Archives of Agriculture and Environmental Science 6(4): 469-476 (2021)
https://doi.org/10.26832/24566632.2021.060408

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes

ORIGINAL RESEARCH ARTICLE

Effect of nutrient management on growth and yield of two tomato varieties in Chittagong Hill Tracts (CHTs) region of Bangladesh

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ARTICLE HISTORY

Received: 28 September 2021
Revised received: 26 November 2021
Accepted: 13 December 2021

Keywords

Inorganic fertilizer
Nutrient
Variety
Vermicompost
Tomato

ABSTRACT

The main goal is to investigate the effect of crop nutrient management on growth and yield of two tomato varieties in the Chittagong Hill Tracts (CHTs) region of Bangladesh. Two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Factor A was two varieties of tomato namely, V_1: BARI 2 and V_2: BARI 15. Factor B was different types of fertilizer like F_0 (Farmers practices), F_1 (vermicompost), F_2 (inorganic fertilizer), F_3 (combined fertilizer: 3/4 vermicompost+ 1/4 inorganic fertilizers), F_4 (control, no fertilizer). Soil characteristics and climatic conditions were recorded. Plant growth, flowering and fruit characters, and yield were found significantly different ($p<0.05$). The highest plant height, flowering and fruit characters related to higher production were found in BARI 15 (V_2) variety influenced by combined application of fertilizer F_3 (3/4 vermicompost + 1/4 inorganic fertilizers). The maximum number of flower clusters per plant (9.66), fruit clusters per plant (8.13), individual fruit weight (117.7 g), fruit numbers per plant (51.17) were found in V_2F_3 and the same parameters were the lowest in V_1F_4. The results showed the highest production (95.50 t/ha) in V_2F_3 followed by V_2F_0 (81.70 t/ha), V_2F_1 (72.17 t/ha) and V_2F_2 (68.06 t/ha), and the lowest yield (27.70 t/ha) in V_1F_4. The highest fruit yield ((95.50 t/ha) found in V_2F_3 showed 80.84% higher compared to the V_1F_4 (27.70 t/ha) treatment. Considering the variety, the highest yield (74.05 t/ha) was found in V_2 which was 40% higher yield compared to V_1. Combined application of vermicompost and inorganic fertilizers performed best as the nutrient management and BARI 15 was found as a suitable variety for the CHTs climatic condition. Hence, the similar type fertilizers proportion can be applied for the other vegetables production in the farmers field for the healthy and eco-friendly environment achievement.

Citation of this article: Shova, S. A., Islam, M. A., Rahman, M. H., Gomes, J., Haque, M. N., & Das, R. S. (2021). Effect of nutrient management on growth and yield of two tomato varieties in Chittagong Hill Tracts (CHTs) region of Bangladesh. *Archives of Agriculture and Environmental Science*, *6*(4), 469-476, https://dx.doi.org/10.26832/24566632.2021.060408

INTRODUCTION

Synthetic or inorganic fertilizers are extensively used in agriculture as a fast available source of nutrient for plant caused higher plant productivity. After the second world war, heavily application of nitrogen fertilizer was introduced for higher production of crops to meet up the demand of increased population in 1950s. After that, it led the 'green revolution' in 1960s for the introduction of high yielding and fertilizer responsive crop varieties. Current scenario is the application of excessive content of synthetic fertilizers a serious threat to the environment and human health (Ahmed *et al*., 2017). For example, higher nitrate consumption in diet, caused endogenous nitrosation lead to thyroid, cancer, diabetic and neural tube defects during fetus development. It has been reported that soil quality is affected by excessive applications of synthetic fertilizer in Bangladesh (Muhibbullah *et al*., 2005). The sustainability of conventional agriculture in Bangladesh is under threat from the continuous degradation of land and water resources and from declining yields due to the indiscriminate use of inorganic fertilizers. It caused the degradation of soil health, soil quality and environmental impact in the long term.

Alternative issues for sustainable and ecofriendly production of crop using organic fertilizers and biofertilizers as well as Bio

fertilizers such as *Trichoderma* enriched with inorganic fertilizers play a significant role in the growth and yield of crops. These practices have found the potentiality in mustard and tomato where 50% reduced the inorganic (Haque *et al*., 2012). Microorganisms or plant growth promoting rhizobacteria (*Bacillus* spp.) inoculant help to reduce the application of inorganic fertilizers and contribute to improving soil fertility and reducing a negative environmental impact (Adesemoye *et al*., 2009). On the other hand, Organic fertilizers are environmentally friendly, since they are from organic sources (Oyewole *et al*., 2012). Different types organic fertilizers like well-decomposed cow dung, vermicompost, poultry manure etc. are the main organic fertilizer in Bangladesh, where vermicompost produced through the action of earthworms. This process of decomposition results in the production of vermicompost. It contains 1.2–6.1 % nitrogen, 1.8–2.0 % phosphate, and 0.5–0.75 % potassium (Ansari *et al*., 2016). It also contains hormones such as auxins and cytokinin, enzymes, vitamins, and useful microorganisms such as bacteria, actinomycetes, protozoans, and fungi (Ismail, 1996; Sreenivasa *et al*., 2010).

