

Original Research Article

Efficacy of Organic Manures on the Productivity, Shelf-life, and Economic Efficiency of Tomato Varieties in a Long-Term Fertilized Field by Chemical Fertilizers

ABSTRACT

The present study was undertaken to identify the effects of organic manures (OMs) on the productivity, shelf-life, and economic efficiency of tomato varieties for improvement of the continuous application of chemical fertilizers in Bangladesh. A field experiment was conducted during the dry season from October 2012 to March 2013 in an experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experiment was laid out with completely randomized design with 3 replications. Three tomato varieties (BARI Tomato 15, BARI Tomato 14, and BARI Tomato 2) were grown in plots with different manure treatment viz. cow dung (CD), poultry manure (PM), or vermicompost (VC) containing 170 kg ha^{-1} of N_2 , and the results were compared with those from non-fertilized plots (control). The harvested fruits were kept at an ambient temperature, put in a polyethylene bag, and kept at ambient temperature, or put in a polyethylene bag, and kept at 10°C , and the shelf-life of each fruit was monitored. Moreover, cost-effectiveness was calculated based on common tomato production practices of Bangladesh. The effects of OMs on the vegetative growth largely depend on the cultivars. Differing from vegetative growth, the total fruit yield significantly increased with the application of PM and VC, irrespective of the cultivar, while the single fruit weight and fruit number per plant differed largely depending on the cultivar. The shelf-life was also significantly prolonged by the application of PM and VC. On the other hand, the effect of CD on the fruit yield and shelf-life was relatively weak. The results of economic analysis revealed that the benefit-cost ratio was low in CD and VC because of the low fruit yield and high cost, respectively. Among the treatment combinations, PM x BARI Tomato 15 yielded the best result not only from the viewpoints of fruit yield and storability, but also from that of the benefit-cost ratio, indicating the effectiveness of this combination as an alternative option for improving the continuous application of chemical fertilizers in Bangladeshi soil.

Keywords: Continuous chemical fertilizer, economic efficiency; fruit yield; organic tomato; shelf life; vegetable production.

1. INTRODUCTION

Although tomatoes are produced in an area of 18,160 ha and they are the 5th biggest cash crop in Bangladesh [1], approximately 80% are grown in fields located in areas with floods caused by four major rivers: Padma (Ganges), Meghna, Brahmaputra, and Jamuna, during the rainy season [2].

Therefore, tomatoes in Bangladesh are mainly produced from the late rainy to dry season using chemical fertilizers (CF). As a result, a large amount of the nutrients remaining in the soil after the harvest, especially nitrate nitrogen, is easily washed away from the field during the next rainy season, polluting ground water, and often causing serious human health damage, such as methemoglobinemia [3]. Nevertheless, tomatoes have been successively produced for many years using only CF mainly due to their ease of handling [4]. One of the solutions for avoiding such an over-accumulation of CFs after fruit harvest is to absorb the remaining CFs in the soil using other crops, and keep them in the soil as a form of organic compound or exclude them from the field [5]. However, such cultivation is often difficult because only a few crops can be cultivated during the rainy season. In addition, the exclusion of organic compounds from the field will rapidly reduce soil fertility. In fact, the average organic matter content in a tomato field of Bangladesh is only $<1.5\%$ [2]. Therefore, the utilization of organic manures (OMs) as a

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Comment [U2]: No fertilizers are remaining but some nutrients such as N and P

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substitute for CFs will be a more promising technique not only for improving soil physics and the environment, but also for reducing runoff [6]. Among OM_s, types of manure such as cow dung (CD), poultry manure (PM), and vermicompost (VC) are suitable substitutes for CFs, because farmers in Bangladesh can obtain them easily [4, 7].

