AEZ-16 (Middle Meghna River Floodplain) having non-calcareous grey floodplain soil. The top soils are strongly acidic and sub-soils are slightly acidic to slightly alkaline. The general fertility level was medium with low N and organic matter content. The annual temperature of the area is 25.5 °C and about 2,295 mm of precipitation falls annually. The soil of the experimental field contained 6.1 pH, 1.1% organic matter, 0.19 cmol $kg^{-1}$ K, 15 mg $kg^{-1}$ P & also S, 0.19 mg $kg^{-1}$ Zn and 0.2 mg $kg^{-1}$ B.

### Treatments and design

The experiment was laid out in a randomized complete block design (RCBD) with 7 treatments replicated 3 times. In the first year, the treatments were $T_0$: Native fertility, $T_1$: 100% Recommended dose (RD) of N as prilled urea (PU), $T_2$: 100% RD of N as neem coated urea (NCU), $T_3$: 100% RD of N as di-ammonium phosphate (DAP), $T_4$: 125% RD of N as PU, $T_5$: 125% RD of N as NCU, and $T_6$: 125% RD of N as DAP. But in the second year, USG was used instead of DAP. Excess amount of phosphorus supplied from DAP treatment was adjusted by TSP for PU and NCU treatments. Each plot was 5.2m in length and 1.2m in width. The spacing between the blocks and plots was 1m and 0.5m, respectively. Two rows per plot were used with 60cm and 40cm between the row and plant, respectively was used. Each row had 13 plants making a total of 26 per plot. Except for DAP, which had 20% N, all other sources had 46% N. The three sources varied in physical forms even though their nitrogen contents were identical. The NCU was prilled urea covered with neem oil extract. Before final land preparation, decomposed cowdung @ 5 t/ha was used as a blanket dosage. The recommended doses of P, K, S, Zn, and B were applied at 30, 40, 15, 2, and 1 kg $ha^{-1}$ in the forms of TSP, MoP, gypsum, chelated zinc and solubor, respectively, based on the FRG 2018.

## Crop management

Decomposed cowdung and all the chemical fertilizers except nitrogenous fertilizer were applied as a blanket dose following Fertilizer Recommendation Guide-2018. BARI tomato-15, a high-yielding tomato variety was used as a test crop. The seeds were sown on 25 October, 2019 and 11 November, 2020. Twenty-five days old seedlings were transplanted in the main plot on 19 November, 2019 and 05 December 2020 when the seedlings were 10-15 cm in height. Every seedling was irrigated individually after transplanting and continued upto 5 days until the establishment of the root in soil. Three splits of nitrogenous fertilizers were applied in equal splits as per treatment at 15, 30, and 45 days after transplanting. Gap filling, plant protection, irrigation, and other intercultural operations were done as and when necessary.

## Data collection and analysis

Data on the yield and yield attributing parameters were recorded. Five representative plants from 2 rows of each plot were randomly taken and tagged for data collection. Data on 50% flowering, plant height, number of fruits/plants, the weight of fruit/plant, individual fruit weight, yield/plant, and fruit yield per hectare were collected. The date of 50% flowering was 19 December, 2019 and 30 December 2020. The data were subjected to “STATISTIX 10” software, a statistical tool for analysis of variance (ANOVA) and and Duncan’s multiple range test (DMRT) (Gomez and Gomez, 1984) was used to assess significant differences between the means.

## Calculation of nitrogen use efficiency (NUE)

The N use efficiency (NUE) was estimated in terms of relative agronomic efficiency of N ($AE_N$). The $AE_N$ refers to the increase in grain yield from addition of nitrogen, expressed as kg grain increase $kg^{-1}$ N applied (modified after Dobermann, 2005):

$$AE_N = (GY_{NA} - GY_{NC})/N_{RN}$$

where $GY_{NA}$ represents grain yield (kg $ha^{-1}$) obtained from N addition, $GY_{NC}$ represents grain yield (kg $ha^{-1}$) from N control ($N_0$) and $N_{RN}$ indicates rate of N added.

