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RESEARCH ARTICLE

DIFFERENT SOURCES NITROGEN BASED FERTILIZERS ON GROWTH, YIELD AND NUTRITIONAL QUALITY OF TOMATO (*Lycopersicon esculentum* MILL.)

M. Asib Biswas[a], M. Ashraful Islam[a]*, I. Mosaddek Ahmed[b], M. Mokter Hossain[a], M. Abdul Halim[c]

[a] Department of Horticulture, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.
[b] Plant Physiology Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur 1701, Bangladesh.
[c] Department of Genetic and Plant Breeding, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.
**Corresponding Author Email: ashrafulmi@bau.edu.bd*

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ABSTRACT

Integration of inorganic and organic fertilizer is a very important tool for sustainable production of tomatoes contributing to human health. There were six treatments followed the design of RCBD with three replications to observe the growth, yield and the nutritional quality like lycopene and β-carotene of tomato. Treatments were; F_1: Control, F_2: Pond sediments-100%, F_3:50%F_2+50%F_6, F_4:50% F_2+50%F_5, F_5: soil test based (STB) nitrogen as urea, and F_6: vermicompost-100%. Statistically significant variations were found for the plant growth and yield. The highest growth and yield performances were found from the treatment F_4. Fruit clusters, fruit numbers and fruit weight per plant were found highest in the treatment F_4, whereas the lowest was found in the control. The highest marketable yield of tomato (96.17 t/ha) was obtained from the treatment F_4 which was 20%, 29%, 13%, and 41% higher compared to F_5, F_2, F_6, and F_1 treatments, respectively. The highest amount of lycopene (67.31 ppm) and β-carotene (53.52 ppm) were found from F_4 and F_6, respectively, whereas the lowest amount was 42.59 ppm lycopene and 13.85 ppm β-carotene from F_5 and F_1, respectively. Inorganic and organic fertilizer like pond sediments can be applied for the sustainable production of tomato with friendly environment.

KEYWORDS

Tomato, pond sediments, vermicompost, lycopene, β-carotene.

1. INTRODUCTION

Fertilizer management is one of the most important factors which assures crop production. Nitrogen (N) is one of the main sources of nutrients for plant growth and it is utilized for crops in large amounts to get higher yields. Often, chemical fertilizers of N sources are used in excess amounts and as a consequence, soil and water are subject to heavy pollution. Waterway pollution, chemical burn to crops, increased air pollution, acidification of the soil and mineral depletion of the soil are the adverse effects of chemical fertilizers (Kumar and Prakash, 2019). It has been documented that N supply is positively correlated to fruit yield but overuse application did not increase the crop yield (Le Bot et al., 2001). Biofertilizers are enriched with micronutrients and beneficial microbes to improve the soil structure, aid aeration and release nutrients slowly, and support root development leading to higher growth, yield and quality of crops (Ansari et al., 2016). Tool of sustainable production technology in different vegetables like tomatoes, cabbage, Indian spinach, carrots and okra where fertilizers with 75% less chemicals integrated with vermicompost have been reported to achieve higher yield (Islam et al., 2017ab; Akther et al., 2019; Farjana et al., 2019; Afrin et al., 2019). Vermicompost as organic fertilizers contains humic acids that contribute to plant growth and yield. On the other hand, fish feed and fertilization in fish ponds result in the accumulation of organic matter, as pond sediments are a good source of organic matter to improve the soil health as well as for the crop growth and yield (Ihejirika et al., 2012; Islam et al., 2020; Li and Yakupitiyage, 2003; Rahman et al., 2004). The higher content of organic matter can improve the soil health and increase the crop yield (20-25%) when compared to the control; ultimately the use of pond sediments can reduce eutrophication and fertilizer use to better the environment (Islam et al., 2020).