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In Bangladesh, local tomato varieties have been used commercially for production, but the continuous use of such varieties often results in low yields, high disease susceptibility, and a short shelf-life [4, 7]. For improving such a difficult situation, the Bangladesh Agricultural Research Institute (BARI) newly developed a few promising tomato varieties: BARI Tomato 15, BARI tomato 14, and BARI tomato 2, which show a high fruit yield (approximately 80 t ha⁻¹), high disease tolerance, and long shelf-life, but the results, were also obtained using only CFs [8].

Therefore, if the cultivation of these varieties using OM_s can lead to similar results to those using CFs, they will offer an alternative method in fields where CFs are applied continuously.

However, the utilization of OM_s cannot be employed easily as an applicable technique from an economical perspective, because the price of OM_s is often higher than that of CFs, especially when compared with the nitrogen level [4, 7].

In our experiment, therefore, three newly developed BARI tomato varieties were grown in a field where CFs were applied continuously using three different types of manure, and the results, including the fruit yield, disease tolerance, and shelf-life, were compared with those of a non-fertilized control (NF). In addition, cost analysis was also conducted to evaluate the practicability of this method under the economic and environmental conditions of tomato production in Bangladesh.

2. MATERIALS AND METHODS

2.1 Experimental site and plant cultivation

The field experiment was conducted during the dry season from October 2012 to March 2013 (including shelf-life measurement) in an experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh (23.75° N to 90.34° E at 8.45-m altitude). The area was comprised of shallow and red brown terrace soils with friable clay loam (pH 5.5), and CFs had been continuously applied for longer than 14 years for the cultivation of vegetable crops including tomatoes (Table 1).

Table1. Physical and chemical properties of soil samples taken from 0-15 cm.

Physical properties							
Sand (%)		Clay (%)		Silt (%)		Texture	
27.3		30.2		43.2		Silty Clay loam	
Chemical properties							
Organic Carbon (%)	Nutrient content in soil(mg·kg ⁻¹)				pH (1:2.5)	CEC (cmol kg ⁻¹)	Organic matter (%)
	Total N	Available P	Available K	Available S			
	0.45	700	20	152			

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As the results, 700 mg kg⁻¹ of N₂ remained at the onset of plant cultivation. The standard amount of N₂ application for tomato production in Bangladesh is 170 kg ha⁻¹ [2]. Therefore, 20, 14, and 11 t ha⁻¹ of CD, PM, and VC, respectively, were applied to equalize the amount of applied N₂ among the three plots (Table 2).

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Table 2. Properties of OM_s used in the experimental field.

Properties	Cow dung (CD)	Poultry manure (PM)	Vermicompost (VC)
Amount of applied manures (t·ha ⁻¹)	20	14	11
Amount of N (kg·ha ⁻¹)	170	170	170
Amount of P (kg·ha ⁻¹)	60	98	110
Amount of K (kg·ha ⁻¹)	100	140	110
C:N	24.1	18.5	18.5

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The size of a unit plot was 2.4 × 2.4 m, and the distances between the plots and blocks were 0.5 and 1.0 m, respectively.

The experiment had a completely randomized design with four OMs and three variety combinations, and three replications were prepared for each treatment combination (36 plots in total) and compared with the plot with no fertilizers (considered as control).

The average temperature, total precipitation, and average humidity during the experimental period were 23.1°C, 24.6 mm, and 71%, respectively (Weather report, 2013). Seeds were sown on 12 October, 2012 in a seedbed, and healthy seedlings were transplanted into the experimental plots 35 days after transplanting (DAT). Plants were grown for 75 days in the experimental plots (30 January, 2013), and the effects of combination with OMs and varieties were investigated using the parameters of both vegetative and reproductive growth.

Fruits were harvested at 3-day intervals at the pink stage. Harvesting was started at 60 DAT and continued for the next 30 days. After harvest, fifteen uniform fruits per combination were divided into three groups, and each five fruits were kept at an ambient temperature (approx. 24°C), put in a perforated polythelene bag (0.08-mm thickness) and kept at ambient temperature, or put in a polyethylene bag and kept at 10°C. The shelf-life of each fruit was estimated by eye to assess whether any physical or physiological changes had occurred.

