RESEARCH ARTICLE

EXOGENOUSLY APPLIED MORINGA LEAF EXTRACTS AND MIXED FERTILIZERS IN SOIL TO IMPROVE GROWTH AND YIELD OF TOMATO (*LYCOPERSICON ESCULENTUM* MILL.)

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ARTICLE DETAILS

Article History:

Received 23 May 2020
Accepted 24 June 2020
Available online 16 July 2020

ABSTRACT

Sustainable production of horticultural crops demand judicious application of integrated nutrient management and biostimulant like moringa leaf extract (MLE) which provides different macro and micronutrient including phytohormones. Two factors experiment was laid out in randomized complete block design (RCBD) with 3 replications to observe fertilizers and moringa leaf extract (MLE) effects on growth and yield of tomato. Fertilizer were F_0 (control), F_1 (vermicompost), F_2 (inorganic fertilizer), F_3 ($2/3 F_1 + 1/3 F_2$). Foliar application of MLE were M_0 (control), M_1 , M_2 and M_3 where MLE sprayed at one, two- and three-weeks interval after transplanting, respectively. In case of fertilizers, F_3 gave the highest growth, 54.65%, 13.67% and 12.65% higher yield of tomato compared to sole application of vermicompost (F_1), inorganic fertilizer (F_2) and control (F_0), respectively. In case of MLE, the highest growth and yield was found from M_1 ; and the yield was 42.38 % higher compared to control. Among the treatments combination, the highest growth and yield like plant height (59.90 cm), flowers/plant (57.08), fruits/plant (25.67), fruit diameter (5.00 cm), fruit length (6.83 cm), individual fruit weight (67.65g), yield (1.52 kg/plant and 57.00 t/ha) was found from F_3M_1 and the lowest was found from F_0M_0 . Our results suggested that about 75% less amount of inorganic fertilizer with judiciously incorporated vermicompost and exogenous application of MLE at one week interval could be used to improve the quality and productivity of tomato; and this can sustain the sustainable horticulture technology as environmentally friendly.

KEYWORDS

fertilizer, moringa leaf extract, tomato, vermicompost, sustainable horticulture

1. INTRODUCTION

Sustainable production of vegetables is one of the most important factors for contributing higher production considering the healthy ecosystems, soil health, food production, the community, and the economy. Farmers are highly dependent on inorganic fertilizers as a source of plant nutrients and the high cost of chemical fertilizers is associated with land and soil degradation as well as environmental pollution (Phiri, 2010). The current global scenario firmly emphasizes the need to adopt eco-friendly agricultural practices for sustainable food production (Islam et al., 2017ab, Islam et al., 2020). It contributes to improving soil fertility and reducing negative environmental impact. Both chemical fertilizers and pesticide have the adverse effect on human health and the environment and reduce those indicators are getting more attention in the world to feed the increased trend population from the limited amount land.

Tomato (*Lycopersicon esculentum* Mill.) is an herbaceous plant belonging to the family Solanaceae. In the world, total tomato production is 182 million tons from 4.8 million hectares (FAOSTAT, 2019). People are aware about their good health through consuming safe consumption of fruits and vegetables. Because, they contain different antioxidant molecules like carotenoids, phenolics compounds, and ascorbate. Tomatoes is a rich

source of lycopene, minerals, and vitamins such as ascorbic acid and β -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). 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, and exogenous application of biostimulant which provide plant required macro and micronutrients to prevent nutritional diseases to crop. Fertilizers; both major (NPK) and micronutrients are one of the important potential inputs for the growth and yield of crop. Although, haphazard application of chemical fertilizers especially N sources are used in excess amounts and as a consequence of adverse effects of chemical fertilizers through waterway pollution, chemical burn to crops, increased air pollution, acidification of the soil, and mineral depletion of the soil (Kumar and Prakash, 2019).

Biofertilizers such as vermicompost and vermiwash increase the organic

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Website:
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DOI:
[10.26480/sfna.01.2020.42.47](http://doi.org/10.26480/sfna.01.2020.42.47)

matter content and it is beneficial for the long-term sustainability and crop productivity. Biofertilizers are also enriched with micronutrients and beneficial microbes that enhance the soil quality and aid in slow release of nutrients required for the healthy growth of plants (Ansari et al., 2016). The effectiveness of organic sources of fertilizers can be improved by combining them with chemical fertilizers, as well as the efficient use of chemical fertilizers for crop production (Chadha et al., 2006). Already, some researchers have applied the combined application of organic and inorganic fertilizer which promotes the sustainable production of vegetables like tomatoes, brinjal, cabbage, Indian spinach, carrots, and okra (Afrin et al., 2019; Farjana et al., 2019; Islam et al., 2017ab; Islam et al., 2020; Ullah et al., 2008). In this technology, they reduced 75% chemical fertilizer replaced by organic fertilizer and achieved higher yield of those crops considering the better soil health and environment and crop production cost.