Lately, more attention is now focused on promoting the health benefits through consuming fruits and vegetables because they contain different antioxidant molecules like carotenoids, phenolics compounds, and ascorbate. The food value of tomatoes (*Lycopersicon esculentum* Mill.) is very high due to its rich source of lycopene, minerals, and vitamins such as ascorbic acid and $\beta\beta$-carotene, which contributes to human health for cancer prevention, eye protection and immunity system strengthening (Field et al., 2002; Friedman et al., 2009; WHO, 1996; Zhang et al., 2016). Additionally, tomatoes are one of the most important nutritious vegetables in the world. In Bangladesh, yearly tomato yield is producing 385 thousand MT from the 28 thousands hectare land, but there is still a gap in production to fulfil the national demand (BBS,2018).

The growth, yield and quality of tomatoes can be increased significantly through the judicious application of different organic manures, chemical fertilizers, or by the combination of organic and inorganic fertilizers, which supply required macro and micronutrients to prevent nutritional diseases. Very few studies are available to find out the correlation of nitrogen fertilizer on tomato fruit and antioxidant content (Dumas et al., 2003; Colla et al., 2003). Tomato leaf polyphenolic compounds have been shown to increase in response to low nitrogen supply, but no significant variations were observed in tomato fruit (Stewart et al., 2001; Wilkens et al., 1996; Stout et al., 1998). Our novel study explores the effect of pond

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sediments, vermicompost, and other inorganic fertilizers containing N on the growth, yield, and nutrition quality, including lycopene and β-carotene of tomato fruits.

2. MATERIALS AND METHODS

2.1 Experimental site and soil characteristics

The field experiment was conducted at the farmers' pond dyke area of Fakirakanda village, Mymensingh sadar upazila in Fall 2018 to Spring 2019 (Figure 1). Meteorological data of the experimental time are presented in the Figure 2. The field experiment was carried out on a medium high land, which is belongs to Old Brahmaputra Flood plain Alluvial Tract of Agro-ecological zone 9 (AEZ-9) at about 24°71' and 24°42' N latitude and 90°42 ' and 90°25'E longitude (UNDP, 1998). Soil samples of the experimental plots were collected from a depth of 0 to 15 cm. The soil texture of our experimental plot was silty-loam with a 6.7 p^H and total N was 0.07%, which categorizes as low. We applied urea, vermicompost (0.51% N), pond sediments (0.08% N) in order to improve the soil nitrogen status of the experimental plot following the Fertilizer Recommendation Guide in Table 1 (FRG, 2018). In addition to inorganic fertilizers, vermicompost was used to consider the soil health and environment; as well as pond sediments (decomposed fish feed), which have the potential to be reused as organic sources of fertilizers for crop production. Laboratory work was conducted at the laboratory of Horticulture Department, Bangladesh Agricultural University and Horticulture Division of Bangladesh Agricultural Research Institute.

Figure 1: Map of Bangladesh showing the study area in Mymensingh Sadar Upazila of Mymensingh district, and embedded Google Earth image showing the locations of pond dyke area of Fakirakanda village; GPS collection of experimental plot: 24°42'29.40"N 90°25'19.07"E. Scale applicable to map of Bangladesh only.