2.2 Economic analysis

Production costs were also compared among the treatment combinations. All non-material and material input costs and interest on the capital cost were considered for computing the production cost. The bank interest was regarded as 13% per year for six months according to the rules of bank loans. The farm gate price of tomatoes at harvest was considered to be US\$ 0.07 kg⁻¹. Analyses were performed according to the procedure of Alam et al. [9].

The benefit-cost ratio (BCR) was calculated as follows: $BCR = \frac{\text{gross return}}{\text{Total cost of production}}$

2.3 Statistical analysis

The means of all treatments were calculated and analysis of variance (ANOVA) for each of the characters studied was performed with the f-test. The differences among treatment means were evaluated by Duncan's multiple range test, and data were analyzed using MSTAT-C software at P≤0.05 [10].

3. RESULTS AND DISCUSSION

3.1 Plant growth and number of leaves

The plant height was often significantly promoted by the application of OMs, but there was no clear trend among cultivars (Fig. 1A). However, the application of OMs did not increase the number of leaves per plant (Fig. 1B). Among the treatment combinations, BARI Tomato 15 x PM showed the highest plant height.

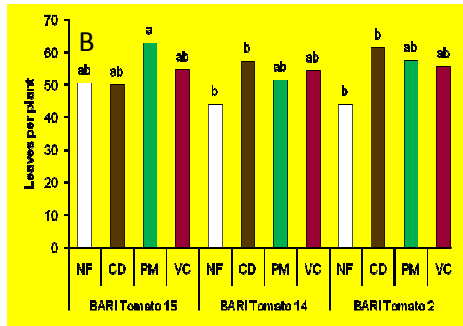
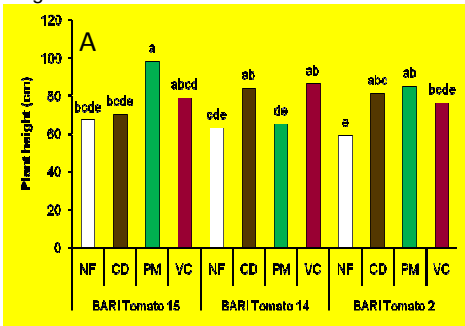


Fig. 1. Plant height (A) and number of leaves (B) of tomato seedlings as affected by the combinations of manure and varieties.

NF, CD, PM, and VC are non-fertilized control, cow dung, poultry manure, and vermi-compost, respectively. Different letters in a figure show significant differences at $P \leq 0.05$.

3.2. Fruit yield

The total fruit yield increased significantly by the application of PM and VC, irrespective of cultivar (Fig. 2C). Both the fruit number and single fruit weight were also affected prominently by different OMs compared to those of control (Fig. 2A and B). However, the results varied largely among the varieties.

Among the treatment combinations, all yield factors of PM x BARI Tomato 15 showed the highest values due to the higher plant growth under the same treatment combinations. Moreover, the fruit yield of PM x BARI Tomato 15 was 86 t ha^{-1} , being comparable to that of CFs [8]. Therefore, PM x BARI Tomato 15 is a promising combination as an alternative to CFs from the perspective of fruit yield.

3.3. Soil Chemical properties

Among the three OMs, the C:N ratio of CD was higher than of the other OMs (Table 2), suggesting that nutrients in CD may be predominantly used by micro-organisms rather than the plants [12]. In addition, the P content in CD was the lowest among the three OMs (Table 2) also suggesting that the slight effect of CD might be due to a lower P content [12]. Although the effect of CD was not apparent in BARI Tomato 14 and BARI Tomato 15, the application of OMs was obvious in BARI Tomato 2, revealing the utility of OMs for BARI Tomato 2.

