

Original Research Article

Effects of Organic Manure on the Productivity, Shelf-life, and Economic Efficiency of Tomato Varieties for Improvement of the Continuous Application of Chemical Fertilizers in Bangladesh

ABSTRACT

The present study was undertaken to identify the effects of organic manure 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. Three tomato varieties: BARI 15, 14, and 2 were grown in plots fertilized with cowdung (CD), poultry manure (PM), or vermicompost (VC) containing $170 \text{ kg} \cdot \text{ha}^{-1}$ of N_2 , and the results were compared with those from non-fertilized plots. 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 organic manure 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 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.

Key words: 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 groundwater, 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 fertilizers (OFs) as a 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 OFs, types of manure such as cowdung (CD), poultry manure (PM), and vermicompost (VC) are suitable substitutes for CFs, because farmers in Bangladesh can obtain them easily [4, 7].

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 (V15), BARI tomato 14 (V14), and BARI tomato 2 (V2), which show a high fruit yield (approximately $80 \text{ t}\cdot\text{ha}^{-1}$), 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 OFs 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 OFs cannot be employed easily as an applicable technique from an economical perspective, because the price of OFs 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 ($\text{pH } 5.5$), 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			

As the results, $700 \text{ mg}\cdot\text{kg}^{-1}$ of N_2 remained at the onset of plant cultivation. The standard amount of N_2 application for tomato production in Bangladesh is $170 \text{ kg}\cdot\text{ha}^{-1}$ [2]. Therefore, 20, 14, and $11 \text{ t}\cdot\text{ha}^{-1}$ of PM, CD, and VC, respectively, were applied to equalize the amount of applied N_2 among the three plots (Table 2).

85 **Table 2. Properties of OFs used in the experimental field.**

Properties	Cowdung (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

86 *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,*
87 *respectively.*

88 The experiment had a completely randomized design with four organic manures and three variety
89 combinations, and three replications were prepared for each combination (36 plots in total).

90 The average temperature, total precipitation, and average humidity during the experimental period were
91 23.1 °C, 24.6 mm, and 71%, respectively (Weather report, 2013).

92 Seeds were sown on 12 October, 2012 in a seedbed, and healthy seedlings were transplanted into the
93 experimental plots 35 days after transplanting (DAT).

94 **2.2 Evaluation of the combined effects with OFs and varieties**

95 Plants were grown for 75 days in the experimental plots (30 January, 2013), and the effects of
96 combination with OFs and varieties were investigated using the parameters of both vegetative and
97 reproductive growth.

98 Fruits were harvested at 3-day intervals at the pink stage. Harvesting was started at 60 DAT and
99 continued for the next 30 days.

100 After harvest, fifteen uniform fruits per combination were divided into three groups, and each five fruits
101 were kept at an ambient temperature (approx. 24°C), put in a perforated polythelene bag (0.08-mm
102 thickness) and kept at ambient temperature, or put in a polyethylene bag and kept at 10°C. The shelf-life
103 of each fruit was estimated by eye to assess whether any physical or physiological changes had occurred.

104 **2.3 Economic analysis**

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

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

111 **2.4 Statistical analysis**

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

115 **3. RESULTS AND DISCUSSION**

116 **3.1 Plant growth and fruit yield**

118 The plant height at 75 DAT was often significantly promoted by the application of OFs, but there was no
119 clear trend among cultivars (Fig. 1A). On the other hand, the application of OFs did not increase the
120 number of leaves per plant (Fig. 1B). Among the combinations, V15 x PM showed the highest plant height.

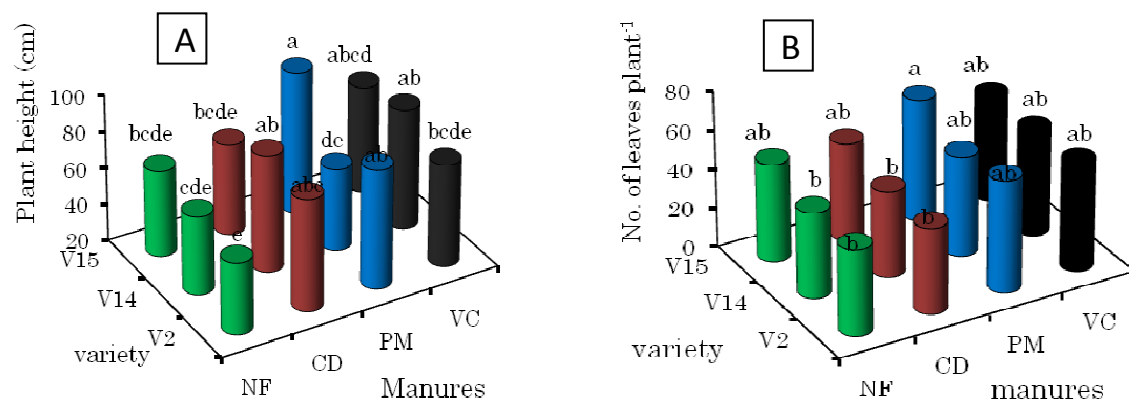


Fig. 1. Plant height (A) and number of leaves (B) of tomato seedlings at 75 DAT as affected by the combinations of manure and varieties.