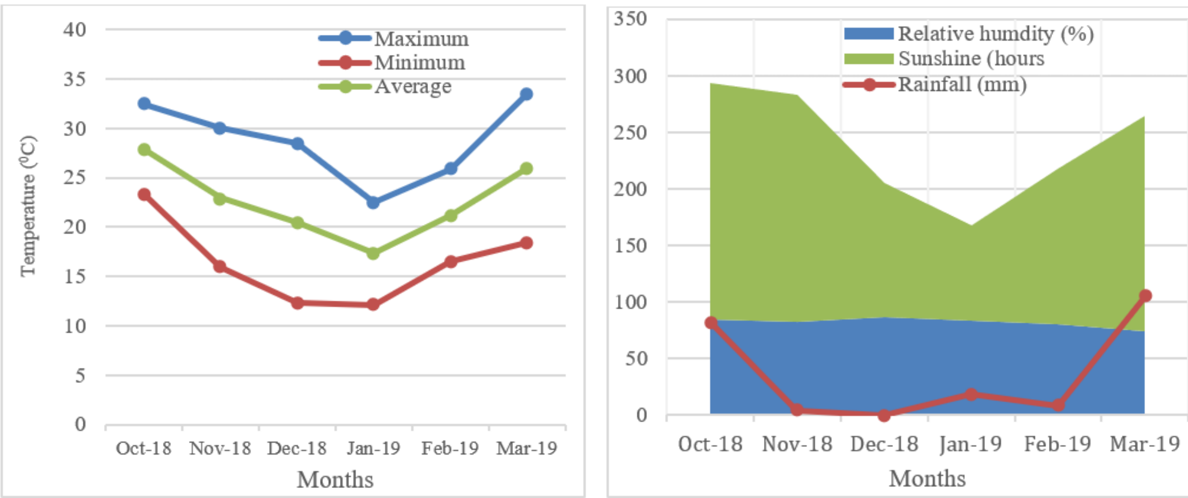

Figure 2: Meteorological data of the Sadar upazila under Mymensingh district of experimental time; temperature data (left side) and relative humidity (%), rainfall (mm) and sunshine (hours) in the right side. Source: Weather yard, Department of Irrigation and Water Management, Records of Climatologically observation, Bangladesh Agricultural University, Mymensingh

Table 1: Treatments of the experiment

Treatments		**Fertilizer dose/ha**
F_1	Control	No manures and fertilizers
F_2	Pond sediments (PS): 100%	PS: 40 t
F_3	50% PS + 50% Vermicompost (VC)	PS: 20 t + VC: 10 t
F_4	50% PS + 50% Urea	PS: 20 t + Urea: 147.22 kg
F_5	STB (soil test based) N as Urea	Urea: 294.44 kg
F_6	VC: 100%	VC: 20 t

2.2 Plant materials

The tomato cultivar used in the experiment was Roma VF. This is a high yielding determinate type of tomato variety. Tomato seedlings were raised in one 3m x 1m seedbed at the Horticulture farm of Bangladesh Agricultural University (BAU), Mymensingh. Weeding, mulching, and watering in the seedbed were done as needed. Seedlings germinated within a week and were transplanted (30 d) into the field. Plant spacing was kept at 60 cm× 60 cm in the field plots (3.2 m × 1.2 m) with 80 cm distance between the blocks and 40 cm between the unit plots.

2.3 Treatments details and fertilizers application

The single factorial treatment has six treatments mentioned in Table 1. This experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. In total, there were 18-unit plots. The soil analysis interpretation was low. According to FRG, inorganic fertilizer doses are: N=135 kg/ha, P= 38kg/ha, K=60kg/ha, S=13kg/ha (FRG, 2018). Considering the soil status of N, the full dose of N (urea: 294.44 kg/ha), vermicompost (20 t/ha) and pond sediments (40 t/ha) was used. In all the plots, PKS were applied equally except in the control plot. Vermicompost, ponds sediments, TSP and Gypsum fertilizers were applied during final land preparation. Nitrogen and potassium were applied in two equal splits at 15 and 35 days after transplanting (DAT).

2.4 Intercultural operations

The research plot was irrigated using a watering can after fertilizer application. Staking was done with bamboo sticks to support the tomato plants and weeding was done accordingly when necessary. Furadan 5G was applied to the soil during the final land preparation to suppress soil borne pathogens. Malathion 57 EC (2 ml L^{-1}) was sprayed fortnightly to control insect pests like cutworms, leafhoppers and fruit borers. Additionally, Dithane M-45 (2 g L^{-1}) was sprayed during the vegetative stage and Ridomil (2 g L^{-1}) at a later stage to control late blight disease of the tomatoes.

2.5 Data collection

2.5.1 Plant growth and yield data of tomato

Six plants were selected randomly from each unit plot (considered as one replication) for data collection. Plant height data at 0, 15, 30, 45 and 60 days after transplanting (DAT) were measured in cm. Additionally, growth and yield parameters like no. of fruits per cluster, fruit length (cm), fruit diameter (cm), individual weight of fruits (g), and fruit weight per plant and plot (kg) were recorded, which was converted into ton perha.