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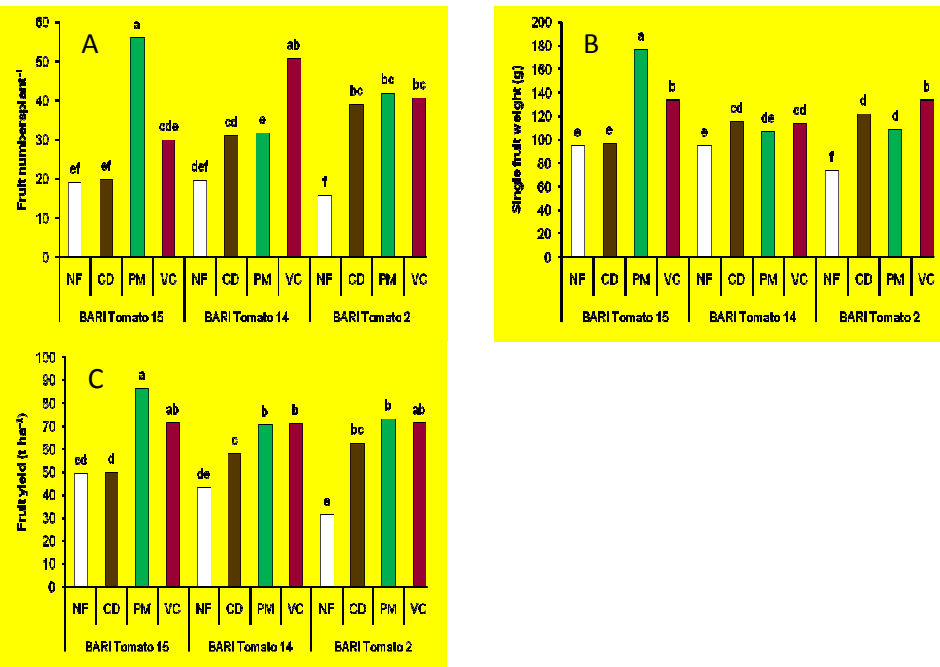


Fig. 2. Fruit number (A) and single fruit weight (B) and yield (C) of the tomato seedlings as affected by the combination of manures and varieties.

NF, CD, PM, and VC are non-fertilized control, cow dung, poultry manure, and vermi-compost, respectively. Different letters in a figure show significant differences at $P \leq 0.05$.

3.4 Shelf-life

Harvested fruits were stored using three different methods according to the market in Bangladesh. The results showed that the shelf-life was mostly extended by the application of OM_s, irrespective of the cultivar (Fig. 3). The most apparent effect was also observed in PM x BARI Tomato 15 when the fruits were stored at an ambient temperature. When the fruits were stored at 10°C, the effect of the shelf-life on OM_s became indistinct. Nevertheless, PM x BARI Tomato 15 showed the longest shelf-life among the treatment combinations. Considering the shelf-life, therefore, PM x BARI Tomato 15 is also the best alternative to CFs for maintaining storability.

Beard [13] reported that storage disorders, such as pepper spot and vein streaking, were found in cabbages, when N₂ higher than 180 kg ha⁻¹ was applied in the form of nitrate. In our experiment, 1.46 kg ha⁻¹ of N₂ remained in the soil before plant cultivation, and OM_s containing 170 kg ha⁻¹ N₂ were applied prior to the start of the experiment.

However, no visible storage disorder was observed except for natural fruit shrinking and fungal disease (data not shown). Therefore, the application of OM_s will also be beneficial from the aspect of inhibiting physiological disorders during storage.