Moringa (*Moringa oleifera*) belongs to the family Moringaceae. There are about 13 species of Moringa of which *Moringa oleifera* is most widely grown in Bangladesh. Since leaves of moringa are rich in zeatin, a natural source of cytokinin and its concentrations varies between 5 mcg and 200 mcg/g of leaves (Davies, 2015; Fuglie, 1999). Besides, it is also rich of ascorbates, carotenoids, phenols, potassium, and calcium, which have plant-growth-promoting capabilities and are often used as exogenous plant growth enhancers (Foidl et al., 2001). Antioxidants such as ascorbic acid and glutathione, which are found at high concentrations in moringa chloroplasts and other cellular compartments, are crucial for plant defense against oxidative stress (Noctor and Foyer, 1998).

Already, moringa leaf extracts (MLE) has been applied in different crops and got positive response to growth, yield, photosynthetic and nutrient uptake (N, P, K, Ca, Mg and Fe) in different crops like tomato, onion and spinach with this exogenous application (Culver et al., 2012; Mohammed et al., 2013; Merwad, 2015). Overall, the sustainable crop production using organic, inorganic fertilizer and exogenous application is a novel technology in Bangladesh. Considering this, the main target of this experiment was to reduce the amount of inorganic fertilizer and biostimulant like exogenous application of MLE to increase the tomato production.

2. MATERIALS AND METHODS

2.1 Experimental site and soil

An experiment was conducted at the Horticulture Farm of Bangladesh Agricultural University (BAU), Mymensingh during the period from October 2018 to February 2019 to study the effect of different types of fertilizers and moringa leaf extracts (MLE) on growth and yield of tomato. The experiment was carried out to the soil series of Old Brahmaputra Flood Plain Alluvial Tract (UNDP, 1988) of AEZ-9. The texture of the soil was silty loam with pH 6.6. Soil series was sonatola series which was non-calcareous dark grey. Information regarding monthly maximum, minimum and average temperature, relative humidity was recorded by Weather Yard of Bangladesh Agricultural University, Mymensingh during the experimental period (Figure 1).

Figure 1: Temperature (°C) and Relative humidity (%) of the experimental time in the area of horticulture farm, BAU, Mymensingh; Source: Weather yard, Department of Irrigation and Water Management, Records of Climatologically observation, Bangladesh Agricultural University, Mymensingh

2.2 Treatments and experimental design

The two factors experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. The experiment consisted of per plant and replication were measured for fruit length (cm) and fruit

two factors; factor A, fertilizers treatments (factor A) were F_0 (No fertilizer), F_1 (Vermicompost), F_2 (Recommended dose of inorganic fertilizer), F_3 ($2/3 F_1 + 1/3 F_2$); and moringa leaf extracts (factor B) were M_0 (No MLE sprayed), M_1 (MLE sprayed one week interval after transplanting), M_2 (MLE sprayed two weeks interval after transplanting), M_3 (MLE sprayed three weeks interval after transplanting). The experimental plants were placed into three blocks each containing sixteen plastic pots. In total there were 48 pots in the experiment which were placed randomly.

2.3 Raising of seedlings and transplanting

Roma VF variety was selected for the study. Seeds were sown in nursery beds (3 m × 1 m), one seedbed/variety. Weeding, mulching and watering in seedbeds were done as needed. Seedlings germinated within a week. Healthy and uniform size 30 days old seedlings were uprooted separately from the seed bed so as to minimize damage to the roots. One seedling was transplanted in one experimental pot (10 L) in the afternoon of November 3, 2018. Light irrigation was given immediately after transplanting by using a watering cane.

2.4 Application of manures and fertilizers

Earthen pots having the diameter of 35 cm and 30 cm depth, and 10 kg soil samples for the experimental pots were collected from a depth of 0 to 15 cm. Fertilizer was given as considering the mass volume of soil considering the bulk density of one hectare soil (1.3 t/m³). Urea, MoP, TSP and Zn fertilizers were applied at recommended doses as the inorganic treatments and vermicompost was applied as organic fertilizer (Table 1). Vermicompost, TSP and gypsum fertilizers were applied one week earlier of planting. Nitrogen and potassium were applied in two equal splits at 15 and 35 days after transplanting (DAT). Irrigation was given followed by fertilizer application; also, when necessary.