2.5.2 Nutritional analysis of tomato

Lycopene in the tomato samples was extracted by a hexane–acetone–ethanol (2:1:1, v: v: v) mixture following the methods (Beerh and Siddappa, 1959; Fish et al., 2002). The absorbance of the hexane solution containing lycopene was then estimated at 503 nm on a spectrophotometer (T 60 UV-VIS, UK) using hexane as a blank and the sample weight. Pigments were extracted with acetone and petroleum ether, and the β-carotene was estimated from the absorbance measurement at 451 nm with a spectrophotometer (T 60 UV-VIS, UK), according to the method (Lime et al., 1957).

2.6 Statistical analysis

Effects of treatments on growth and yield data as well as the nutrient content data were analyzed by analysis of variance (General Linear Model procedure) and Tukey's pairwise comparison test by Duncan's Multiple Range Test (DMRT) at 5% level of probability using Minitab Version 17 (Minitab Inc., State College, PA, USA).

3. Results and Discussion

3.1 Influence of different nitrogen sources on growth and yield of tomato

observed up to 60 DAT as no growth was observed after flowering and fruiting initiation. The maximum plant height was 84.53 cm at 60 DAT in the plants grown under the treatment F_6 (20 t vermicompost/ha) and the lowest plant height was 62.36 cm at 60 DAT under the treatment F_1 (control). Plant height was measured at 60 DAT and there was no significant difference ($p =< 5\%$) found among the F_3, F_4 and F_5 treatments, which is logical considering that equal amounts of nutrients were provided through different sources, including pond sediments, vermicompost, and urea, as well as the rest of the phosphorous (P), potassium (K) and sulphur (S) sources fertilizers were provided in the same amount to all the plots.

Table 2: Effect of treatments on plant height of tomato at different days after transplanting (DAT)

Treatments	Plant height (cm) at different days after transplanting (DAT)				
	0 DAT	15 DAT	30 DAT	45 DAT	60 DAT
F_1	7.13±0.13a	9.53±0.39c	20.79±1.25d	36.25±1.18b	62.36±1.99c
F_2	5.98±0.25a	10.26±0.39bc	24.37±1.23abc	45.03±2.61a	82.22±8.26a
F_3	7.90±0.69a	10.82±0.55ab	21.74±0.75cd	36.33±1.54b	66.39±3.35bc
F_4	7.00±0.25a	10.46±0.72bc	27.08±1.35a	46.20±3.25a	78.93±2.68ab
F_5	7.79±0.44a	11.57±0.06a	22.05±0.56bcd	39.47±3.51b	77.83±5.56ab
F_6	7.62±0.45a	10.91±0.46ab	24.82±2.65ab	45.65±5.29a	84.53±8.7a

Mean ± SE (standard error) followed by non-similar letters are significantly different at p<0.05 according to Tukey's test. *F_1: Control, F_2: Pond sediments- 100%, F_3: 50% F_2 + 50% F_6, F_4 : 50% F_2+50% F_5, F_5: STB nitrogen as urea, F_6: Vermicompost- 100%*

Considering the fruit yield parameters, the number of the fruit clusters per plant was found to be statistically significant ($p<0.05$). Table 3 shows that the maximum number of fruit clusters per plant (12.56) was observed in F_4 (50% F_2+ 50% F_5) and the minimum number of fruit clusters per plant (7.78) was found in F_1 (control). Pond sediments contain macro and micro nutrients, including the addition of urea, which can be promoted to increase the number of fruit clusters per plant in this experiment (Haque et al., 2016). Also, a group researchers found the highest number of tomato fruits in the integrated treatment of vermicompost and inorganic fertilizers in comparison to the sole application of inorganic or organic fertilizers (Islam et al., 2017b). Figure 3 shows that the number of fruits per plant showed distinct variation in response to different treatments and the variation was statistically significant.

