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Research Article


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# Vermicompost induced growth and yield performance of capsicum (*Capsicum annuum* L.) at sustainable rooftop farming system

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## ABSTRACT

Rooftop farming is gaining rapid popularity in urban areas, especially since the beginning of the global COVID-19 pandemic. For housebound people rooftop farming is not only a way of potentially management of their time but also the execution of creativity. For rooftop farming vermicompost (VC) can be the most sustainable media for growing high value fruits and vegetables crops. In this regard, an experiment was carried out as a rooftop farming system at Charfassion upzila in the Bhola district of Bangladesh to observe the growth and yield performance of capsicum (*Capsicum annuum*) grown in different combinations of vermicompost in the winter season (2020-2021). Different agronomic and yield parameters were measured at the intervals of 30, 60, and 90 days and at the final harvest of 120 days after sowing. Among the measured parameters a mixed type of performance was achieved from varied doses of vermicompost applications and inorganic fertilizer treatment. Among the measured valuable parameters; the highest fruit length (8.85 cm), fruit diameter (10.3 cm), no. of fruits (9.51 plant$^{-1}$), total wt. of fresh fruits (405.32 g/plant), fresh fruits yield (11.26 t ha$^{-1}$), no. of branches (30.0 plant$^{-1}$), stem girth (6.3 cm), root fresh wt. (8.80 g/plant), stem fresh wt. (23.35 g/plant), petiole fresh wt. (6.09 g/plant), total fresh biomass (65.54 g/plant), dry wt. of fruits (76.91 g/plant), dry wt. of total fruits: biomass ratio (7.35) and benefit-cost ratio (12.40), respectively, were observed in $T_5$ (20t VC ha$^{-1}$). So, from the overall findings of this study $T_5$ with 20t VC application ha$^{-1}$ is recommended to achieve better growth and yield of capsicum through the sustainable way of rooftop and urban farming systems and to improve soil fertility status.

**KEYWORDS:** Capsicum, Vermicompost, Rooftop Gardening, Sustainable Farming

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## INTRODUCTION

*Capsicum annum* L. belongs to the family Solanaceae. It is an annual herb or shrub, a profusely branching bushy plant (Aminifard & Bayat, 2016; Gangadhar *et al.*, 2020). The species of this family are consumed as a salad in big cities restaurants, and it interred into family dining in the sub-continent (Aminifard & Bayat, 2016). It is a rich source of vitamin A, C, E, ascorbic acid, carotenoids and phenolic compounds and is considered an excellent source of antioxidants in human diets (Reddy *et al.*, 2017; Gangadhar *et al.*, 2020). Most of the chilies are belongs to the genus Capsicum, and it is believed to have originated in the mountain ranges of Peru of South America. It was first introduced to India by the Portuguese at the end of the 15$^{th}$ century and now is widely distributed in all tropical and sub-tropical countries including India (Gangadhar *et al.*, 2020). Off season vegetables are best suited for production on small farms and play a major role in the economic exhilaration of small and marginal farmers, who constitute the major (~80%) farming community, especially in rural areas. Capsicum is considered as money-spinner for hill farmers as they fetch high remuneration due to off-season cultivation (Sharma *et al.*, 2010; Jaipaul *et al.*, 2011).

In organic farming, nutrients are supplied through different sources of nutrients *viz.*, farmyard manure (FYM), vermicompost, poultry manure, and sheep manure etc. Vermicompost is the casting from the earth worms produced by different species of

*Eisenia fetida*, *Eudrilus eugeniae*, and *Perionyx excavates* etc. extensively used in vegetable production (Gangadhar *et al.*, 2020). After, the green revolution, an increase in production was achieved at the cost of soil health. Sustainable production at higher levels is possible only by the proper use of inputs which will help to increase the organic matter content of soils, thus reducing the bulk density and decreasing compaction. Vermicompost is added from time to time and further added to store of organic matter (Palaniappan & Annadurai, 1999; Gangadhar *et al.*, 2020). There has been a growing awareness to reduce the application of inorganic fertilizers to soils at a global level in order to avoid their adverse effects. Vermicompost's are stabilized and non-thermophilic products, which are produced by interactions of earthworms and microorganisms and have great potential as soil amendments. Vermicompost's are finely divided peat-like materials with high porosity, aeration, drainage, water holding capacity and microbial activities, which make them excellent soil amendments or conditioners (Aminifard & Bayat, 2016). A study has revealed that vermicompost may be potential sources of nutrients for field crops if applied in suitable ratios with synthetic fertilizers. Also, vermicompost may contain some plant growth-stimulating substances. Vermicompost contains some plant growth hormones and humic acids which improve the growth and yield of plant crops (Zaman *et al.*, 2018). Humic acid enhances the soil moisture content and vermicompost retains more water than other manures (Godavari *et al.*, 2017). The addition of vermicompost and chemical fertilizer to the field crop could be a very good option considering the nutrient availability for maintaining soil fertility and productivity (Zaman *et al.*, 2018). It has been widely accepted that organic farming alone could serve as a holistic approach towards achieving sustainable agriculture as it is nature based, environment friendly and ensures the conservation of resources for the future (Reddy *et al.*, 2017) and is perfectly suited for rooftop gardening in urban areas. For the above context, the present experiment was undertaken to determine the growth and yield performance of capsicum (*Capsicum annuum*) with the influence of vermicompost at rooftop farming system, mainly to accelerate the urban farming concept.