Now-a-days, soil environment degradation has reached at an extreme level due to not wisely application of chemical or inorganic fertilizers. Currently, it is a serious issue to develop the technology which will maintain soil health and friendly environment for the better production of crops. The organic fertilizers provide nutritional requirements, suppress plant pest populations, and increase the yield and quality of agricultural crops in ways similar to inorganic fertilizers (Maske *et al*., 2015; Tonfack *et al*., 2009). Already, there are some researchers have been conducted effectiveness of organic sources of fertilizers on different vegetables like tomato, okra, cabbage, carrot etc. (Chadha *et al*., 2006; Islam *et al*., 2017a, b; Akther *et al*., 2019; Farjana *et al*., 2019; Afrin *et al*., 2019; Biswas *et al*., 2020). They have found the higher productivity and crop yield with reduce amount application of inorganic fertilizer with combination of organic fertilizer. For example, 80.84% higher yield was found in tomato in combination of 75% vermicompost and 25% inorganic fertilizer compared to control in the plain land of Horticulture farm, Mymensingh, Bangladesh. Though, it has not been trialed at the large scale of farmers field or the promising areas of hill tracts region. Considering this, the current experiment was conducted in the farmers field to evaluate the performances of nutrient management on growth and yield of two tomato varieties in the Chittagong Hill Tracts (CHTs) region of Bangladesh. At the same time, reduction and elimination of the adverse effects of inorganic fertilizers on human health and the environment is a strong indicator that organic agriculture is gaining worldwide attention (Aksoy, 2001; Chowdhury, 2004).

Tomato is grown in the summer and winter seasons in Bangladesh. However, production varies in various regions due to varieties, seasons, climatic conditions, planting times, management practices and soil properties (Nandwani *et al*., 2014). Planting time and varietal selection influenced tomato production from 4.51 to 55.91 t/ha. (Ahammad *et al*., 2009). In Bangladesh, the yield of tomato is not yet satisfactory as compared to tomato growing countries of the world. The cultivated area under winter tomato in Bangladesh is 28.34 thousand hectares with a total production of 3.88 thousand metric tons (BBS, 2019). Main growing region of tomato in Bangladesh is Chattogram, Rajshahi and Jashore. CHTs is the part of Chattogram division where 62515 MT tomato is found from 6150 ha land where mainly tribal refugees are settled down (BBS, 2019). So, it is necessary to increase the production of tomato with giving emphasis the hilly areas land with sustainable technology to meet up the demand of our country. Variety selection and fertilizer management is one of the major inputs for cop production. Hilly areas have remained fallow land, and neglected considering weather, lack of government awareness, proper education, proper storage system, and nutritional insecurity. Under this consideration, this experiment was conducted in the Alikadam sub-districts of Bandarban under CHTs region to investigate the performance of vermicompost and inorganic fertilizer application on the two varieties tomato.

MATERIALS AND METHODS

Description of study area

The research was conducted at the farmers field located at Alikadam sub-districts under Bandarban districts lies between 21°21' and 21°50' north latitudes and in between 92°15' and 93°34' east longitudes. This sub-district area is located in the relatively plain land of the Bandarban hilly region. Soil status of the experimental field is analyzed and mentioned in the Table 1. Climacteric data of winter tomato growing seasons (October 2019 to March 2020) of the experimental period is mentioned in Figure 1. Experimental area is shown in Figure 2.

Land preparation and experimental design

The experiment was conducted in the year 2019 (October)-2020 (March). Land was prepared by ploughed and cross ploughed. Ploughed was followed by laddering to break the clods and to break soil during land preparation, weeds and other stubbles of the previous crops were collected and removed from the land. Seeds of tomato variety used in the experiment was BARI 2 and BARI 15 tomato, which are high yielding determinate type released by Bangladesh Agricultural Research Institute (BARI). Tomato seedlings were raised in one seedbed of 3m × 1m size and it was sown in October. The soil was well prepared and converted into loose friable and dried much by spading. All weeds and stables were removed. Seed were sown on the seedbed on after sowing, seeds were covered with light soil. The emergence of seedlings took place within 5 to 6 days after sowing. The two factors experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. Two varieties were considered as factor A and five level of fertilizers as factor B mentioned below:

Factor A: Varieties	Factor B: Fertilizers
V_1: BARI 2	F_0: Farmer's practice
V_2: BARI 15	F_1: Vermicompost 10 ton/ha
	F_2: Inorganic fertilizers (NPKS)
	F_3: Combined fertilizer (3/4 vermicompost +1/4 inorganic fertilizer)
	F_4: Control

So, total number of unit plots were 30 (2 × 5 × 3). The treatment combinations were randomly assigned to each unit plot so as to allot one treatment combination once in one block. The unit plots were 2.4m × 2.5m (6 m^2) in size with 60 cm distance between the blocks and 50 cm between the unit plots. Spacing of tomato plants were 60 cm × 50 cm. So, total number of plants per plot was 20.