Table 1: Manures and fertilizer doses for different treatments		
Treatments	Fertilizer amount (dose/ha)	Fertilizer applied per pot (g)
F_0 (Control)	-	-
F_1 (Vermicompost)	10 ton	100g
* F_2 (inorganic fertilizer)	Urea=250kg TSP=200kg MoP=140kg Gypsum=70kg	Urea=2.5g TSP=2.0g MoP=1.4g Gypsum=0.70g
F_3 (Combined of $2/3 F_1$ and $1/3 F_2$)	$2/3 F_1$ and $1/3 F_2$	$2/3 F_1$ and $1/3 F_2$

*Recommended dose of inorganic fertilizer according to Fertilizer Recommendation Guide (FRG): N=115kg, P=40kg, K=70kg, S=13kg (FRG, 2018)

2.5 Preparation and application of moringa leaf extract (MLE)

Young moringa leaves (not more than 30 days old) were collected from Horticulture Farm of Bangladesh Agricultural University. An amount (20 g) of moringa leaves were mixed with 675 ml of 80% ethanol and grinding them by following the modified protocol (Culver et al., 2012). The suspension was stirred using a homogenizer to help maximize the amount of the extract. The solution was filtered using No.2 Whatman filter paper. The extraction was used for application and kept in the refrigerator (0°C) to avoid from being contaminated by some harmful microorganism and other unfavorable environmental conditions. MLE were applied according to the design as treatments. Application rate of extract was 25 ml per plant as foliar spray.

2.6 Intercultural operations

Weeding were accomplished as and when necessary throughout the growth period. Staking was done with bamboo sticks to support tomato plants. Watering can was used to facilitate irrigation as and when necessary.

2.7 Harvesting and data collection

Fruits were harvested at full maturity. Harvesting was started on 29 January and continued up to February, 2019. Data were collected from the planted plant in each pot. Plant height (15, 30 and 45 DAT) was recorded (cm) from the ground to the tip of stem. Data on number of fruits, flower clusters and number of fruit clusters per plant were recorded. Three fruits diameter (cm) by slide calipers. Total five harvest was recorded from 29

January to 20 February. Fruits were harvested at the maturing index (when fruits become 10% red color) and sum of tomato weight was considered as yield per plant and converted to ton per ha considering the standard spacing (60cm x50 cm) for the cultivar Roma VF. Fresh tomato was cut into pieces and kept in an oven for drying at 65°C until a constant mass reached. Total dry matter (DM) was calculated from the total sum of dry weight of tomato fruit.

2.8 Statistical analysis

The data in respect of growth, yield and yield components were analyzed statistically to obtain the level of significance using the MSTAT-computer package program. The means of all the treatments were calculated and the analysis of variance for each of the characters under study was performed by F test. Mean comparisons between treatments were performed by the Duncan's Multiple Range Test (DMRT) at 5% level of probability according (Gomez and Gomez, 1984).

3. RESULTS AND DISCUSSION

3.1 Effect of different types of fertilizers on growth and yield of tomato

Fertilizer application showed the significant different on growth and yield of tomato. Combined application of fertilizer (F_3 : 2/3 vermicompost + 1/3 inorganic fertilizers) gave the highest plant height (57.79 cm) at 45 days after transplanting (DAT), flowers/plant (44.08), fruits/plant (23.25) among the all treatments (Table 2). In comparison, F_3 performed 12.65 % higher plant height (at 45 DAT), 117.67 % higher flowers/plant, 112.91 % higher fruits/plant compared to control (Table 2 and Figure 2). The increase in number of fruit owing to this treatment might be due to the greater availability of mineral nutrient from nitrification of vermicompost and inorganic fertilizer to the plants. The fruit length (6.13 cm) and fruit diameter (4.50 cm) was also higher 8.08 % and 7.66%, respectively compared to control.

Fertilizer	No. of flower cluster/plant	No. of Fruit Clusters/Plant	No. of Fruits/Plant	Fruit Length (cm)	Fruit Diameter (cm)	Individual fruit weight (g)	Fruit weight/plant (kg)	Dry matter of fruit (%)
F_0	4.50d	3.76d	10.92d	5.67b	4.18b	54.07c	0.598d	8.11d
F_1	6.415c	4.50c	14.92c	5.77b	4.25b	55.08c	0.86c	8.62c
F_2	7.99b	6.08b	20.92b	5.83ab	4.32b	56.55b	1.17b	8.75b
F_3	8.917a	6.59a	23.25a	6.13a	4.50a	59.07a	1.33a	9.36a
SE ($\pm$)	0.07	0.05	0.20	0.11	0.06	0.38	0.02	0.04

Means followed by different letter(s) within a parameter are significantly different using DMRT. Standard error ($\pm$ SE) are given for mean group of a parameter. Here, F_0 = Control (No fertilizer), F_1 = Vermicompost, F_2 = Recommended dose of chemical fertilizer, F_3 = Combined fertilizers (2/3 F_1 + 1/3 F_2)

Figure 2: Effect of different organic and inorganic fertilizers on plant height at different days after transplanting.