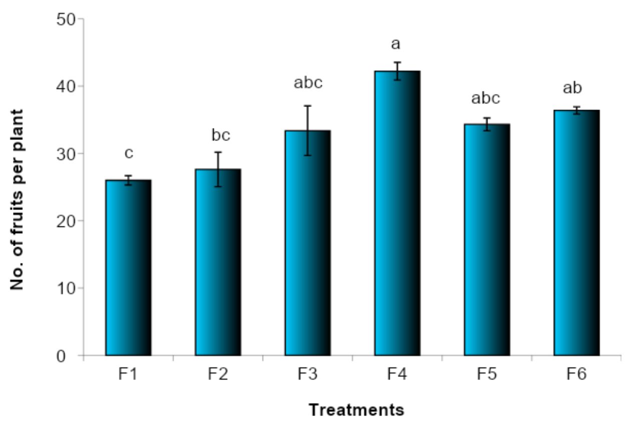

Figure 3: Effect of different sources of nitrogenous fertilizers on number of fruits per plant. Vertical bars represent the ± SE (Standard Errors). Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. *F_1: Control, F_2: Pond sediments- 100%, F_3: 50% F_2 + 50% F_6, F_4 : 50% F_2+50% F_5, F_5: STB nitrogen as urea, F_6: Vermicompost- 100%*

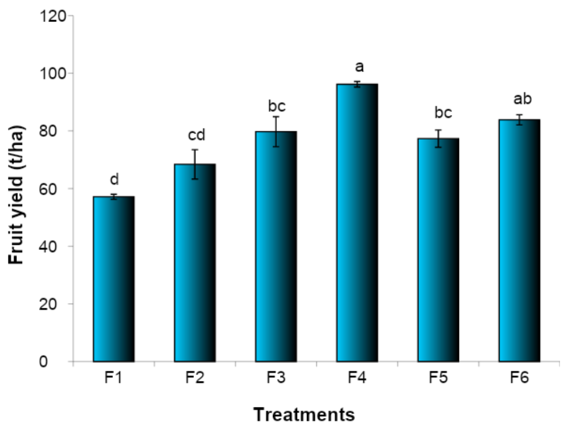

Figure 4: Effect of different sources of nitrogenous fertilizers on fruit yield of tomato. Vertical bars represent the ± SE (Standard Errors). Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. *F_1: Control, F_2: Pond sediments- 100%, F_3: 50% F_2 + 50% F_6, F_4 : 50% F_2+50% F_5 , F_5: STB nitrogen as urea, F_6: Vermicompost- 100%*

Table 3: Effect of treatments on yield and yield contributing characters of tomato

Treatments	No. of fruit clusters per plant	Fruit length (cm)	Fruit diameter (cm)	Individual weight of fruit (gm)	Weight of fruits per plant (kg)	Weight of fruits per plot (kg)
F_1	7.78 ± 0.22b	5.97 ± 0.06b	5.47 ± 0.05bc	97.42 ± 6.27b	2.06 ± 0.03d	20.59 ± 0.32c
F_2	8.67 ± 0.88ab	6.31±0.06a	5.59±0.06ab	105.60±5.48a	2.46±0.18cd	24.62±1.83bc
F_3	10.33 ± 1.17ab	5.46±0.03c	5.67 ± 0.07a	95.57 ± 13.92b	2.87 ± 0.19bc	32.04 ± 2.58a
F_4	12.56 ± 0.48a	5.90 ± 0.05b	5.50 ± 0.03bc	95.96 ± 2.16b	3.46 ± 0.03a	34.62 ± 0.345a
F_5	10.56 ± 1.10ab	5.53 ± 0.04c	5.35 ± 0.04c	91.98 ± 13.43b	2.78 ± 0.11bc	27.83 ± 1.08ab
F_6	11.11 ± 0.59ab	5.89 ± 0.09b	5.76 ± 0.08a	103.80 ± 7.40a	3.02 ± 0.07ab	30.18±0.639ab

Mean ± SE (standard error) followed by non-similar letters are significantly different at p<0.05 according to Tukey's test. *F_1: Control, F_2: Pond sediments- 100%, F_3: 50% F_2 + 50% F_6, F_4 : 50% F_2+50% F_5, F_5: STB nitrogen as urea, F_6: Vermicompost- 100%*