Fertilizer application

Different levels combination of vermicompost as organic fertilizer and inorganic fertilizer were applied as treatment in the field (Table 2). Here, F_0 was the farmers practice which is mainly practiced by the farmers in the experimental area. Inorganic fertilizers were applied according to the Fertilizer Recommendation Guide (FRG, 2018) and Vermicompost (10 t/ha) was considered as the organic fertilizer. Full amount of vermicompost (F_1) was applied during final land preparation in the experimental plots. In case of inorganic fertilizers, full amount TSP and gypsum fertilizers were applied as basal during final land preparation; and urea and MoP fertilizers were applied in two equal splits at 15 and 35 DAT (days after transplanting).

Intercultural operations

Weeding was accomplished as and when necessary, throughout the growth period to keep the crop free from weeds. Several irrigations were given throughout the growing season. Besides this irrigation was done after every fertilization. Malathion 57 EC was applied at the rate of 2 ml/L as preventive measure against insect pests. Dithane M-45 was applied as fungicide @ 1.5 ml/l as preventive measure against disease such as late blight, early blight of tomato.

Collection of data

Five plants were selected randomly from each unit plot for data collection in such a way that the border effect should be avoided at the highest precision. Plant height was recorded as cm at 15, 30, 45 and 60 DAT from the ground to the tip of stem. Data on flower clusters/plant, flowers/cluster and number of fruit clusters per plant, fruits/cluster, number of fruits were recorded by using formula. Number of total flowers and clusters per plant were recorded which was converted as flowers/cluster, and flower clusters/plant. Average data of five plants were considered as one replication out of three; and randomly selected five fruits per plot were measured for fruit length (cm) and fruit diameter (cm) by slide caliper, and the average data was used as one replication. Fruits were harvested at the proper maturity index (when fruits become 10% red color). The matured fruits were harvested and the fruits weigh were measured by using measuring balance. The weigh balance was used to take the weight of fruits per plot. Fruits were harvest periodically and it was recorded in each time which was totally sum up and finally all the harvested fruits considered as total fruit weight per plot as kilogram (kg) and converted it to ton per hectare using the following formula.

Fruit yield (t/ha) = (Fruit yield per plot (kg) ×10000 / area of plot in m^2) ×1000

Statistical analysis

Effects of treatments on growth and yield data were analyzed by analysis of variance (General Linear Model procedure) and Tukey's pairwise comparison test following Duncan's Multiple Range Test (DMRT) at 5% level of probability ($p< 0.05$)) using Minitab Version 17 (Minitab Inc., State College, PA, USA).

Table 1. Chemical properties of the experimental plot soil.

Soil status	Values
Total nitrogen (%)	0.10
Available phosphorus (mg/Kg soil)	16.1
Exchangeable K (meq/100g soil)	0.23
Available boron (mg/Kg soil)	0.31
pH	5.7

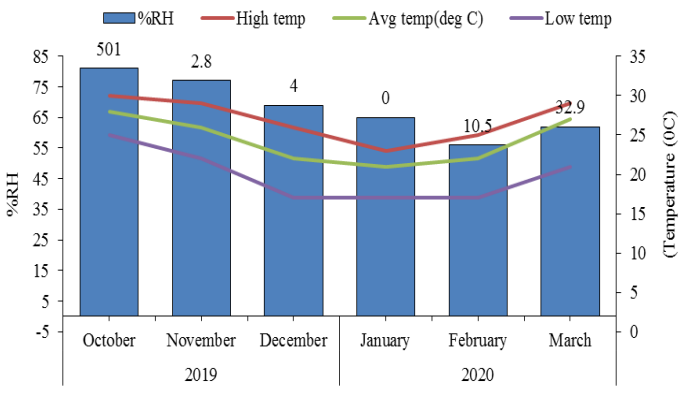

Figure 1. *The maximum, average and minimum air temperatures (^{0}C), % relative humidity (RH) and total rainfall (mm) recorded during the cropping cycles (October 2019 to March 2020) in the growing season of tomato. Rainfall value (mm) is mentioned above the column bar of each month. Source: World Weather online: https://www.worldweatheronline.com/*

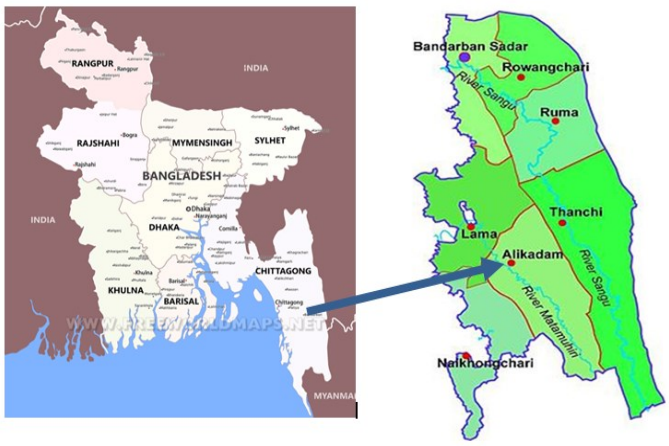

Figure 2. *Map of Bangladesh showing in the left side and the study area Alikadam sub-district of Bandarban Distract (right side) under Chittagong Hill Tracts (CHTs) region.*

Table 2. Doses of manures and fertilizer application as treatment.