## MATERIALS AND METHODS

### Plant Materials, Study Area and Experimental Design

A pot experiment was carried out on the rooftop of Mr. Alauddin's house at Charfesson Upzila in Bhola district of Bangladesh to find out the growth and yield performance of capsicum (*Capsicum annuum*) with the application of vermicompost in the winter season (2020-2021). Soil samples (0-15 cm depth) were collected from the paddy field of the Research farm of Charfasson Govt. College. The samples were air dried, ground and sieved through a 3 mm sieve for chemical analysis and a 2 mm sieve for physical analysis. The laboratory analysis revealed the soil's physical and chemical properties as; soil pH 8.36, organic C 0.63%, available N 0.24%, available P 0.06%, available K 1.23%, available S 0.15%, sand 12.3%, silt 51.34% and clay 36.36%, the maximum water retention capacity was 37% and textural class of the soil was silty clay loam, respectively). Thai variety capsicum seeds were bought from nearby seed shops. The experiment was laid out in a completely randomized block design having seven treatments with three replications. Each pot was filled with ten kg of prepared soil. The treatments were $T_1$: 0.0t VC ha$^{-1}$ (control), $T_2$: 5t VC ha$^{-1}$, $T_3$: 10t VC ha$^{-1}$, $T_4$: 15t VC ha$^{-1}$, $T_5$: 20t VC ha$^{-1}$, $T_6$: 25t VC ha$^{-1}$ and $T_7$: 50% (NPK: 40:15:25 kg ha$^{-1}$). Recommended basal doses of NPK (20-10-15 kg ha$^{-1}$) were applied to each treatment except the treatment of 50% recommended doses of NPK. The doses were selected according to the Fertilizer Recommendation Guide of the Bangladesh Agricultural Research Council (BARC, 2018). At the time of initial pot soil preparation; vermicompost was added at the final pot soil filling; N, P and K were applied as urea, triple super phosphate and muriate of potash, respectively. Two seeds were sown into each pot on 29 December 2020. After two weeks of germination, one seedling was removed keeping the healthiest one. Intercultural practices i.e., weeding, spading, fencing, pesticide *etc.* were applied when needed. Different agronomic parameters *viz.*, plant height, leaf number, leaf area, leaf area index and number of fruits were measured at the intervals of 30, 60 and 90 days after sowing of seeds. Finally, plants were harvested after 120 days of sowing seeds at the period of maturity. Different organs of capsicum plants *viz.*, stem, root, leaf, fruit petiole and fruits were collected and measured fresh weight and then dried in an oven at a temperature of 65° C. The dry weight of different growth parameters and fruits were measured and kept in airtight plastic bags separately.

## STATISTICAL ANALYSIS

Recorded data were analyzed by using one-way ANOVA test of SPSS version 17.0 and a difference of mean among treatments were determined by Least Significance Difference (LSD) test at 5% level of significance.

## RESULTS AND DISCUSSION

### Plant Growth Parameters

The results of growth parameters are discussed in Table 1 and 2. Most of the growth parameters were found statistically significant ($P<0.05$) over the control treatments and in some cases, treatments to treatments were observed statistically identical.

### Plant Height and Leaf Number

Results showed that plant height (cm) and leaf numbers (plant$^{-1}$) were gradually increased with the growth period irrespective of the treatments and the values were statistically significant ($P\leq0.05$) over the control at 30, 60, 90 and 120 days (at harvest, Table 1). Moreover, plant height (cm) and leaf numbers (plant$^{-1}$) also increased with the increased levels of vermicompost in most of the cases. The maximum plant height (21.50 cm) and highest numbers of leaves (202.5 plant$^{-1}$) at harvest were recorded in the treatment $T_3$ (10t VC ha$^{-1}$) and $T_2$ (5t VC ha$^{-1}$), respectively. In most of the cases the initial two treatments ($T_2$ and $T_3$) with the lowest doses of VC application and $T_7$ with the highest doses of NPK application (50% NPK: 40:15:25 kg ha$^{-1}$) exhibited non-significant ($P \geq 0.05$) variation with control treatments, but on an average the lowest values were recorded in the control treatment (Table 1). Furthermore, in between 50% NPK treatments and vermicompost treatments; vermicompost showed better results than NPK for plant height and numbers of leaves. Belliturk *et al.* (2017) found that vermicompost can easily be used with P and K fertilization for higher growth and yield of pepper (*Capsicum annuum* L.). Rekha *et al.* (2018) showed that the application of 50% vermicompost significantly improved all parameters like; length of shoot, length of inter node, number of leaves and number of branches in *Capsicum annum* plants.