Vertical bars represent $\pm$ SE (standard errors). Same letter indicate are not statistically significantly. Here, F_0 = Control (No fertilizer), F_1 = Vermicompost, F_2 = Recommended dose of chemical fertilizer, F_3 = Combined fertilizers (2/3 F_1 + 1/3 F_2)

Figure 3: Effect of MLE on plant height at different days after transplanting.

Vertical bars represent $\pm$ SE (standard errors). Same letter indicate are not statistically significantly. Here, M_0 = Control (no MLE sprayed), M_1 = MLE sprayed at one week interval after transplanting, M_2 = MLE sprayed two

weeks interval after transplanting, M_3 = MLE sprayed three weeks interval after transplanting.

Figure 4: Combined effect of fertilizers and MLE on plant height at different days after transplanting

Vertical bars represent $\pm$ SE (standard errors). Same letter indicate are not statistically significantly. Here, F_0 = Control (No fertilizer), F_1 = Vermicompost, F_2 = Recommended dose of chemical fertilizer, F_3 = Combined fertilizers (2/3 F_1 + 1/3 F_2), and M_0 = Control (no MLE sprayed), M_1 = MLE sprayed at one week interval after transplanting, M_2 = MLE sprayed two weeks interval after transplanting, M_3 = MLE sprayed three weeks interval after transplanting.

Figure 5: Effect of different organic and inorganic fertilizers on fruit yield of tomato.

Vertical bars represent $\pm$ SE (standard errors). Same letter indicate are not statistically significantly. Here, F_0 = Control (No fertilizer), F_1 = Vermicompost,

F_2 = Recommended dose of chemical fertilizer, F_3 = Combined fertilizers (2/3 F_1 + 1/3 F_2)

Individual fruit weight, fruit diameter, fruit length and fruit yield per plant are important yield contributing parameters which are the significantly positive effect by integrated plant nutrient management. Similar reports were also found (Das et al., 2015; Sharma et al., 2010). They found higher plant height, higher fruit diameter, higher fruit length in application of inorganic fertilizers with organic manure. The highest individual fruit weight (59.07g), fruit weight per plant (1.33kg) and yield (49.54 t/ha) was found from F₃ and they are 9.25 % 122.40% and 115.76 % higher, respectively compared to control. It is also found that F₃ treatment recorded 13.67% and 54.65% higher yields as compared to the sole application of chemical fertilizer and vermicompost respectively. On the other hand, the second highest yield (44.03 t/ha) was found from F₂ and subsequently from F₁ (32.54 t/ha) and F₀ (22.96 t/ha), respectively.

Similar trend of flower clusters per plant and fruits clusters per plant and fruit numbers per plant found among the all fertilizer treatments. This results are statistically significant at 95% level of probability. The highest fruit length and diameter were found from F₃ treatment. But no significant differences of fruit length and diameter were found among the rest treatments. Higher number of flowers and fruit cluster promote the higher yield of tomato. The possible reasons for maximum values of higher yield from F₃ treatment might be due to the tremendous increase in the microbial population due to decomposition of organic matter with the subsequent release of available nutrients to the plants for growth. Organic manures applied with inorganic fertilizers improved the effectiveness of chemical fertilizers. A group researchers got the highest yield of tomato from the combined application of inorganic fertilizer and vermicompost compared to other fertilizers like sole application of inorganic fertilizer, vermicompost and control (Islam et al., 2017b).

Similarly, researchers also found the higher yield from the combined application of organic and inorganic fertilizers on cabbage, brinjal, carrot, okra and Indian spinach (Afrin et al., 2019; Akhter et al., 2019ab; Farjana et al., 2019; Islam et al., 2017a; Ullah et al., 2008). They argued that this fertilizer combination is giving better result due to supply of both type organic and inorganic fertilizers. Because, inorganic fertilizers used to release nutrients quickly to plant and organic fertilizers slowly release the nutrient which contain macro and micro nutrients, growth-promoting indole acetic acid (IAA), gibberellic acid (GA) and beneficial microorganisms (Ansari et al., 2016; Sreenivasa et al., 2010). Ultimately, it is helping to reduce the amount of inorganic fertilizer and cost of production. The highest dry matter content (9.36%) found in F₃ which is 15.41% higher than control treatment.

3.2 Effect of moringa leaf extracts (MLE) on growth and yield of tomato

Biostimulant like moringa leaf extracts (MLE) spray showed the significant different on growth and yield of tomato (Table 3). The higher growth and yield of tomato were found significantly different from MLE spray at one week interval after transplanting of tomato (M₁) compared to other treatments. The highest plant height (57.86 cm) was found in M₁ at 45 days after transplanting (DAT) and it was about 10.77 % higher plant height (57.86 cm) compared to no spray (control). The highest number of flower clusters per plant (8.09) and fruit clusters per plant (6.25) were found from M₁ and the second highest flower clusters per plant (7.0) and fruit clusters per plant (5.43) were found from M₂ and the lowest was found from control. These results were found statistically significantly different.