## Results and Discussion

### Growth and yield contributing characters

The effect of N-sources with doses on plant height are presented in Tables 1 and 2. In the first year, the results showed that N amount supplied from different N-sources had a significant effect on the plant height of tomato at the final harvest. The tallest plant (119.0 cm) was observed with $T_6$ treatment (125% RD of N as DAP) while the shortest plant (90.7 cm) was noted in $T_0$ treatment (N-control). But in the second year, the tallest plant (109.07 cm) was observed with $T_5$ treatment (125% RD of N as NCU) while the shortest plant (95.53 cm) was noted in $T_0$ treatment (N-control). Plant height increased with an increasing amount of N from native fertility to 125% of RD of N (Table 1). Barraclough *et al*. (2014) defined that plant height is highly influenced by 'N-rate' followed by 'growth stage' and then 'genotype'. However, the fruit number per plant varied from 47.6 to 68.3, while the maximum number of fruits per plant (68.3) was counted in the $T_6$ treatment (125% RD of N as DAP) which was statistically identical to the $T_4$ (125% RD of N as PU) and $T_5$ (125% RD of N as NCU) treatments and the lowest number of fruit/plant (47.6) was counted in $T_0$ (N-control). In the case of average fruit weight, the heaviest fruit (93.3 g) was harvested from the $T_6$ treatment (125% RD of N as DAP) which was statistically par with $T_2$ (100% RD of N as NCU), $T_3$ (100% RD of N as DAP), $T_4$, (125% RD of N as PU) and $T_5$ (125% RD of N as NCU) treatments, and the lightest average fruit weight (78.3 g) was noted in $T_0$ treatment (N-control).

**Table 1.** Yield and yield complements of tomato as influenced by different nitrogen sources and rates in 2019-20

| Treatments | Plant height at final harvest (cm) | No. of fruits/ plant | Fruit wt./plant (kg) | Average fruit wt. (g) | Fruit yield (t/ha) |
|---|---|---|---|---|---|
| $T_0$: N-control | 90.7 e | 47.6 d | 1.77 e | 78.3 c | 55.2 c |
| $T_1$: 100% RD of N as PU | 94.0 de | 57.3 c | 2.26 d | 84.7bc | 65.3bc |
| $T_2$: 100% RD of N as NCU | 95.7cde | 57.0 c | 2.61 c | 86.0 ab | 68.9 ab |
| $T_3$: 100% RD of N as DAP | 103.0bc | 62.3bc | 2.70 c | 87.7 ab | 73.2 ab |
| $T_4$: 125% RD of N as PU | 101.6bcd | 65.6 ab | 2.84bc | 88.7 ab | 74.3 ab |
| $T_5$: 125% RD of N as NCU | 110.0 b | 67.3 ab | 2.97 b | 92.0 ab | 74.6 ab |
| $T_6$: 125% RD of N as DAP | 119.0 a | 68.3 ab | 3.35 a | 93.3 a | 77.4 a |
| F-Test | ** | ** | ** | ** | ** |
| CV (%) | 4.73 | 5.40 | 5.58 | 4.80 | 8.99 |

** $P<0.01$

In a column for each character, the mean values followed by the same letter are not significantly different at the 0.05 level of probability by DMRT.

The fruit yield per plant and per plot revealed that the treatment $T_6$ (125% RD of N as NCU) produced the highest yield (3.35 kg and 53.7 kg) whereas the lowest yield (1.77 kg and 38.4 kg) was obtained from treatment $T_0$ (N-control). However, the yield per hectare ranged from 55.2 to 77.4 ton. The maximum average per hectare yield (77.4 t/ha) was recorded in $T_6$ (125% RD of N as NCU) treatment which was statistically similar to the $T_2$ (100% RD of N as USG), $T_3$ (100% RD of N as NCU), $T_4$ (125% RD of N as PU) and $T_5$ (125% RD of N as USG) treatments while the minimum yield (55.2 t/ha) was noted in $T_0$ (N-control) treatment. Fageria and Carvalho (2014) stated that yield of crop is affected by N rate applied to it. Another study by Bufogle *et al*. (1997) reported that the response of crop to ammonium sulfate and urea depends on soil or climatic conditions.

**Table 2.** Yield and yield complements of tomato as influenced by different nitrogen sources and rates in 2020-21

| Treatments | Plant height at final harvest (cm) | No. of fruits/ plant | Fruit wt./ plant (kg) | Average fruit wt. (g) | Fruit yield (t/ha) |
|---|---|---|---|---|---|
| $T_0$: N-control | 95.5 c | 44.2 d | 1.87 c | 87.0 d | 40.3 d |
| $T_1$: 100% RD of N as PU | 101.0 bc | 59.4 b | 2.30 b | 99.0 abc | 48.4 bcd |
| $T_2$: 100% RD of N as USG | 105.7 ab | 51.4 bcd | 2.07 bc | 95.3 bc | 46.9 cd |
| $T_3$: 100% RD of N as NCU | 105.2 ab | 51.9 bcd | 2.04 bc | 93.0 cd | 45.2 cd |
| $T_4$: 125% RD of N as PU | 107.1 ab | 50.8 cd | 2.23 b | 100.7 abc | 54.9 abc |
| $T_5$: 125% RD of N as USG | 109.07 a | 70.0 a | 3.08 a | 104.3 a | 58.6 ab |
| $T_6$: 125% RD of N as NCU | 109.0 a | 54.7 bc | 2.19 b | 102.8 ab | 60.3 a |
| CV (%) | 4.18 | 8.56 | 7.18 | 4.62 | 12.3 |
| F-Test | * | ** | ** | ** | * |