## Leaf Area ($cm^2$) and Leaf Area Index

Results showed that leaf area ($cm^2$) and leaf area index were significantly ($P < 0.5$) increased over the control in most of the cases (Table 2). The findings further revealed that leaf area ($cm^2$) and leaf area index gradually increased with the growth period irrespective of the treatments. Moreover, the parameters also increased with the increase of different levels of vermicompost in most of the cases.

However, the variations among the treatments, in most of the treatments were found statistically not significant. The highest leaf area (31.25 $cm^2$) and leaf area index (8.98) at harvest were found in the treatments $T_6$ (25t VC $ha^{-1}$) and $T_3$ (10t VC $ha^{-1}$), respectively. Minimum values were recorded in the control treatment in most cases. Reddy *et al.* (2017) opined that the application of vermicompost showed a significant increase in leaf area and leaf area index and overall growth and yield of chili.

## Effects of Vermicompost on Different Fruit Parameters of Capsicum Plant

The performance of vermicompost and NPK 50% on the different observations of fruits of capsicum plant are shown in Table 3.

## Days to First Flowering

Significantly ($P \leq 0.05$) the minimum days (48.35 DAS) to first flowering was counted in treatment $T_5$ (20t VC $ha^{-1}$) whereas the highest days (58.17 DAS) was recorded in the control treatment. This means that the $T_5$ treatment exhibited a better response among other vermicompost and NPK 50% treatment, respectively (Table 3). Ganeshnauth *et al.* (2018) and Bilal *et al.* (2019) also reported similar findings that the application of vermicompost significantly reduced the days to first flowering in different chili varieties.

## Fruits Length (cm) and Fruits Girth (cm)

Analysis results revealed that significantly ($P \leq 0.05$) the highest fruit length (8.85 cm) and fruits girth (10.30 cm), respectively, were also produced under the treatment $T_5$ (20t VC $ha^{-1}$) whereas the lowest value was recorded in the control treatment for both of the parameters (Table 3). Rekha *et al.* (2018) and Rahman and Akter (2019) also opined those different doses of vermicompost applications significantly increased the fruit length and diameter of capsicum. However, statistically identical results were observed among most of the treatments for fruit diameter.

**Table 1: Effects of vermicompost on the height (cm) and number of leaves ($plant^{-1}$) of capsicum plant**

| Treatments | Height (cm) | | | | Numbers of leaf ($plant^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | Days after sowing | | | | | | | |
| | 30 | 60 | 90 | At harvest | 30 | 60 | 90 | At harvest |
| $T_1$: Control (Without VC) | $9.25^b$ | $11.75^b$ | $16.5^{ab}$ | $19.0^{ab}$ | $32.0^b$ | $51.67^b$ | $100.0^{cd}$ | $117.5^b$ |
| $T_2$: 5t vermicompost $ha^{-1}$ | $11.0^b$ | $11.00^b$ | $13.5^b$ | $14.5^b$ | $37.5^b$ | $69.00^b$ | $103.0^c$ | $202.5^a$ |
| $T_3$: 10t vermicompost $ha^{-1}$ | $14.0^{ab}$ | $18.00^a$ | $20.0^a$ | $21.5^a$ | $48.0^{ab}$ | $83.50^{ab}$ | $92.0^c$ | $107.5^c$ |
| $T_4$: 15t vermicompost $ha^{-1}$ | $11.5^{ab}$ | $13.50^{ab}$ | $16.0^{ab}$ | $16.5^{ab}$ | $49.5^{ab}$ | $90.50^{ab}$ | $116.0^a$ | $125.0^{bc}$ |
| $T_5$: 20t vermicompost $ha^{-1}$ | $15.0^a$ | $17.00^{ab}$ | $18.0^{ab}$ | $19.0^{ab}$ | $53.5^a$ | $115.00^a$ | $108.5^b$ | $150.0^b$ |
| $T_6$: 25t vermicompost $ha^{-1}$ | $11.35^b$ | $18.50^a$ | $21.5^a$ | $18.5^{ab}$ | $55.5^a$ | $95.00^{ab}$ | $108.0^b$ | $130.0^{bc}$ |
| $T_7$: 50% (NPK: 40:15:25 kg $ha^{-1}$) | $13.0^{ab}$ | $16.50^{ab}$ | $17.5^{ab}$ | $18.75^{ab}$ | $54.5^a$ | $86.50^{ab}$ | $100.0^{cd}$ | $95.0^c$ |
| LSD at 5% | 3.57 | 5.55 | 6.03 | 6.16 | 13.61 | 42.75 | 32.21 | 38.25 |