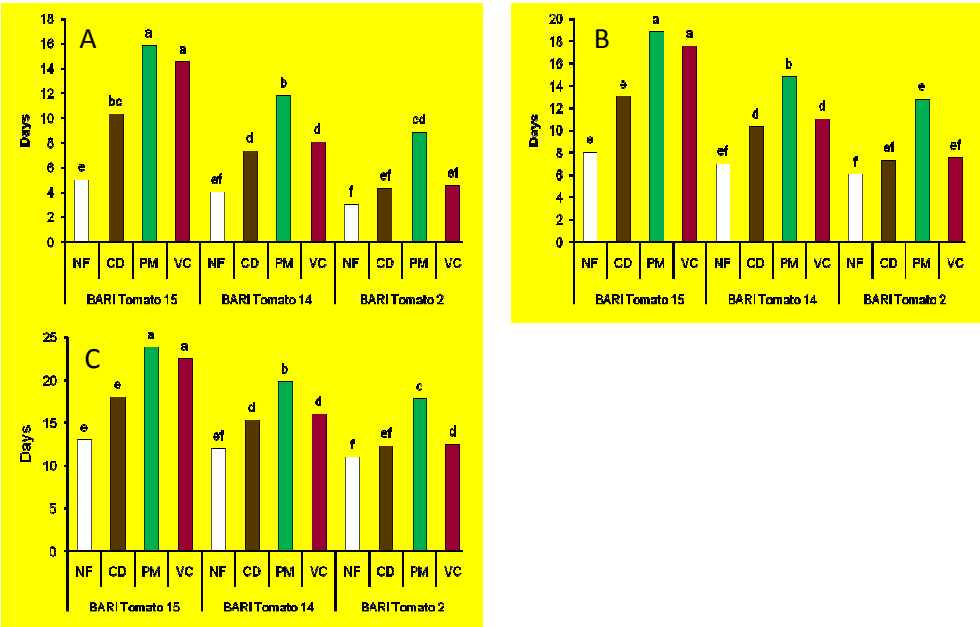


Fig. 3. Shelf-life of stored tomato fruits as affected by the combination of manures and varieties. Harvested fruits were stored at (A): ambient temperature without bagging, (B): ambient temperature with a polyethylene bag, and (C): 10°C with a polyethylene bag. NF, CD, PM and VC are non-fertilized control, cow dung, poultry manure, and vermi-compost, respectively. Different letters in a figure show significant differences at $P \leq 0.05$.

3.5 Economic analysis

In the economic analysis, one cropping season of tomato and the bank interest during the period were regarded as 6 months and 13% of the land value (US\$ 666.7), respectively, according to the rules of Bangladesh bank (Table 3). In addition, 5% of the farmer's input cost was also added as a miscellaneous cost.

Economic analysis showed that PM x BARI Tomato 15 yielded the highest net return (US\$ 3675.7) and BCR (2.98), followed by PM x BARI Tomato 2 (US\$ 2821.2 and 2.52) (Table 3). Although the fruit yield of

VC was as high as that of PM in **BARI Tomato 2** and **BARI Tomato 14** (Fig. 2), BCR was lower than PM because of the high price. Fruit yield of CD was the lowest among the applied **OMs**, but BCR was higher than VC because the price of CD (256.4 US\$) was 1/6 of that of VC (1538.5 US\$). The total production cost was the cheapest for NF, but BCR was not necessarily high due to it having the lowest yield. This indicates that the application of **OMs** is more promising than non-fertilizing cultivation from an economic aspect, even if excess nutrients remain in the soil.

Table 3. Cost and return of tomato production as affected by the combination of **OMs and varieties.**