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Treatment F_4 showed the maximum number of fruits (42.21) per plant and the minimum number of fruits (26) was observed in F_1 (control). Deficiency of micronutrients in the soil negatively affects the fruit yield, quality and premature fruit dropping. Pond sediments contain different micronutrients which promote better growth, flowering, fruit set, higher yield and quality of horticultural products (Ram and Bose, 2000). Fruit clusters and fruit numbers per plant varied in numbers but no significant variation was found among the F_2, F_3, F_5 and F_6 treatments. The F_4 treatment provided the quick release of nutrients from inorganic sources and slow release of nutrients from pond sediments. A group researcher found that the higher content of organic matter in pond sediments enriched with deposition of wasted feeds and fish excreta gave higher yield of Indian spinach, which was also found in 100% pond sediments in comparison to the control (Islam et al., 2020).However, some researchers did not show any combination of inorganic fertilizers in their study (Islam et al., 2020). Fruit length and diameter of the tomatoes were found to be significantly different. The highest fruit length (6.31 cm) and fruit diameter (5.67 cm) were found in the F_2 and F_3 treatments respectively, whereas the lowest fruit length and diameter 5.53 cm and 5.31 cm were found in the F_3 and F_5 treatments, respectively. The reasons for the different fruit lengths and fruit variations are not known. The individual weight of fruit was found to be significantly higher in the sole application of pond sediments (F_2) and vermicompost (F_6) in comparison to the control and other treatment combinations. Pond sediments and vermicompost are nutrient-rich organic fertilizers containing various essential micronutrients and beneficial soil microbes like nitrogen-fixing bacteria and mycorrhizal fungi, which scientifically proves that miracle growth promoters and protectors can be the reasons of this result (Sinha, 2009).

Table 3 and Figure 4 show that the weight of fruits per plant, weight of fruits per plot, as well as the yield per hectare were found to be significantly different. The highest number of fruits per plant, weight of fruits per plot and yield (t/ha) were found in the F_4 treatment, which was the combination of F_2 (pond sediments) and F_5 (urea). The combination of inorganic fertilizers and pond sediment gave better results, which could be the reason for mixing of quick and slow released fertilizers sources. However, better results were not found in combination of both slow releasing nutrients sources fertilizers like pond sediments and vermicompost (F_3). Several scientists conducted studies on different vegetables like tomato, okra, cabbage and carrot and they reported that the better result of those crop yields was due to the combination of vermicompost and inorganic fertilizers (Islam et al., 2017ab; Farjana et al., 2019; Akhter et al., 2019; Afrin et al., 2019). They explained that vermicompost reduces the amount of inorganic fertilizer for sustainable production, improves the soil health for future crop production, and protects the environment. On the other hand, urea supplies nitrogen and pond sediments while organic fertilizers supply most of the macro and micro nutrients that promote flowering, fruit setting, and prevent fruit dropping, thus increasing fruit yield (Azarmi et al., 2008; Mehdizadeh et al., 2013).

3.2 Influence of different types of fertilizers on nutritional quality of tomato fruit

Tomatoes are an unique source of antioxidants, vitamins, carotenoids (lycopene and β-carotene) and phenolic compounds. In this experiment, we observed the influence of different types of fertilizers on the important nutrients of tomatoes, including lycopene and β-carotene. Figure 5 shows that the lycopene content in the tomatoes was found to be significantly different. The highest amount of lycopene content (67.31 ppm) found was in the treatment F_4 (50% F_2+50% F_5) and the second highest amount was found in the control. However, Figure 6 shows that the highest amount of β-carotene (53.52 ppm) was found in the treatment F_6 (vermicompost) and the lowest was found in the control, but no significant difference found among the treatments of F_2, F_3, F_4, and F_5. With the correlation of growth and yield, we may assume that treatment F_4 provides higher nutrients of both macro and micronutrients resulting in higher growth and yields.