Treatments	Fertilizer amount (per ha)
*Farmers practice (F_0)	Farmers practices
Vermicompost (F_1)	10 ton
* Inorganic fertilizer (F_2)	Urea=292.95kg, TSP=225kg, MoP=150kg, Gypsum=93.75kg
Combined Fertilizers (F_3):3/4 vermicompost +1/4 inorganic fertilizer	7.5 ton vermicompost, Urea=73.19kg, TSP=56.25kg, MoP=37.5kg, Gypsum=23.44kg
Control (F_4)	No fertilizer

**Farmer was allowed to use the fertilizer according to his in general practice (F_1) and recommended inorganic fertilizer (F_2) was used according to FRG, 2018.*

RESULTS AND DISCUSSION

Influence of different types fertilizers on growth and production of tomato

Plant height was measured at 15, 30, 45 and 60 days after transplanting (DAT). There was significant variation due to different types fertilizers in respect of plant height. The maximum plant height (69.95 cm) at 60 DAT was found in the plants grown under combined application of vermicompost and inorganic fertilizers (F_3: 3/4 vermicompost +1/4 inorganic fertilizers) while the lowest plant height (59.35 cm) was observed from control (F_4: no fertilizer) (Figure 3). The 2nd and 3rd highest plant height was found from the farmers practice (F_0) and vermicompost (F_1), respectively (Figure 3). In the comparison of plant height growth trend, it has been found that the highest plant height found in F_3 which was 4.99 %, 1 %, 9.69 % and 17.86% higher compared to farmers practices (F_0), vermicompost (F_1), inorganic fertilizers (F_2) and control (F_4). Similarly, F_3 gave the highest plant height at different days when it was calculated on 15 DAT (11.47 cm), 30 DAT (31.33 cm) and 45 DAT (61.09 cm).

Organic fertilizers contain beneficial microorganisms and different types of macro and micro nutrient to improve the soil health, water and nutrient holding capacity (Ansari *et al.*, 2016). Plant growth and yield contributing characters influences the production. It was found that the largest number of flower clusters per plant (9.50), number of flowers per cluster (9.13), number of fruit clusters per plant (7.83), fruit numbers per cluster (7.33), weight of individual fruit (116.82) were found in application of combined fertilizer F_3 (3/4 vermicompost +1/4 inorganic fertilizers) (Table 3). Considering fruit parameters, the highest number of fruits per plant (40.50), fruit diameter (5.42 cm) and fruit length (6.02 cm) was found from the F_3 treatment, and no fertilizer application (F_4: control) produced the lowest number of flower clusters per plant (7.12), flowers per cluster (6.69), fruit clusters per plant (5.47), fruits number clusters (4.55), weight of individual fruit (81.04 g) (Table 3). The lowest number of fruits per plant (22.35), fruit diameter (4.97 cm), fruit length (5.63 cm) was found from the control treatment (F_4).

Tomato yield was found significantly difference among the fertilizer treatment. The highest yield of tomato (76.05 t/ha) was found in F_3 and the lowest yield (40.25 t/ha) was found in control (F_4) (Figure 4). This result is consistent as a number of fruits per plant was found higher from the same treatment, F_3. No significant different of yield were found among the treatments F_0, F_1 and F_2. So, the highest yield found in F_3 which was 88.94%, 30.33 %, 34.94%, 28.61% higher compared to other treatments control (F_4), farmers practices (F_0), sole application of vermicompost (F_1), inorganic fertilizers (F_2), respectively. It indicates that the 2nd highest yield was found in the farmers practice where mainly inorganic fertilizers were practiced and this was higher amount compared to the sole application of inorganic fertilizers (F_2). Similar finding was found reported by Patil *et al.* (2004) and Reddy *et al.* (2002). The combined fertilizer treatment was the best for tomato production, which could be interpreted as the release of nutrients from organic and inorganic fertilizers continuously during the growing period of tomato. Inorganic fertilizer is applied in split according to FRG (2018) and vermicompost release macro and micronutrient slowly which also contain different beneficial microbes ultimately help to improve the soil condition and nutrient availability to plant (Ansari *et al.*, 2016; Islam *et al.*, 2017b; Biswas *et al.*, 2020). Also, Ronga *et al.* (2020) observed the production of tomato with comparison of sole application of biochar. They found that the combined application of liquid digestate and biochar gave the highest yield of tomato compared to sole application of biochar and liquid digestate.

Growth and production variation of two tomato varieties under the geographical condition of CHTs region

More consistent differences for the plant height were found due to variation of cultivars growing in the Chittagong Hill Tracts (CHTs) region. The plant height (75.25 cm) was higher in BARI 15 (V_2) than in BARI 2 (V_1) (56.35 cm) at 60 days after transplanting (DAT) (Figure 5). In this experiment, BARI 15 variety (V_2) gave 33.54% higher plant height (75.25 cm) at 60 DAT compared to variety BARI 2 (V_1). Similarly, flower and fruiting characters were found dominant in V_2 compared to V_1. The highest number of flower clusters per plant (8.47), flower numbers per cluster (8.29), fruit clusters number per plant (7.32), fruits number per cluster (6.59), individual fruit weight (101.96 g) was higher in V_2 compared to V_1 (Table 4). Fruit parameters like fruit length (5.87 cm), fruit diameter (5.19 cm), fruit number per plant (41.39) was found higher in V_2 compared to V_1(Table 4). Yield of tomato was recorded and the highest yield (74.05 t/ha) was found in V_2 which gave 40% higher yield compared to V_1 (Figure 6). Across all the parameters especially, flower number, fruit number and fruit weight were found higher from the variety 2 (BARI 15) and the findings are very consistent. Because, V_2 gave the better result under the different treatments.