*, $P<0.05$; **, $P<0.01$. In a column for each character, the mean values followed by the same letter are not significantly different at the 0.05 level of probability by DMRT.

In 2020-21, the fruit number per plant varied from 44.2 to 70.0, while the maximum number of fruits per plant (70.0) was counted in the $T_5$ treatment (125% RD of N as USG) which was statistically significant compared to other treatments (Table 2). Average fruit weight showed a similar trend in the second year. The fruit yield per plot revealed that treatment $T_6$ (125% RD of N as NCU) produced the highest yield (37.63 kg) whereas the lowest yield (25.16 kg) was obtained from $T_0$ treatment (N-control). The maximum average per hectare yield (60.3 t/ha) was recorded in the $T_6$ treatment (125% RD of N as NCU) which is statistically similar to the $T_4$ (125% RD of N as PU) and $T_5$ (125% RD of N as USG ) treatments while the minimum yield (40.3 t/ha) was noted in the $T_0$ treatment (N-control). Treatments $T_4$ (125% RD of N as PU), $T_5$ (125% RD of N as USG), and $T_6$ (125% RD of N as NCU) resulted in 34.6-36.2%, 35.1-45.4% and 40.2-49.6% increased yield over control in two years, respectively (Fig. 1).

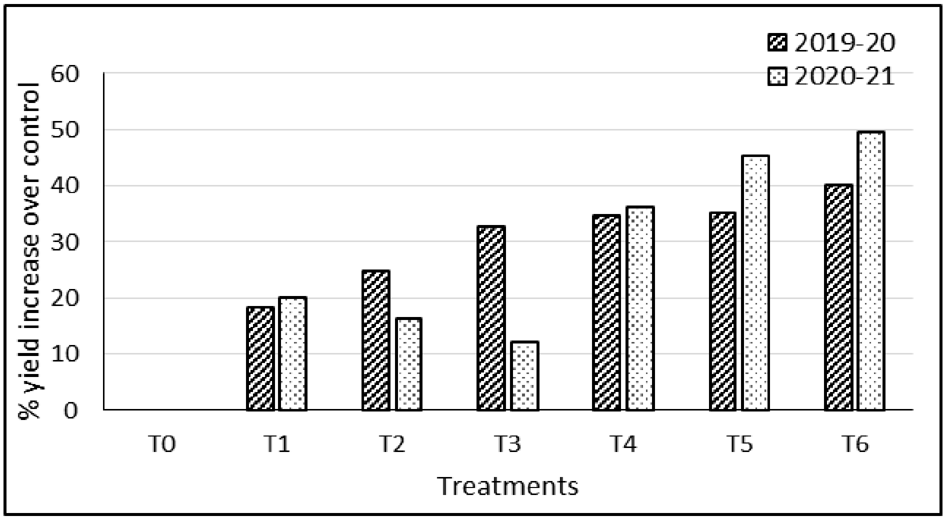


**Fig. 1**: Increase in percent yield of tomato over control as influenced by the application of PU, NCU, and DAP

## Agronomic use efficiency of nitrogen

Agronomic use efficiency of nitrogen ($N_{AUE}$) refers to the increase in fruit yield of tomato per kg of nitrogen applied (Tables 3 and 4).

**Table 3.** Agronomic use efficiency ($N_{AUE}$) of different forms of nitrogen in 2019-20

| Treatments | Quantity of N applied | Increase in Nitrogen over N-control ($T_0$ treatment) | Quantity of fruit yield obtained | Increase in fruit yield over N control ($T_0$ treatment) | Agronomic use efficiency of N ($N_{AUE}$) |
|---|---|---|---|---|---|
| | | | (kg ha$^{-1}$) | | (kg kg$^{-1}$) |
| $T_0$: N-control | 0 | - | 55200 | - | - |
| $T_1$: 100% RD of N as PU | 120 | 120 | 65300 | 10100 | 84.2 |
| $T_2$: 100% RD of N as NCU | 120 | 120 | 68900 | 13700 | 114.2 |
| $T_3$: 100% RD of N as DAP | 120 | 120 | 73200 | 18000 | 150.0 |
| $T_4$: 125% RD of N as PU | 150 | 150 | 74300 | 19100 | 127.3 |
| $T_5$: 125% RD of N as NCU | 150 | 150 | 74600 | 19400 | 129.3 |
| $T_6$: 125% RD of N as DAP | 150 | 150 | 77400 | 22200 | 148.0 |