VC=Vermicompost. RDF=Recommended Doses of Fertilizers. [abc]Data bearing different superscripts in the same column differ significantly at 5% level

**Table 2: Effects of vermicompost on the leaf area ($cm^2$) and leaf area index of capsicum plant**

| Treatments | Leaf area ($cm^2$) | | | | Leaf area index ($plant^1$) | | | |
|---|---|---|---|---|---|---|---|---|
| | Days after sowing | | | | | | | |
| | 30 | 60 | 90 | At harvest | 30 | 60 | 90 | At harvest |
| $T_1$: Control (Without VC) | $11.75^b$ | $15.00^b$ | $13.25^e$ | $19.50^d$ | $0.17^f$ | $1.54^c$ | $2.50^b$ | $4.32^b$ |
| $T_2$: 5t vermicompost $ha^{-1}$ | $12.75^b$ | $15.75^b$ | $13.50^e$ | $19.25^d$ | $0.90^e$ | $2.05^c$ | $2.62^b$ | $7.33^{ab}$ |
| $T_3$: 10t vermicompost $ha^{-1}$ | $17.75^b$ | $25.50^a$ | $28.75^a$ | $24.00^b$ | $1.56^b$ | $4.01^a$ | $4.98^a$ | $8.98^a$ |
| $T_4$: 15t vermicompost $ha^{-1}$ | $13.25^b$ | $25.50^a$ | $18.00^d$ | $30.50^a$ | $1.24^d$ | $4.35^a$ | $3.93^a$ | $7.19^{ab}$ |
| $T_5$: 20t vermicompost $ha^{-1}$ | $13.75^b$ | $21.63^{ab}$ | $21.63^c$ | $21.25^c$ | $1.39^c$ | $4.69^a$ | $4.42^{ab}$ | $6.00^{ab}$ |
| $T_6$: 25t vermicompost $ha^{-1}$ | $13.88^b$ | $13.81^b$ | $26.00^b$ | $31.25^a$ | $1.45^b$ | $2.47^{bc}$ | $5.29^a$ | $7.95^a$ |
| $T_7$: 50% (NPK: 40:15:25 kg $ha^{-1}$) | $19.50^a$ | $19.38^b$ | $18.63^d$ | $23.70^b$ | $1.98^a$ | $3.16^b$ | $3.51^{ab}$ | $4.24^b$ |
| LSD at 5% | 5.49 | 5.99 | 10.66 | 9.25 | 0.14 | 0.88 | 2.16 | 3.47 |

VC=Vermicompost, [abc]mean values bearing different superscripts in the same column differ significantly at 5% level

## Number of Fruits and Average Weight of Fruits

No. of fruits (plant$^{-1}$) and average weight of fruits (g) were also measured significantly ($P \leq 0.05$) higher under vermicompost treatments over the control treatment (Table 3). The highest no. of fruits (9.51 plant$^{-1}$) was counted under treatment $T_5$ (20t VC ha$^{-1}$), and the maximum weight of fruits (44.0 g) were recorded under treatment $T_6$ (25t VC ha$^{-1}$), respectively. Ganeshnauth *et al.* (2018) and Bilal *et al.* (2019) reported that vermicompost application was very effective to increase the no. of fruits and average fruit weight of capsicum. Significantly the lowest values were also measured in the control treatment for both parameters. Results further revealed that no. of fruits (plant$^{-1}$) and average weight of fruits (g) were also found statistically identical among other treatments for most of the cases.

## Total Weight of Fresh Fruits (g/plant) and Yield (t/ha)

Total weight of fresh fruits (g plant$^{-1}$) and yield (t ha$^{-1}$) differed significantly ($P \leq 0.05$) over the control treatment (Table 3). The highest total wt. of fresh fruits (405.32 g plant$^{-1}$) and yield (11.26 t ha$^{-1}$) were measured under the same treatment of $T_5$ (20t VC ha$^{-1}$). In comparison to different vermicompost treatments and 50% NPK, vermicompost treatments showed better results over NPK in respect of fruit production in most of the cases. So, from the findings it is proven that vermicompost itself is sufficient to provide all required nutrients for better growth and yield of capsicum at rooftop gardening system as a medium of organic and urban farming. Another study conducted by Aminifard and Bayat (2016) also showed that the highest fruits yield in capsicum was achieved in plants treated with 5t ha$^{-1}$ vermicompost. Results further revealed that fresh fruits yield per plants statistically continues to increase with the increase of vermicompost application until treatment $T_5$ (20t VC ha$^{-1}$) with the maximum production, but a further increase of vermicompost application ($T_6$: 25t VC ha$^{-1}$) drastically reduced the fresh fruit production, though it was the second highest fresh fruit production. So, among all those vermicompost treatment $T_5$ (20t VC ha$^{-1}$) was the best and recommended for the highest and most sustainable production of capsicum without increasing extra cost by applying over doses of vermicompost.