Table 3: Effect of exogenous application of moringa leaf extract (MLE) on growth, fruit characteristics and yield of tomato.

Moringa extract	leaf	No. of flower cluster/plant	No. of Fruit Cluster/Plant	No. of Fruits/Plant	Fruit Length (cm)	Fruit Diameter (cm)	Individual fruit weight (g)	Fruit weight/plant (kg)	Dry matter of fruit (%)
M ₀		6.25d	4.34d	14.92d	5.49c	4.07c	49.56d	0.82d	7.89d
M ₁		8.09a	6.25a	20.08a	6.242a	4.658 a	62.51a	1.177a	9.523a
M ₂		7.00b	5.43b	18.92b	5.925ab	4.308b	57.94b	1.050b	8.595c
M ₃		6.50c	4.92c	16.08c	5.725bc	4.217 bc	54.76c	0.907c	8.825b
SE (±)		0.07	0.05	0.202	0.111	0.057	0.376	0.018	0.044

Means followed by different letter(s) within a parameter are significantly different using DMRT. ±SE (standard error) are given for mean group of a parameter. Here, M₀= Control (no MLE sprayed), M₁= MLE sprayed at one week interval after transplanting, M₂= MLE sprayed two weeks interval after transplanting, M₃= MLE sprayed three weeks interval after transplanting.

Similar significant trend of fruits number per plant were found where the highest number fruits per plant (20.0) was found from M₁ and the lowest (14.92) was found from M₀. So, about 34.58 % higher no. of fruit/plant was found from M₁ compared to M₀. The highest fruit length (6.24 cm) and fruit diameter (4.66 cm) were found from M₁, and the lowest fruit length (5.49 cm) and fruit diameter (4.07 cm) were found from M₀. But no significant different was found among the spray of MLE at two (M₂) and three weeks (M₃) interval application. The highest individual fruit weight (62.51g) and fruit weight per plant (1.177kg), fruit yield (44.34 t/ha) found from M₁ and the lowest individual fruit weight (49.56g), fruit weight per plant (0.822kg) and fruit yield (31.14 t/ha) from M₀ (Table 3 and Figure 6).

Figure 6: Effect of MLE on fruit yield of tomato

Vertical bars represent ±SE (standard errors). Same letter indicate are not statistically significantly. Here, M₀= Control (no MLE sprayed), M₁= MLE

sprayed at one-week interval after transplanting, M₂= MLE sprayed two weeks interval after transplanting, M₃= MLE sprayed three weeks interval after transplanting.

The highest (44.34 t/ha) and lowest (31.14 t/ha) fruit yield found from M₁ and M₀ respectively (Table 3 and Figure 6). So, 42.38 % higher yield was found from M₁ compared to control. MLE contain phytohormones which increases the cell division and other metabolic activity of plants. It seems MLE spray at week interval is better compared to two or three weeks interval. MLE has the influence on crop production found significantly increased above ground dry matter yield (DM), root dry matter weight and plant height in tomato (Culver et al., 2012). Similarly, found significantly increased plant height; stem girth, number of leaves, cob weight, cob length, kernel row and cob girth of sweet corn from the the application of MLE (Fadare et al., 2018).

The highest yield in terms of cob weight was observed 16.8% and 16.3% higher than the control for dry and fresh methods, respectively. Besides, foliar spray of MLE applied at tillering stage of wheat increased biomass at the boot stage by 37% and grain yield increased by 34% compared to nil MLE spray (Brockman and Brennan, 2017). All the study indicate that it is necessary to fine tuning the application of MLE considering the different crops. Because, exogenous application of MLE has a positive effect on photosynthetic and enzymatic activities that improve the efficiency of nutrients that are utilized, thereby improving the growth, yield and quality of crop (Arif et al., 2019).

3.3 Combined effect of different types of fertilizers and MLE on growth and yield of tomato

The combined effect of different types of fertilizers and MLE on growth and yield found significant except fruit length and fruit diameter. The maximum plant height (59.90 cm) was found in F₃M₁ (2/3 F₁ + 1/3 F₂ + MLE sprayed in every week) treatment. It is interesting to note that the F₃M₁ treatment recorded 26.18% more plant height and the days to first flowering (28.00) in F₃M₁ which is 36.90% earlier than control treatment (Table 4). Among the yield contributing parameters the number of flowers/plant and number of fruits/plant is of special importance which

contributes a lot in having maximum total yield per plant and in this study it was F_3M_1 (2/3 vermicompost and 1/3 RDIF + MLE sprayed at every week interval) treatment which recorded maximum number of fruits/plant (25.67) and maximum number of flowers/plant recorded

(57.00) from F_3M_1 (1/3 RDIF + 2/3 vermicompost + MLE sprayed in one week interval). It is interesting to note here that F_3M_1 treatment recorded 185.22% more number of fruits in comparison to control.