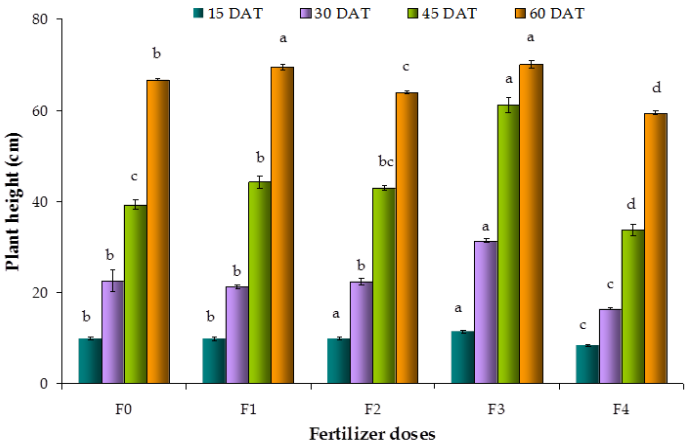

Figure 3. *Effect of different types fertilizer practices on plant height at different days after transplanting (DAT). Vertical bars represent ±SE (standard errors). Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. Here, F_0 = Farmers practices, F_1 = Vermicompost, F_2 = Inorganic fertilizers, F_3 = combined fertilizer (3/4 vermicompost + ¼ inorganic fertilizer), F_4 = Control.*

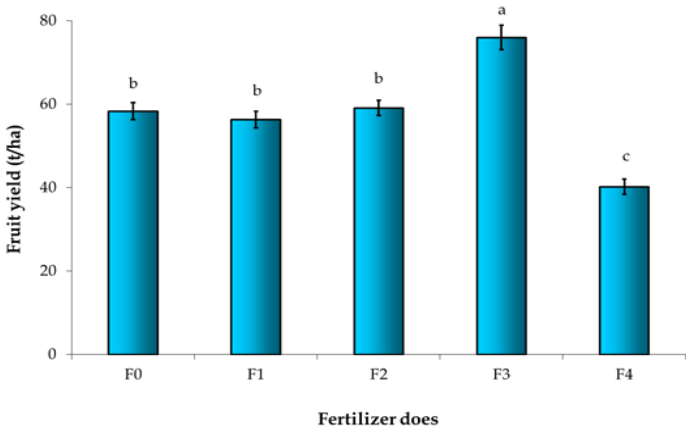

Figure 4. *Effect of different types fertilizer practices on yield of tomato (t/ha). Vertical bars represent ±SE (standard errors). Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. Here, F_0 = Farmers practices, F_1 = Vermicompost, F_2 = Inorganic fertilizers, F_3 = combined fertilizer (3/4 vermicompost + ¼ inorganic fertilizer), F_4 = Control.*

Table 3. Effects of fertilizers on flower clusters numbers per plant, flower numbers per cluster, fruit cluster numbers per plant, fruits numbers per cluster, individual fruit weight (g), fruit length (cm), fruit diameter (cm) and fruit numbers per plant.

Fertilizers	Flower cluster numbers / plant	Flowers numbers / cluster	Fruit cluster numbers / plant	Fruit numbers / cluster	Individual fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit numbers / plant
F_0	7.37±0.09bc	7.38±0.06d	7.10±0.08b	6.75±0.08b	97.87±1.11c	5.81±0.02b	5.28±0.03b	32.55±0.60b
F_1	8.20±0.15b	8.07±0.09c	7.00±0.06b	6.80±0.10b	104.65±1.35b	5.79±0.02b	5.04±0.02cd	31.26±1.41b
F_2	7.97±0.44bc	8.40±0.20b	7.23±0.13b	6.40±0.06c	93.24±2.16d	5.72±0.01c	5.09±0.02c	32.36±2.48b
F_3	9.50±0.42a	9.13±0.10a	7.83±0.06a	7.33±0.12a	116.82±0.57a	6.02±0.03a	5.42±0.01a	40.50±3.14a
F_4	7.12±0.17c	6.69±0.07e	5.47±0.03c	4.55±0.10d	81.04±2.19e	5.63±0.02d	4.97±0.02d	22.35±2.25c
P-value	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Means ±SE (standard error) followed by different letter(s) within a parameter are significantly different using DMRT. Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. Here, F_0 = Farmers practices, F_1 = Vermicompost, F_2 = Inorganic fertilizers, F_3 = combined fertilizer (3/4 vermicompost + ¼ inorganic fertilizer), F_4 = Control.