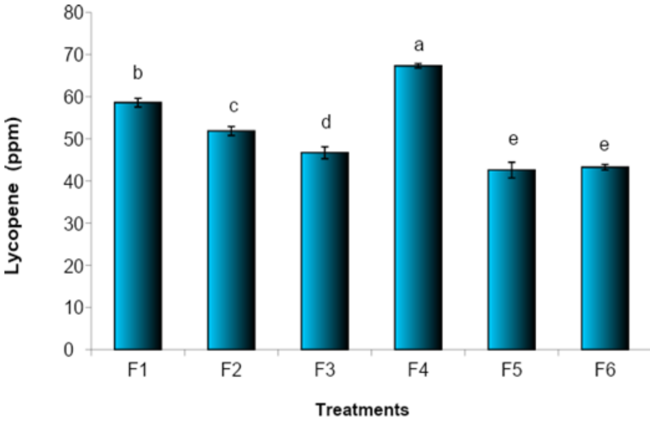

Figure 5: Effect of different sources of nitrogenous fertilizers on lycopene content of tomato. Vertical bars represent the ± SE (Standard Errors). Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. *F_1: Control, F_2: Pond sediments- 100%, F_3: 50% F_2 + 50% F_6, F_4 : 50% F_2+50% F_5, F_5: STB nitrogen as urea, F_6: Vermicompost- 100%*

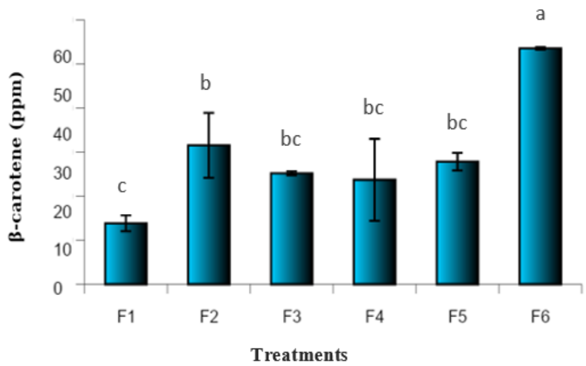

Figure 6: Effect of different sources of nitrogenous fertilizers on β-carotene content of tomato. Vertical bars represent the ± SE (Standard Errors). Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. *F_1: Control, F_2: Pond sediments- 100%, F_3: 50% F_2 + 50% F_6, F_4 : 50% F_2+50% F_5, F_5: STB nitrogen as urea, F_6: Vermicompost- 100%*

The uptake of higher nutrients gives the higher lycopene content but it is unclear about the lycopene content found from other treatments. Similarly, the influence of different types of fertilizers on β-carotene content variation is not clear, although the use of vermicompost is considered a technique capable of increasing the nutritional value of fruits such as tomatoes. Moreover, some researchers reviewed the health value of organic food considering the influence of nutrient management and others on the nutrient content and did not find any consistent results for nutrient content (Miceli et al., 2007; Huber et al., 2011). Similarly, a group researcher analyzed the minerals and vitamins of Indian spinach, which was growing under different ratios of pond sediments, but did not get consistent results (Islam et al., 2020). Overall, a few studies have shown that β-carotene content seems to escalate with increased nitrogen supply. However, the impact of nitrogen supply on lycopene content and antioxidant properties of fruits is more controversial (Dumas et al., 2003; Colla et al., 2003). Additionally, antioxidant properties, lycopene, β-carotene, and phenolic are the most important secondary metabolites that indicate the quality of tomatoes both on the shelf life and in processed products.

4. Conclusions

Soil test based (STB) nitrogen fertilizers were provided from different sources of fertilizers, including pond sediments, vermicompos and urea. This study shows that plants require both macro and micro nutrients for completion of life cycle. Thus, integration of fertilizers like pond sediments and urea as source of N was found to have better growth and yield of tomatoes. The fish pond sediments enriched with uneaten fish feed and wastes can provide different types of macro and micro nutrients and inorganic fertilizer that promote tomato plant growth. Lycopene and β-carotene, both found in tomato fruits, are very important for human health. The highest content of lycopene and β-carotene was recorded from the integration of pond sediments, inorganic fertilizer and vermicompost. The combination of both inorganic and organic fertilizers (pond sediments and/or vermicompost) can be applied for better growth, production and nutritional quality of tomato.

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Author Contributions

Asib Biswas assisted in the field data collection and manuscript preparation, Ashraful Islam designed field experiment, supervised to conduct experiment, data analysis and contributed for manuscript preparation. Mosaddek Ahmed helped to nutritional data analysis, Mokter Hossain reviewed the manuscript preparation, Abdul Halim assisted in manuscript preparation.

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