V15, 14, and 2 are BARI tomato 15, 14, and 2, respectively, and NF, CD, PM, and VC are non-fertilized control, cowdung, poultry manure, and vermi-compost, respectively.

Different letters in a figure show significant differences at $P \leq 0.05$.

Reproductive growth, shown as the total yield, increased significantly by the application of PM and VC, irrespective of the cultivar (Fig. 2C). However, the effect of OFs on the fruit number per plant and single fruit weight differed largely depending on the cultivar (Fig. 2-A and B). Differing from PM and CV, CD often did not increase reproductive growth significantly. Among the three OFs, the C:N ratio of CD was higher than of the other OFs (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 OFs (Table 2) also suggesting that the weak effect of CD might be due to a lower P content [12]. Although the effect of CD was not apparent in V14 and V15, the application of OFs was apparent in V2, revealing the utility of OFs for V2.

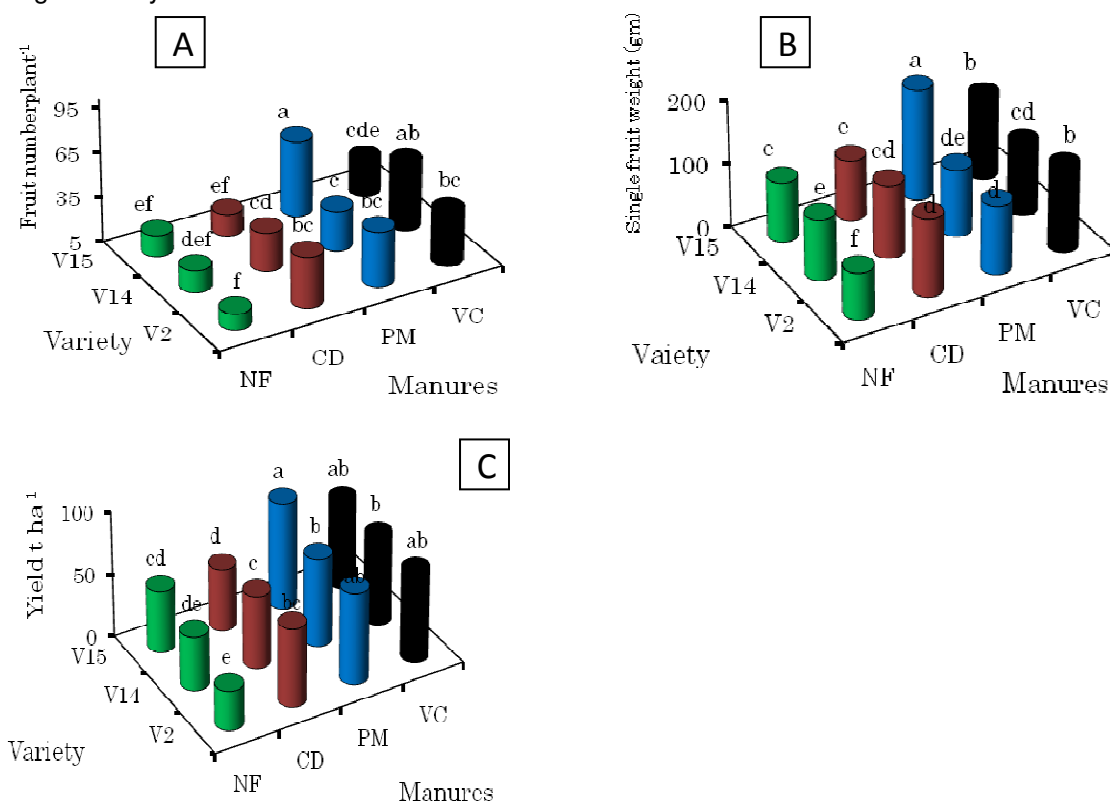


Fig. 2. Fruit number (A) and single fruit weight (B) and yield (C) of the tomato seedlings at 75 DAT as affected by the combination of manures and varieties.

V15, V14, and V2 are BARI tomato 15, 14, and 2, respectively, and NF, CD, PM, and VC are non-fertilized control, cowdung, poultry manure, and vermi-compost, respectively.

Different letters in a figure show significant differences at $P \leq 0.05$.

Among the combinations, the maximum values of the three reproductive factors were found in the combination of PM x V15, as shown in the vegetative growth, indicating that V15 had OF specificity for the promotion of whole-plant growth. Moreover, the total yield of PM x V15 was $86 \text{ t} \cdot \text{ha}^{-1}$, being comparable to that of CFs [8]. Therefore, PM x VC is a promising combination as an alternative to CFs from the perspective of fruit yield.