Table 3 presents the agronomic use efficiency of different forms of nitrogen ($N_{AUE}$) in 2019-20 ranging from 84.2 to 150.0 kg kg$^{-1}$. The highest $N_{AUE}$ (150.0 kg kg$^{-1}$) was obtained from 100% RD of N as DAP treated plot ($T_3$ treatment). Among the three sources, $N_{AUE}$ was the highest in DAP treated plot followed by the neem coated urea (NCU) treated plot. The lowest agronomic use efficiency ($N_{AUE}$) was obtained from the prilled urea (PU) treated plot ($T_1$ treatment, $N_{AUE}$ = 84.2 kg $kg^{-1}$). This might be because photosynthesis has an impact on tomato NUE in the end. Dilip and Bao-LuoMa (2016) reported that the NUE of crops has been significantly affected by the effects of N sources on the photosynthetic pigments in leaves. Higher nitrogen use efficiency (NUE) in corn is significantly influenced by the source of fertilizer N (Freeman *et al.*, 2007, Bushong *et al.*, 2014).

**Table 4.** Agronomic use efficiency ($N_{AUE}$) of different forms of nitrogen in 2020-21

| Treatments | Quantity of nitrogen applied | Increase nitrogen over N-control ($T_0$ treatment) | Quantity of fruit yield obtained | Increase fruit yield over N control ($T_0$ treatment) | Agronomic use efficiency of nitrogen ($N_{AUE}$) |
|---|---|---|---|---|---|
| | (kg $ha^{-1}$) | | | | (kg $kg^{-1}$) |
| $T_0$: N-control | 0 | - | 40300 | - | - |
| $T_1$: 100% RD of N as PU | 120 | 120 | 48400 | 8100 | 67.5 |
| $T_2$: 100% RD of N as USG | 120 | 120 | 46900 | 6600 | 55.0 |
| $T_3$: 100% RD of N as NCU | 120 | 120 | 45200 | 4900 | 40.8 |
| $T_4$: 125% RD of N as PU | 150 | 150 | 54900 | 14600 | 97.3 |
| $T_5$: 125% RD of N as USG | 150 | 150 | 58600 | 18300 | 122.0 |
| $T_6$: 125% RD of N as NCU | 150 | 150 | 60300 | 20000 | 133.3 |

On the other hand, in 2020-21 the agronomic use efficiency of different forms of nitrogen ($N_{AUE}$) ranged from 40.8 to 133.3 kg $kg^{-1}$ (Table 4). The highest $N_{AUE}$ (133.3 kg $kg^{-1}$) was obtained from 125% RD of N as NCU treated plot ($T_6$ treatment). Among the three sources, $N_{AUE}$ was the highest in the 125% NCU treated plot followed by the 125% urea super granule (USG) treated plot. The lowest agronomic use efficiency of nitrogen ($N_{AUE}$) was obtained from a 100% neem-coated urea (NCU) treated plot ($T_3$ treatment, $N_{AUE}$ = 40.8 kg $kg^{-1}$). This may be due to more availability of nitrogen. Because when plants receive more nitrogen than they need, they can take up and utilize the excess nitrogen more efficiently, resulting in higher nitrogen use efficiency. Beatty *et al.*, (2010) stated that the NUE of barley grown in a field depends on the varied amount of N applied. On the other hand, neem-coated urea reduces nitrogen loss through slow release and nitrification inhibition characteristics and enhances nitrogen availability resulting positive growth effect in plants. Rehman *et al.*, (2021) reported that neem-coated urea significantly improved, AUE, N uptake efficiency (NUptE), NUE, and N productive efficiency (NPE) compared to the normal urea.

## Conclusion

Considering the yield, nitrogen fertilizer supplied from neem-coated urea performed better compared to other nitrogen sources. Performance of the 125% recommended dose of N was superior to 100% of RD of N. The highest chemical nitrogen dose gave the most significant yield advantage for tomato. The treatments using 125% NCU and 100% RD of N as DAP showing the higher agronomic use efficiency of nitrogen ($N_{AUE}$). The neem-coated urea treatment yielded higher potential than the prilled urea due to higher plant growth.

## Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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