Table 4: Combined effects of fertilizers and MLE on plant growth and yield of tomato

Treatment	No. of flower cluster/plant	No. of Fruit Cluster/Plant	No. of Fruits/Plant	Fruit Length (cm)	Fruit Diameter (cm)	Individual fruit weight (g)	Fruit weight/plant (kg)	Dry matter of fruit (%)
F_0M_0	4.33i	3.00k	9.000i	5.27	4.07	48.37g	0.50f	7.42h
F_0M_1	4.67i	4.67h	13.67g	5.97	4.47	59.44c	0.806e	8.86d
F_0M_2	4.67i	4.05i	11.33h	5.83	4.13	56.28de	0.580f	8.04f
F_0M_3	4.33i	3.33j	9.670i	5.60	4.07	52.18f	0.506f	8.11f
F_1M_0	5.33h	3.33j	11.67h	5.50	4.03	48.25g	0.740e	7.99f
F_1M_1	7.67ef	5.34g	17.00f	6.03	4.57	60.23c	0.950d	9.22bc
F_1M_2	6.33g	4.67h	16.67f	5.87	4.23	56.80de	0.940d	8.37e
F_1M_3	6.33g	4.67h	14.33g	5.67	4.17	55.02e	0.800e	8.88d
F_2M_0	7.33f	5.33g	18.67e	5.50	4.07	49.40g	0.970cd	7.71g
F_2M_1	9.00b	7.00b	24.00b	6.13	4.60	62.70b	1.43a	9.31b
F_2M_2	8.33cd	6.33d	22.33c	5.87	4.40	58.31 cd	1.25b	8.95cd
F_2M_3	7.33f	5.67f	18.67e	5.80	4.20	55.79e	1.03cd	9.02cd
F_3M_0	8.00de	5.70f	20.33d	5.70	4.10	52.21f	1.08c	8.44e
F_3M_1	11.0a	8.00a	25.67a	6.83	5.00	67.65a	1.52a	10.7a
F_3M_2	8.67bc	6.67c	25.33a	6.13	4.47	60.36c	1.43a	9.02cd
F_3M_3	8.00de	6.00e	21.67c	5.83	4.43	56.05de	1.29b	9.29b
SE ($\pm$)	0.139	0.091	0.404	0.223	0.114	0.755	0.037	0.088

Means followed by different letter(s) within a parameter are significantly different using DMRT. $\pm$ SE (standard error) are given for mean group of a parameter.

Here, F_0 = Control (No fertilizer), F_1 = Vermicompost, F_2 = Recommended dose of chemical fertilizer, F_3 = Combined fertilizers (2/3 F_1 + 1/3 F_2), and M_0 = Control (no MLE sprayed), M_1 = MLE sprayed at one week interval after transplanting, M_2 = MLE sprayed two weeks interval after transplanting, M_3 = MLE sprayed three weeks interval after transplanting.

F_3M_1 treatment had the highest fruit weight (67.65 g), higher fruit diameter (5.00 cm) and higher fruit length (6.83 cm). It can be noted here that F_3M_1 treatment recorded 22.85% higher fruit diameter, 29.60% higher fruit length, 44.2% higher dry matter content as compared to control. These results indicated the positives effects of integrating vermicompost + NPKS with MLE. MLE with fertilizers results better growth for high zeatin contents which enhance cell division. This finding is closely related to the data were collected on plant height, plant dry weight, CGR, NAR and fruit yield due to effects of aqueous extract of moringa and N rates with interactions on the parameters (Muhamman et al., 2013).

Figure 7: Combined effect of different organic, inorganic fertilizer and MLE on fruit yield of tomato

Vertical bars represent $\pm$ SE (standard errors). Same letter indicate are not statistically significantly. Here, F_0 = Control (No fertilizer), F_1 = Vermicompost, F_2 = Recommended dose of chemical fertilizer, F_3 = Combined fertilizers (2/3 F_1 + 1/3 F_2), and M_0 = Control (no MLE sprayed), M_1 = MLE sprayed at one week interval after transplanting, M_2 = MLE sprayed two weeks interval after transplanting, M_3 = MLE sprayed three weeks interval after transplanting. Among them most important yield contributing parameter is fruit yield per plant (g) which was noticed in the same treatment i.e. F_3M_1 treatment recorded highest fruit yield (1.52 kg) per plant and (57.00 t) per hectare. The

increased yield with integrated nutrient management application may be due to the fact that plant supplied with abundant NPKS continuously during plant growth and phytohormones resulting increased yield of the tomato. In case of other treatments combination, inorganic fertilizer become exhaustion due to quickly used by the plant; and vermicompost released slowly might not be fulfilling the demand continuously for the plant growth. Where as, MLE application at one week interval is the potential though supplement of zeatin and other phytohormones. So, treatment combination of integrated fertilizer and MLE spray at one week interval showed the great potentiality for growth and yield of plant.