Table 4. Main effect of variety on flower cluster numbers per plant, flower numbers per cluster, fruit cluster numbers per plant, fruits numbers per cluster, individual fruit weight (g), fruit length (cm), fruit diameter (cm), fruit number per plant.

Variety	No of flower clusters / plant	Flower number/ cluster	Fruit cluster numbers/ plant	Fruit numbers/ cluster	Individual fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit numbers/ plant
V_1	7.49±0.35b	7.58±0.04b	6.53±0.08b	6.15±0.03b	95.48±0.56b	5.72±0.01b	5.13±0.02b	22.22±1.48b
V_2	8.57±0.02a	8.29±0.09a	7.32±0.03a	6.59±0.04a	101.96±0.64a	5.87±0.02a	5.19±0.01a	41.39±1.85a
P-value	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.04

Means±SE (standard error) followed by different letter (s) within a parameter are significantly different using DMRT. Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. Here, V_1 = BARI tomato 2, V_2 = BARI tomato 15.

This is a positive correlation of the fruit characteristics and yield of tomato. Yield variation between two varieties might be due to the genetic variability, heritability and genetic advance, including the environmental conditions effects and adopted different management practices (Meena *et al.*, 2015; Ronga *et al.*, 2020). Azad *et al.* (2019) reported that yield of tomato BARI 15 and BARI 2 mentioned in the *Krishi Projuki hatboi* are mostly similar. So, result findings are not similar to the report of *Azad et al.* (2019). This variation might be due to the climatic factors favorable for the BARI 15 which produced higher yield compared to BARI 2 (Figure 1).

Combined effect of different types of fertilizers and variety on growth and production of tomato in CHTs region

The combined effect of different types of fertilizers and variety on growth and yield was found significantly different (*p<0.05*). In this experiment, it was found that maximum plant height (78.96 cm) was found in V_2F_3 (3/4 vermicompost + 1/4 inorganic fertilizers with BARI 15) treatment. It is interesting to note that the V_2F_3 treatment recorded 53.84% more plant height than V_1F_4 (control) treatment (Figure 7).

Among the flowers and fruit contributing parameters number of flower clusters per plant, number of flowers per cluster, number

Table 5. Combined effects of variety and fertilizers on flower cluster number per plant, flower number per cluster, fruit cluster number per plant, fruits number per cluster, individual fruit weight (g), fruit length (cm), fruit diameter (cm) and fruit numbers per plant.

Treatment combination	Flower cluster numbers per plant	Flower numbers per cluster	Fruit cluster numbers per plant	Fruit numbers per cluster	Individual fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit numbers/ plant
V_1F_0	6.33±0.29d	7.43±0.03cde	6.40±0.12e	6.67±0.09b	96.94±0.86c	5.71±0.02d	5.12±0.06bc	17.15±0.58ef
V_1F_1	8.20±0.31bc	7.60±0.15cd	6.60±0.06de	6.67±0.12b	101.60±2.04c	5.67±0.01d	5.03±0.05bcd	22.30±0.33de
V_1F_2	7.66±0.70c	7.86±0.18c	6.80±0.12d	5.87±0.27c	85.01±2.06d	5.64±0.01d	5.15±0.02b	26.13±3.77cd
V_1F_3	9.33±0.93ab	8.60±0.20b	7.53±0.15bc	7.00±0.20b	115.90±1.64a	5.99±0.03a	5.37±0.02a	29.83±3.63c
V_1F_4	5.93±0.09d	6.37±0.12f	5.33±0.09f	4.53±0.13d	77.91±1.46e	5.56±0.03e	4.94±0.06d	15.67±1.68f
V_2F_0	8.80±0.12abc	7.33±0.13de	7.80±0.06ab	6.83±0.09b	98.80±2.16c	5.90±0.02b	5.44±0.02a	47.95±1.79a
V_2F_1	8.20±0.46bc	8.53±0.15b	7.40±0.15c	6.93±0.12b	107.70±1.30b	5.90±0.03b	5.04±0.04bcd	40.22±2.49b
V_2F_2	8.26±0.29bc	8.93±0.29b	7.67±0.18bc	6.93±0.18b	101.50±3.21c	5.79±0.02c	5.01±0.04cd	38.58±1.19b
V_2F_3	9.66±0.29a	9.66±0.09a	8.13±0.18a	7.67±0.18a	117.70±0.71a	6.05±0.03a	5.45±0.03a	51.17±3.01a
V_2F_4	7.90±0.06c	7.00±0.12e	5.60±0.06f	4.57±0.09d	84.17±3.11d	5.69±0.03d	4.99±0.04cd	29.03±3.09c
P-value	0.05	0.01	0.01	0.02	0.01	0.02	0.01	0.02

Means±SE (standard error) followed by different letter(s) within a parameter are significantly different using DMRT. Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. Here, F_0 = Farmers practices, F_1 = Vermicompost, F_2 = Inorganic fertilizers, F_3 = combined fertilizer (3/4 vermicompost + ¼ inorganic fertilizer), F_4 = Control, V_1 = BARI tomato 2, V_2 = BARI tomato 15.