## Effects of Vermicompost on other Morphology and Fresh Weight of Different Organs of Capsicum Plant

The numbers of branches, root length (cm), stem diameter (cm) and fresh weight of different organs of capsicum plants were also significantly affected by the induced effect of vermicompost and NPK 50% fertilizer application (Table 4).

## Number of Branches Plant$^{-1}$

The number of branches was counted at final harvest and observed that the highest no. of branches plant$^{-1}$ (30.0) were produced by the plants grown under treatment $T_5$ (20t VC ha$^{-1}$), followed by $T_6$ (29.33), which was statistically non-significant with $T_5$, while the minimum numbers of branches (16.0) were counted at control treatment $T_1$. Statistically identical ($P \geq 0.05$) results were found under treatments $T_3$, $T_4$ and $T_7$, respectively (Table 4).

## Stem Girth and Root Length (cm)

Stem girth or diameters of capsicum under different vermicompost treatments and inorganic fertilizer were found

**Table 3: Effect of vermicompost on the fruits parameters of capsicum plant**

| Treatments | Days to first flowering | Fruit length (cm) | Fruit girth (cm) | No. of fruits (plant$^{-1}$) | Average wt. of fruits (g) | Total fresh wt. of fruits (g/plant) | Yield (t ha$^{-1}$) |
|---|---|---|---|---|---|---|---|
| $T_1$: Control (Without VC) | 58.17$^{a}$ | 4.50$^{c}$ | 6.30$^{d}$ | 6.88$^{b}$ | 20.10$^{e}$ | 138.29$^{e}$ | 3.84$^{d}$ |
| $T_2$: 5t vermicompost ha$^{-1}$ | 55.67$^{ab}$ | 6.50$^{bc}$ | 8.67$^{c}$ | 6.20$^{b}$ | 25.41$^{d}$ | 157.54$^{d}$ | 4.38$^{d}$ |
| $T_3$: 10t vermicompost ha$^{-1}$ | 53.87$^{bc}$ | 5.50$^{c}$ | 7.16$^{cd}$ | 7.54$^{ab}$ | 36.33b$^{c}$ | 273.93$^{c}$ | 7.61$^{bc}$ |
| $T_4$: 15t vermicompost ha$^{-1}$ | 54.33$^{b}$ | 7.60$^{b}$ | 9.87$^{ab}$ | 9.11$^{ab}$ | 34.20$^{c}$ | 311.56$^{b}$ | 8.65$^{bc}$ |
| $T_5$: 20t vermicompost ha$^{-1}$ | 48.35$^{d}$ | 8.85$^{a}$ | 10.30$^{a}$ | 9.51$^{a}$ | 42.62$^{ab}$ | 405.32$^{a}$ | 11.26$^{a}$ |
| $T_6$: 25t vermicompost ha$^{-1}$ | 49.17$^{d}$ | 6.88$^{b}$ | 9.60$^{b}$ | 7.56$^{ab}$ | 44.00$^{a}$ | 332.64$^{b}$ | 9.24$^{b}$ |
| $T_7$: 50% (NPK: 40:15:25 kg ha$^{-1}$) | 52.67$^{c}$ | 5.27$^{c}$ | 7.17$^{cd}$ | 7.10$^{b}$ | 37.21$^{b}$ | 264.19$^{c}$ | 7.34$^{c}$ |
| LSD at 5% | 16.9/NS | 1.13 | 3.07 | 2.24 | 10.72 | 31.27 | 1.7 |

VC=Vermicompost, DAS: Days after sowing, $^{abc}$Data bearing different superscripts in the same column differ significantly at 5% level

**Table 4: Effects of vermicompost on morphology and fresh weight of different organs and harvesting traits of capsicum plant**