4. CONCLUSION

Our findings revealed that about 75% less amount inorganic fertilizer and judiciously incorporated vermicompost as organic fertilizer increased the yield of tomato. Because, this integration of fertilizer application was compared with the sole application of inorganic and vermicompost as well. On the other hand, exogenous application of moringa leaf extract (MLE) at one week interval after transplanting showed the potential growth and yield of tomato compared to the MLE application at two and three weeks interval and control. In this experiment, the combined treatments of organic and inorganic fertilizer; and MLE are the sources of macro-micro nutrient and phytohormones which enhanced the better growth and yield of tomato. This work can promote the sustainable horticulture technology considering crop production, soil health and friendly environment. So, further work can be conducted on different varieties of tomato and other crops as well.

ACKNOWLEDGEMENT

The authors express their sincere thanks to the Ministry of Science and Technology for funding this research program through National Science and Technology (NST) fellowship.

AUTHOR CONTRIBUTIONS

Tatia Biswas assisted in the field data collection and prepared manuscript. M. Ashraful Islam designed field experiment, conducted data analysis and contributed for manuscript preparation. Tamanna Haque helped in manuscript review.

REFERENCES

- Afrin, A., Islam, M.A., Hossain, M.M., Hafiz, M.M.H., 2019. Growth and yield of carrot influenced by organic and inorganic fertilizers with irrigation interval. Journal of Bangladesh Agricultural University, 17 (3), Pp. 338-343. <https://doi.org/10.3329/jbau.v17i3.43207>
- Akhter, S., Islam, M.A., Karim, M.R., 2019a. Effects of nutrient management and netting on the growth and yield of okra. Fundamental and Applied Agriculture, 4 (1), Pp. 627-631.
- Akhter, M.M., Islam, M.A., Rahman, M.S., Rahman, M.H., Nandwani, D., 2019b. Effects of organic and inorganic fertilizer combination with