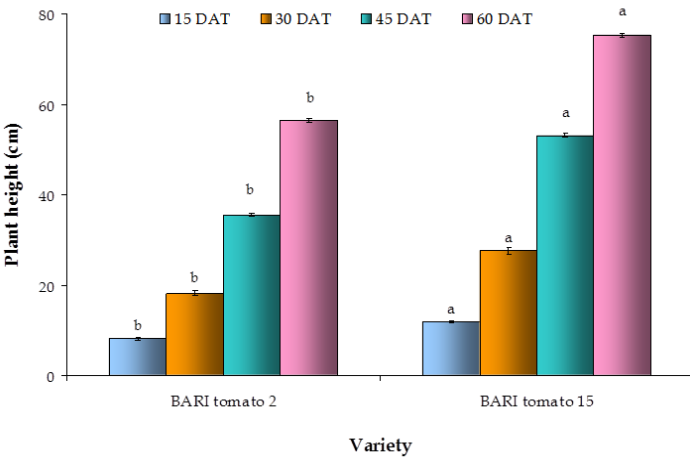

Figure 5. *Effect of tomato varieties on plant height at different days after transplanting (DAT). Vertical bars represent ±SE (standard errors). Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. Here, V_1= BARI tomato 2, V_2= BARI tomato 15.*

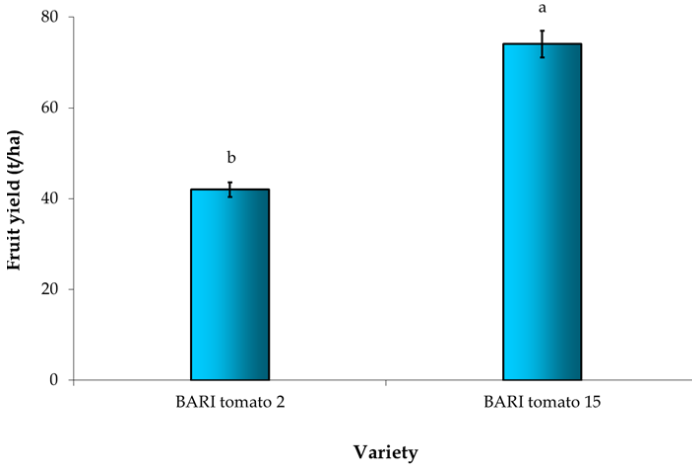

Figure 6. *Effect of tomato varieties on yield of tomato. Vertical bars represent ±SE (standard errors). Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. Here, V1= BARI tomato 2, V2= BARI tomato 15.*

of fruits clusters per plant and number of fruits per cluster is of special importance for having the increased production of tomato. In this study it has been recorded that maximum number of fruit clusters per plant (8.13) and maximum number of flower clusters per plant (9.66) found in the variety BARI 15 (V_2) with the combined application of fertilizer F_3 (3/4 vermicompost + 1/4 inorganic fertilizer) (Table 5). In V_2F_3 treatment had the highest fruit weight (117.70 g), fruit diameter (5.45 cm) and fruit length (6.05 cm) compared to V_1F_4 treatment and the lowest fruit weight, diameter and fruit length were found in variety BARI 2 (V_1) and control (F_4) fertilizer treatment. This increased trend of fruit weight, diameter and length in V_2F_3 was 51.07%, 10.32% and 8.81%, respectively compared to V_1F_4 treatment combination. Besides these parameters, number of fruits per plant is one of the most key parameters to boost up the production. Number of fruits per plant were 51.17 in V_2F_3 which was significantly different from the other treatment's combination except V_2F_0. Although, there is a little gap considering the numbers of fruits per plant were higher in V_2F_3 from V_2F_0. The second highest fruit number per plant in the V_2 of fertilizer treatment F_1 and F_2 (Table 5). Flowering and fruit characters are the key parameters to increase the yield of tomato. Higashide and Heuvelink (2009) reported that tomato grown in the greenhouse conditions and indicated fruit weight is an importance parameter in increasing gains in fresh tomatoes. So, the characters of flowers and fruits indicated that the highest yield should be found in V_2F_3. Fruit yield (95.50 t/ha) in V_2F_3 was recorded in 80.84% higher compared to the V_1F_4 (27.70 t/ha) treatment (Figure 8). The increased yield with integrated nutrient management application may be due to the fact that plant supplied with abundant NPKS and phytohormones resulting increased yield of the tomato. Moreover, vermicompost supplied additional nutrients and improved soil physical properties, which led to better soil physical health. Vermicompost contain