| Treatments | Branches (plant$^{-1}$) | Root length (cm) | Stem girth (cm) | Fresh weight (g plant$^{-1}$) | | | | | | Biomass: Fruits ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Root | Stem | Petiole | Leaf | Total biomass | Fruits fresh biomass (g/plant) | |
| $T_1$: Control (No VC) | 16.00$^{d}$ | 7.33$^{d}$ | 3.50$^{d}$ | 4.25$^{e}$ | 10.26$^{e}$ | 3.87$^{d}$ | 17.96$^{e}$ | 36.33$^{d}$ | 138.29$^{e}$ | 0.26$^{b}$ |
| $T_2$: 5t vermicompost ha$^{-1}$ | 28.17$^{b}$ | 11.00$^{c}$ | 4.25$^{c}$ | 4.69$^{de}$ | 19.48$^{c}$ | 4.72$^{c}$ | 25.8$^{6c}$ | 56.42$^{c}$ | 157.54$^{d}$ | 0.36$^{a}$ |
| $T_3$: 10t vermicompost ha$^{-1}$ | 24.33$^{c}$ | 14.67$^{a}$ | 4.88$^{c}$ | 5.79$^{c}$ | 18.63$^{c}$ | 4.44$^{c}$ | 26.78$^{bc}$ | 55.64$^{c}$ | 273.93$^{c}$ | 0.20$^{c}$ |
| $T_4$: 15t vermicompost ha$^{-1}$ | 24.67$^{c}$ | 13.00$^{ab}$ | 5.67$^{ab}$ | 6.05$^{c}$ | 20.19$^{b}$ | 4.68$^{c}$ | 24.52$^{d}$ | 55.44$^{c}$ | 311.56$^{b}$ | 0.18$^{c}$ |
| $T_5$: 20t vermicompost ha$^{-1}$ | 30.00$^{a}$ | 12.00$^{b}$ | 6.30$^{a}$ | 8.80$^{a}$ | 23.35$^{a}$ | 6.09$^{a}$ | 27.30$^{b}$ | 65.54$^{a}$ | 405.32$^{a}$ | 0.16$^{c}$ |
| $T_6$: 25t vermicompost ha$^{-1}$ | 29.33$^{a}$ | 12.50$^{b}$ | 5.50$^{b}$ | 7.54$^{b}$ | 21.22$^{ab}$ | 5.01$^{b}$ | 27.62$^{b}$ | 61.39$^{b}$ | 332.64$^{b}$ | 0.18$^{c}$ |
| $T_7$: 50% (NPK: 40:15:25 kg ha$^{-1}$) | 25.33$^{c}$ | 12.33$^{b}$ | 4.58$^{c}$ | 5.21$^{d}$ | 16.30$^{d}$ | 4.53$^{c}$ | 28.27$^{a}$ | 54.31a$^{c}$ | 264.19$^{c}$ | 0.21$^{c}$ |
| LSD at 5% | 8.7 | 4.19 | 1.06 | 0.72 | 10.03 | 2.12 | 7.3 | 22.13 | 31.27 | 0.08 |

VC=Vermicompost, $^{abc}$mean values bearing different superscripts in the same column differ significantly at 5% level to differ significantly with the highest stem diameter (6.30 cm) under treatment $T_5$ (20t VC $ha^{-1}$) followed by T4 (5.67 cm) and the lowest stem girth was measured under control treatment (3.50 cm), respectively (Table 4). Furthermore, statistically identical ($P \geq 0.05$) stem diameter was observed under treatment $T_2$, $T_3$ and $T_7$, respectively. On the other hand, significantly ($P \leq 0.05$) the highest root length (14.67 cm) was measured at $T_3$ (10t VC $ha^{-1}$) followed by $T_4$ (13.0 cm) and the lowest was seen under control treatment (7.33 cm), respectively. Moreover, root length under $T_5$, $T_6$ and $T_7$ were found statistically non-significant ($P \geq 0.05$). Arora *et al.* (2011) reported that vermicompost stimulates to influence the microbial activity of the soil, increases the availability of oxygen, maintains normal soil temperature, increases soil porosity and infiltration of water, improves nutrient content and increases growth, yield and quality of the plant.

## Fresh Weight of Stem and Root (g)

Both the fresh weight of the stem and roots were significantly affected by the application of different doses of vermicompost and chemical fertilizer. Interestingly both the highest stem fresh weight (23.35 g) and root fresh weight (8.80 g) were measured under treatment $T_5$ (20t VC $ha^{-1}$). Stem and root fresh weight under chemical fertilizer treatment $T_7$ (50% NPK: 40:15:25 kg $ha^{-1}$) were lower in comparison to most of the vermicompost treatments but were higher over the control treatment. Increased shoot and root biomass production in chili peppers by the application of different types of vermicompost has been reported by Ganeshnauth *et al.* (2018). Furthermore, statistically non-significant values were also seen among different vermicompost treatments for both measured parameters (Table 4).

## Fresh Weights of Petiole and Leaves

Results showed that the fresh weight of the petiole was significantly ($P \leq 0.05$) increased over the control with the highest petiole fresh weight (6.09 g) under treatment $T_5$ (20t VC $ha^{-1}$), followed by $T_6$ (5.01 g; 25t VC $ha^{-1}$) and the lowest was measured at control treatment $T_1$ (3.87 g; no VC), respectively (Table 4). All other vermicompost treatments ($T_2$, $T_3$, $T_4$) including 50% NPK ($T_7$) treatments showed non-significant variations for both measured parameters. On the other hand, very interestingly $T_7$ (50% NPK: 40:15:25 kg $ha^{-1}$) exhibited the highest leaf biomass (28.27 g) compared to all other vermicompost treatments including control. This finding may be due to the effect of inorganic fertilizer on increasing above ground biomass of plants (Tong *et al.*, 2019). But as usual the second highest leaf biomass was measured under vermicompost treatments $T_5$ (27.30 g) and $T_6$ (27.62 g) and the lowest (17.96 g) was found under control treatment $T_1$, respectively (Table 4).