- insect netting on the production of Indian spinach (*Basella alba* L.). Archives of Agriculture and Environmental Science, 4 (3), Pp. 268-272. <https://dx.doi.org/10.26832/24566632.2019.040302>.
- Ansari, A.A., Jaikishun, S., Islam, M.A., Kuri, S.K., Fiedler, K., Nandwani, D., 2016. Principles of vermiculture in sustainable organic farming with special reference to Bangladesh In: Organic farming for sustainable agriculture. (Ed.) Nandwani D. Springer, Switzerland. Pp. 213-219.
- Arif, M., Kareem, S.H.S., Ahmad, N.S., Hussain, N., Yasmeen, A., Anwar, A., Naz, S., Iqbal, J., Shah, G.A., Ansar, M., 2019. Exogenously applied bio-stimulant and synthetic fertilizers to improve the growth, yield and fiber quality of cotton. MDPI Sustainability, 11, Pp. 2171-2185.
- Brockman, H.G., Brennan, R.F., 2017. The effect of foliar application of Moringa leaf extract on biomass, grain yield of wheat and applied nutrient efficiency. Journal of Plant Nutrition, 40 (19), Pp. 2728-2736. doi: 10.1080/01904167.2017.1381723.
- Chadha, S., Rana, S.S., Chaudhury, D.R., 2006. Nutrient management in summer onion (*Allium cepa*) under cold desert conditions of North Western Himalayas. Indian Journal of Agricultural Science, 76 (10), Pp. 629-631.
- Culver, M., Tagwira, F., Albert, Z.C., 2012. Effects of *Moringa* extract on growth and yield of Tomato. Greener Journal of Agricultural Science, 2(5), Pp. 207-211.
- Das, R., Mardal, A.R., Priya, A., Das, S.P., Kabiraj, J., 2015. Effect of integrated nutrient management on the performance of bottle gourd (*Lagenaria Siceraria*). Journal of Applied and Natural Science, 7 (1), Pp. 18-25.
- Davies, P., 2015. Plant hormones and their role in plant growth and development. N. d.: Milton Keynes.
- Fadare, A.F.K., Ayodeji, E.S., 2018. Potentials of *Moringa oleifera* leaf extracts as biostimulant on the field performance of sweetcorn. Journal of Biology, Agriculture and Healthcare, 8 (12), Pp. 50-56.
- FAOSTAT. 2019. Food and Agriculture Organization Corporate Statistical Database. Food and Agriculture Organization of the United Nations (FAO), Statistics Division.
- Farjana, S., Islam, M.A., Haque, T., 2019. Effects of organic and inorganic fertilizers, and mulching on growth and yield of cabbage (*Brassica oleracea* var. *capitata* L.). Journal of Horticulture and Postharvest Research. 2 (2), Pp. 95-104. http://jhpr.birjand.ac.ir/article_1033_167.html.
- Foidl, N., Makkar, H.P.S., Becker, K., 2001. The potential of *Moringa oleifera* for agricultural and industrial uses. In: Proceedings of the International Workshop. What development potential for *Moringa* products. Dares-Salaam, Tanzania, Pp. 47-67.
- FRG, 2012. Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council, Farmgate, Dhaka. Pp. 111.
- Fuglie, L.J., 1999. The miracle tree: *Moringa oleifera*. In: Natural Nutrition for the Tropics, p. 68. Dakar, Senegal: Church World Service.
- Gomez, K.A., Gomez, A.A., 1984. Statistical Procedure for Agricultural Research (2nd Edn.), John Wiley and Sons, New York. Pp. 28-92.
- Islam, M.A., Ferdous, S., Akter, A., Hossain, M.M., Nandwani, D., 2017a. Effect of organic and inorganic fertilizers on the growth and yield of cabbage with different planting spacing. MDPI Agriculture, Basel, Switzerland. 7, Pp. 31. doi:10.3390/agriculture7040031.
- Islam, M.A., Islam, S., Akter, A., Rahman, M.H., Nandwani, D., 2017b. Effect of organic and inorganic fertilizers on soil properties and the growth, yield and quality of tomato in Mymensingh, Bangladesh. MDPI Agriculture, Basel, Switzerland, 7 (3), Pp. 18. doi:10.3390/agriculture7030018.
- Islam, M.A., Jahan, N., Quadir, Q.F., Haque, S.M., 2020. Assessment of fishpond sediments for growth, yield and nutritional quality of Indian spinach (*Basella alba* L.). Archives of Agriculture and Environmental Science, 5 (1), Pp. 33-39. <https://dx.doi.org/10.26832/24566632.2020.050105>.
- Kumar, R., Prakash, O., 2019. The impact of chemical fertilizers on our environment and ecosystem. In Research Trends in Environmental Sciences, Pp. 69-86.
- Merwad, A.M.A., 2015. Effect of *Moringa oleifera* extracts on the growth, yield and nutrient uptake of spinach (*Spinacia oleracea* L.). Greener Journal of Soil Science and Plant Nutrition, 2 (1), Pp. 16-22.
- Muhamman, M.A., Auwalu, B.M., Manga, A.A., Jibrin, J.M., 2013. Effects of aqueous extract of moringa (*Moringa oleifera* Lam.) and nitrogen rates on some physiological attributes and yield of Tomato. International Journal of Chemical, Environmental and Biological Sciences, 1 (1), Pp. 67-74.
- Muhammed, A., Muhammed, H., Muhammed, W., Muhammed, R., Muhammed, I., 2013. Allelopathy of *Moringa*: A review. Science Agriculture, 3 (1), Pp. 9-12.
- Noctor, G., Foyer, C.H., 1998. Ascorbate and glutathione: Keeping active oxygen under control. Annual Review of Plant Physiology and Plant Molecular Biology, 49, Pp. 249-279.
- Phiri, C., 2010. Influence of *Moringa oleifera* leaf extracts on germination and early seedling development of major cereals. Agriculture and Biology Journal of North America, 1 (5), Pp. 774-777.
- Proseus, P., 2006. Biosynthesis-Plant Hormones and Growth Regulators: Chemistry and Biology. Biosynthesis Ag. Co. Switzerland.
- Sharma, A., Parmar, D.K., Kumar, P., Singh, Y., Sharma, R.P., 2008. Azotobacter soil amendment integrated with cow manures reduces need for NPK fertilizers in sprouting broccoli. International Journal of Vegetable Sciences, 14 (3), Pp. 273-285.
- Sreenivasa, M.N., Nagaraj, M.N., Bhat, S.N., 2010. Beejamruth: A source for beneficial bacteria. Karnataka Journal of Agricultural Science, 17, Pp. 72-77.
- Ullah, M.S., Islam, M.S., Islam, M.A., Haque, T., 2008. Effects of organic manures and chemical fertilizers on the yield of brinjal and soil properties. Journal of Bangladesh Agricultural University, 6, Pp. 271-276.
- UNDP. 1988. Land Resources Appraisal of Bangladesh for Agricultural Development, Report 2. Agro-ecological Regions of Bangladesh. BARC/UNDP, Farmgate, Dhaka. Pp. 212-221.