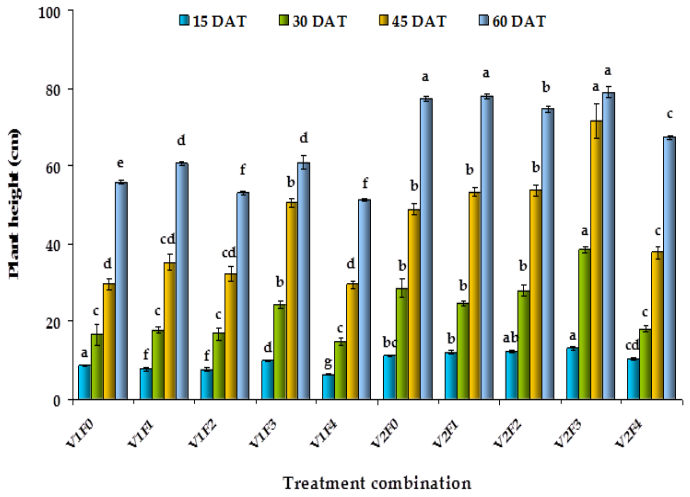

Figure 7. *Combined Effect of different organic and inorganic fertilizers and variety on plant height at different days after transplanting. Vertical bars represent ±SE (standard errors). Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. Here, (F_0 = Farmers practices, F_1 = Vermicompost, F_2 = Inorganic fertilizers, F_3 = combined fertilizer (3/4 vermicompost + ¼ inorganic fertilizer), F_4 = Control), V_1=BARI 2, V_2=BARI 15).*

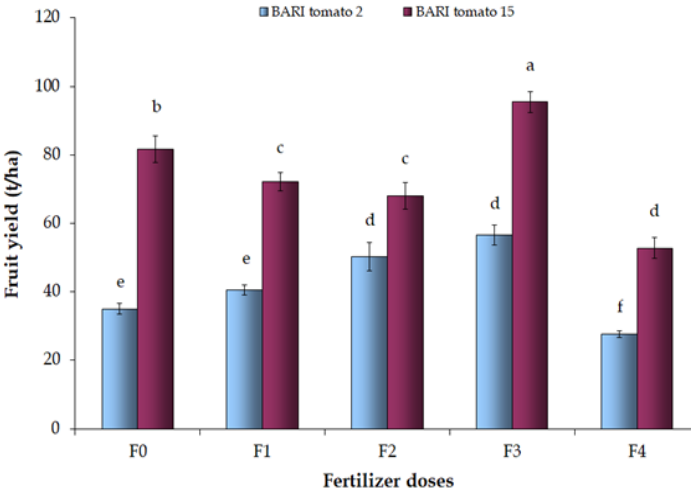

Figure 8. *Combined Effect of different organic and inorganic fertilizers and variety on tomato yield. Vertical bars represent ±SE (standard errors). Mean values with the same letters are not significantly different based on ANOVA followed by a Tukey's test at p<0.05. Here, (F_0 = Farmers practices, F_1 = Vermicompost, F_2 = Inorganic fertilizers, F_3 = combined fertilizer (3/4 vermicompost + ¼ inorganic fertilizer), F_4 = Control), V_1=BARI 2, V_2=BARI 15).*

Plate 1. *Photo showing the field of farmers, growth condition (left side) and the harvesting tomato (right side).*

different macro and micronutrients including beneficial microbes which improve the soil heath and properties and slowly release the nutrient to crop (Ansari *et al.*, 2016). On the other hand, inorganic fertilizers release nutrient quickly which influence the growth and production of crop. Overall, both combination of organic and inorganic fertilizers avails the nutrients during the crop production. Ultimately, this strategy improved the soil health condition resulting higher productivity of crop. Thus, among the treatments combination F_3(3/4 vermicompost + 1/4 inorganic fertilizer) and variety BAR 15 (V_2) showed superior results due to difference in mineralization, availability and utilization of nutrients by the plants. This result is supported by the Akhter *et al.*, 2019; Islam *et al.*, 2017b, where similar type rational application of inorganic fertilizers (1/4) and vermicompost (3/4) gave better yield of tomato and Indian spinach. Both experiments were conducted at the Horticulture farm of Bangladesh Agricultural University characterized as plain land. Here, reduced amount of inorganic fertilizer and added vermicompost as organic fertilizer showed better performances for crop production. On the basis of present investigation, it was concluded that the crop treated with combined fertilizer (3/4 vermicompost + 1/4 inorganic fertilizers) and V_2 showed better performance for all growth and yield parameters. BARI 15 gave higher yield and it might be due to genetically difference and climate suitability for the experimental area.

Conclusion

This study assessed the nutrient management for tomato production in the Chittagong Hill Tracts (CHTs) region of Bangladesh. The growth and yield contributing characters-plant height, flower clusters per plant, flowers per cluster, fruit clusters per plant, fruits per cluster, fruit numbers per pant, individual fruit weight were found superior in BARI 15 (V_2) influenced by combined application of fertilizer (F_3: 3/4 vermicompost + ¼ inorganic fertilizer) compared with sole application of vermicompost, inorganic fertilizers and farmers practice in that region. The lowest growth and yield relating characters were found in BARI 2 tomato variety (V_1) under control treatment. The similar increased trend of tomato production was found under the controlled area confirming the better production with combined application of vermicompost and inorganic fertilizer. Therefore, our results can be practiced in future research for the higher production of vegetables with reduced content of inorganic fertilizers in addition of vermicompost aiming to reach eco-friendly environment and to face the challenge of the different Agro Ecological Zones (AEZs) in Bangladesh.

ACKNOWLEDGMENTS

Author is greatly thankful to Caritas Bangladesh's (CB) funding partner Secours Catholique – Caritas France (SCCF) and Agency France Development (AFD) for the financial and field assistance in the study.

Conflicts of interest

The authors declare no conflict of interest.

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