Items	Treatment combinations											
	NF x BARI Tomato 15	NF x BARI Tomato 14	NF x BARI Tomato 2	CD x BARI Tomato 15	CD x BARI Tomato 14	CD x BARI Tomato 2	PM x BARI Tomato 15	PM x BARI Tomato 14	PM x BARI Tomato 2	VC x BARI Tomato 15	VC x BARI Tomato 14	VC x BARI Tomato 2
^a Price OMs (US\$ ha ⁻¹)	0	0	0	256.4	256.4	256.4	384.6	384.6	384.6	1538.5	1538.5	1538.5
^b Bank interest (US\$ ha ⁻¹)	44.2	44.2	44.2	60.8	60.8	60.8	69.2	69.2	69.2	144.2	144.2	141.7
^c Misce. cost (US\$ ha ⁻¹)	34.0	34.0	34.0	46.8	46.8	46.8	53.2	53.2	53.2	110.9	110.9	110.9
^w Total production cost (US\$ ha ⁻¹)	1424.3	1424.3	1424.3	1710.2	1710.2	1710.2	1853.1	1853.1	1853.1	3139.7	3139.7	3137.2
Yield (t ha ⁻¹)	46.8	46.8	31.2	46.8	54.6	62.4	85.8	70.4	70.2	72.2	71.2	70.2
^v Gross income (US\$ ha ⁻¹)	2003.2	2751.3	3151.9	3178.2	3712.8	4006.4	5528.8	4514.1	4674.4	4567.3	4540.4	4567.3
Net return (US\$ ha ⁻¹)	578.9	1327.0	1727.6	1468.0	2002.6	2296.2	3675.7	2661.0	2821.2	1427.6	1400.7	1470.5
BCR	2.21	1.93	1.47	1.86	2.17	2.34	2.98	2.44	2.52	1.45	1.45	1.41

^a NF, CD, PM and VC are non-fertilized control, cow dung, poultry manure, and vermi-compost, respectively.

^b Prices of CD, PM, and VC were estimated as 256.4, 384.6, and 1,538.5 US\$ t⁻¹, respectively, and the prices of the seeds were the same, irrespective of the variety.

^c Bank interest was estimated as 13% of the sum of the capital cost for 6 months (666.7 US\$) as an overhead cost.

^w Miscellaneous cost was calculated at the rate of 5% of the total input cost.

^v Total production cost is included with input cost (manure, seeds, land preparation, irrigation, etc.), overhead cost (land value, bank interest, etc.) and output cost (if any).

^v Gross income was calculated as the value (US\$) of tomatoes sold at current market price. Market price of tomatoes was regarded as US\$ 64.1 t⁻¹.

For the cultivation of **BARI Tomato 2**, **BARI Tomato 14**, and **BARI Tomato 15**, BARI recommends farmers to apply N: P: K=170:48:100 kg ha⁻¹ as chemical fertilizers to obtain an ideal fruit yield (approximately 80 t ha⁻¹) [8]. When all these **macronutrients** are applied as chemical fertilizers, 450 kg ha⁻¹ of urea (US\$ 0.23 kg⁻¹), 250 kg ha⁻¹ of triple **superphosphate**, (US\$ 0.32 kg⁻¹), and 260 kg ha⁻¹ of **muriate of potash** (US\$ 0.23 kg⁻¹) are commonly utilized. Accordingly, the total cost of fertilizers is calculated as 450 x 0.23 + 250 x 0.32 + 260 x 0.23 = 243.3 US\$ ha⁻¹, and the net return and BCR are 3080.6 US\$ and 2.5, respectively, when the yield is 80 t ha⁻¹.

These values are lower than those of PM x **BARI Tomato 15** (US\$ 3675.7 and 2.98, respectively), but BCR is similar with PM x **BARI Tomato 2** and PM x **BARI Tomato 14**, although the net return is higher (US\$ 2821.2). This indicates that PM is similar or rather more effective for the production of new BARI tomato varieties when grown in a field where CF has been applied continuously for a long time. Singh and Kushwa [14] found that a maximal net return was achieved, when both CFs and **OMs** were applied at the same time, but we found that only **OMs** were often sufficient to achieve better results.

4. CONCLUSION

Among the **treatment combinations**, PM x **BARI Tomato 15** showed the most favorable results with respect to all factors. Therefore, this combination is an effective alternative to improve the condition regarding the continuous application of **CFs** in Bangladesh.

Comment [U10]: Summarize them!

Comment [U11]: Refer also something on the influence on soil properties, this is important for sustainability of the resources used.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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