## Fresh Weight of Total Biomass

The fresh weight of total biomass (g $plant^{-1}$) was found significantly ($P \leq 0.05$) higher than the control treatment (Table 4). The highest total fresh biomass (65.54 g) was produced under treatment $T_5$ (20t VC $ha^{-1}$), followed by $T_6$ (61.39 g; 25t VC $ha^{-1}$), while under treatment $T_7$ (only NKP 50%) the total biomass weight was lower compared to all other vermicompost treatments, though they were statistically identical, the lowest (36.33 g) total biomass was measured under control treatment (Table 4). Alaboz *et al.* (2017) showed that pepper plant height, root weight, and yield were significantly higher under different ratios of vermicompost applications. On the other hand, Gangadhar *et al.* (2020) revealed that the application of vermicompost on N equivalent basis had recorded significantly higher growth parameters *viz.*, plant height, leaf area, leaf area index and total dry matter accumulation at harvest.

## Total Fresh Biomass: Total Fresh Fruits Biomass Ratio

From the findings of the study significantly the highest total fresh biomass over total fresh fruits biomass ratio (0.36) was measured at the lowest vermicompost treatment application $T_2$ (5t VC $ha^{-1}$), followed by control treatment $T_1$ (0.26; no VC treatment), while statistically similar ratios were observed among all other vermicompost treatments including 50% NPK treatments as well (Table 4). Pariari and Khan (2013) observed that the yield attributes including fruit yield were found maximum also with nitrogen received from vermicompost and urea at 50% level.

## Dry Biomass of Plant Parts and Fruits and their Ratios

From the overall findings it was observed that the dry weight of root, petiole and leaves (g $plant^{-1}$) differed non-significantly ($P \leq 0.05$) over the control treatment (Table 5). Furthermore, the highest dry mass for stem (4.77 g $plant^{-1}$) was measured at treatment $T_3$ (10t VC $ha^{-1}$) and the lowest (2.24 g $plant^{-1}$) was found under control treatment $T_1$, while the values under other

**Table 5: Effects of vermicompost on the dry weight of different organs of capsicum plant**

| Treatments | Dry weight (g $plant^{-1}$) | | | | | | Fruits: Total dry mass ratio |
|---|---|---|---|---|---|---|---|
| | Root | Stem | Petiole | Leaves | Total dry mass | Fruits dry mass | |
| $T_1$: Control (No VC) | 1.08 | $2.24^{b}$ | 0.65 | 2.98 | $6.95^{b}$ | $25.14^{e}$ | $3.62^{d}$ |
| $T_2$: 5t vermicompost $ha^{-1}$ | 1.12 | $3.15^{ab}$ | 1.23 | 4.41 | $9.84^{ab}$ | $29.72^{d}$ | $3.02^{e}$ |
| $T_3$: 10t vermicompost $ha^{-1}$ | 1.55 | $4.77^{a}$ | 0.94 | 5.20 | $12.46^{a}$ | $51.20^{c}$ | $4.11^{cd}$ |
| $T_4$: 15t vermicompost $ha^{-1}$ | 1.47 | $3.95^{ab}$ | 0.59 | 3.25 | $9.25^{ab}$ | $59.34^{b}$ | $6.42^{b}$ |
| $T_5$: 20t vermicompost $ha^{-1}$ | 1.65 | $4.02^{ab}$ | 0.84 | 3.95 | $10.47^{ab}$ | $76.91^{a}$ | $7.35^{a}$ |
| $T_6$: 25t vermicompost $ha^{-1}$ | 2.21 | $4.54^{ab}$ | 0.85 | 3.61 | $11.20^{ab}$ | $60.04^{b}$ | $5.36^{c}$ |
| $T_7$: 50% (NPK: 40:15:25 kg $ha^{-1}$) | 1.75 | $3.57^{ab}$ | 0.97 | 4.24 | $10.53^{ab}$ | $52.84^{bc}$ | $5.02^{c}$ |
| LSD at 5% | NS | 2.34 | NS | NS | 5.09 | 8.00 | 0.95 |

VC=Vermicompost, $^{abc}$Data bearing different superscripts in the same column differ significantly at 5% level

**Table 6: Benefit-Cost ratio of capsicum cultivation by the using of different level of vermicompost**

| Treatments | Yield (t ha$^{-1}$) | Selling rate (ha$^{-1}$) | Gross return (BDT.) | Cost of cultivation (BDT.) | Net return (BDT.) | Benefit Cost ratio |
|---|---|---|---|---|---|---|
| $T_1$: Control (No VC) | 3.84 | 100000 | 384000 | 64050 | 319950 | 5.00 |
| $T_2$: 5t vermicompost ha$^{-1}$ | 4.38 | 100000 | 438000 | 69050 | 368950 | 5.34 |
| $T_3$: 10t vermicompost ha$^{-1}$ | 7.61 | 100000 | 761000 | 74050 | 686950 | 9.28 |
| $T_4$: 15t vermicompost ha$^{-1}$ | 8.65 | 100000 | 865000 | 79050 | 785950 | 9.94 |
| $T_5$: 20t vermicompost ha$^{-1}$ | 11.26 | 100000 | 1126000 | 84050 | 1041950 | 12.40 |
| $T_6$: 25t vermicompost ha$^{-1}$ | 9.24 | 100000 | 924000 | 89050 | 834950 | 9.38 |
| $T_7$: 50% (NPK: 40:15:25 kg ha$^{-1}$) | 7.34 | 100000 | 734000 | 65300 | 668700 | 10.24 |

VC=Vermicompost; BDT. Bangladeshi taka, selling rates were considering its freshness and fruits size. All inputs and selling rate were considered to local market prices. The price of fruits will be varied year to year, so it depends on harvesting period and market price

treatments were deferred non-significantly. For total dry mass, the highest value (12.46 g plant$^{-1}$) was also noted at treatment $T_3$ (10t VC ha$^{-1}$) and significantly the lowest total dry mass (6.95 g plant$^{-1}$) was measured under control treatment $T_1$, while the total dry mass values for other treatments were statistically similar (Table 5). Significantly the highest total fruit dry matter (76.91 g plant$^{-1}$) was measured at treatment $T_5$ (20t VC ha$^{-1}$) followed by $T_6$ and $T_4$ (statistically identical) and the lowest total fruit dry matter (25.14 g plant$^{-1}$) was counted under control treatment $T_1$, respectively. Alauddin *et al.* (2021) reported that the application of organic manure significantly increased dry matter production plant$^{-1}$ of sunflower. The total dry mass and fruit dry mass ratios differed significantly among treatments, while the highest ratio (7.35) was observed at $T_5$ (20t VC ha$^{-1}$), followed by $T_4$ (6.42) and the lowest was seen under treatment $T_2$ (3.02; 5t VC ha$^{-1}$). On the other hand, the ratios under the highest doses of vermicompost treatment $T_6$ (25t VC ha$^{-1}$) and only NPK treatment $T_7$ varied non-significantly (Table 5).

### Benefit-Cost ratios

Variable benefit-cost ratios were observed among the treatments (Table 6). Economic analysis of the yield of capsicum fruits showed that the highest benefit-cost ratio (12.40) was found in the $T_5$ treatment (20t VC ha$^{-1}$). The next highest benefit-cost ratio was (10.24) under treatment $T_7$ ($N_{40}P_{15}K_{25\ kg}$ ha$^{-1}$) where only NPK fertilizers were used. Similarly, the lowest benefit-cost ratio (5.00) was recorded in the control treatment where no vermicompost was added except a basal dose of NPK. So, undoubtedly $T_5$ (20t VC ha$^{-1}$) can be recommended for successful growth and yield of capsicum considering the highest benefit-cost ratios at roof top farming system.

## CONCLUSIONS

From the overall findings of this study, it has been clearly observed that capsicum plant growth and fruit yield were increased as vermicompost quantities were increased and the best performance was achieved under treatment $T_5$ with 20t vermicompost application ha$^{-1}$. The capsicum plant growth and fruit yield did not improve significantly even though the vermicompost application continued to increase further. From the results it is also evident that the application of only NPK 50% (40:15:25 kg ha$^{-1}$) couldn't show acceptable outcomes except for some improvement of minor parameters, so it can never be justified to use only chemical fertilizers for any crop production prioritizing the issues on human health and environmental pollution. From the final benefit-cost analysis also the highest ratios were achieved from treatment $T_5$. So, indisputably treatment $T_5$ (20t VC ha$^{-1}$) can be recommended for the efficacious plant growth and yield of not only capsicum but also other suitable vegetable crops by the environmentally friendly vermicompost application through the sustainable way of rooftop and urban farming system.

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## AUTHOR CONTRIBUTIONS

Data curation, M. R.; Formal analysis, M. A.; Funding, Supervision, & Project administration, M. K. R; Methodology, M. A.; Resources, G. M. M. & M. S. R.; Writing original draft, M. A.; Writing review & editing, M. A. A.

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