3.2 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 OFs, irrespective of the cultivar (Fig. 3-A, B, and C). The most apparent effect was also observed in PM x V15 when the fruits were stored at an ambient temperature, irrespective of bagging. When the fruits were stored at 10°C , the effect of the shelf-life on OFs became indistinct. Nevertheless, PM x V15 showed the longest shelf-life among the combinations. Considering the shelf-life, therefore, PM x V15 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 N_2 higher than 180 kg ha^{-1} was applied in the form of nitrate and/or calcium nitrate. In our experiment, $1.46 \text{ kg} \cdot \text{ha}^{-1}$ of N_2 remained in the soil before plant cultivation, and OFs containing 170 kg ha^{-1} N_2 were applied prior to the start of the experiment. However, no apparent storage disorder was observed except for natural fruit shrinking and fungal disease (data not shown). Therefore, the application of OFs will also be beneficial from the aspect of inhibiting physiological disorders during storage.

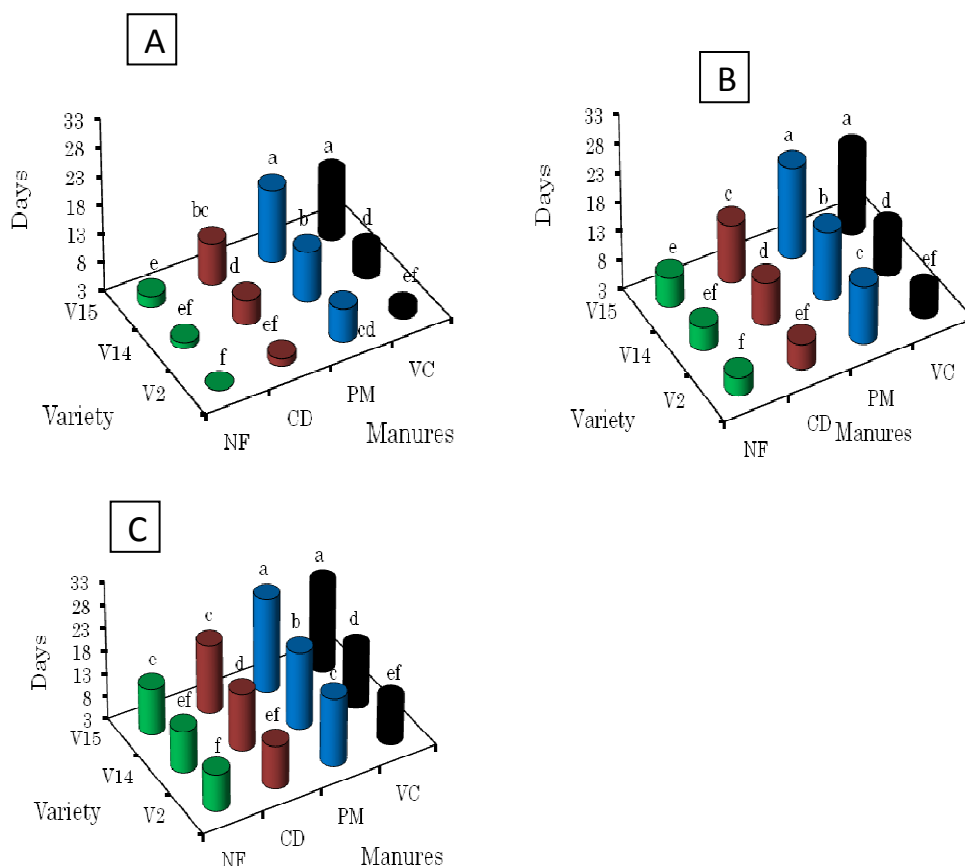


Fig. 3. Shelf-life of stored tomato fruits as affected by the combination of manures and varieties. Harvested fruits were stored at (A): ambient temperature without bagging, (B): ambient temperature with a poly bag, and (C): 10°C with a poly bag.

V15, 14, and 2 are BARI tomato 15, 14, and 2, respectively, and NF, CD, PM and VC are non-fertilized control, cowdung, poultry manure, and vermi-compost, respectively.

Different letters in a figure show significant differences at $P \leq 0.05$.

3.3 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.

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

Items	Combination											
	NF	NF	NF	X	CD	X	CD	CD	PM	PM	PM	VC
	X	X	V2		V15	X	X	X	X	X	X	VC
	V15	V14				V14	V2	V15	V14	V2	V15	V14
^z Price of OFs (US\$·ha ⁻¹)	0	0	0		256.4	256.4	256.4	384.6	384.6	384.6	1538.5	1538.5
^y 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
^x 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
^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
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
^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
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
BCR	2.21	1.93	1.47		1.86	2.17	2.34	2.98	2.44	2.52	1.45	1.45

^z 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.

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

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

^w 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.

Economic analysis showed that PM x V15 yielded the highest net return (US\$ 3675.7) and BCR (2.98), followed by PM x V2 (US\$ 2821.2 and 2.52) (Table 3). Although the fruit yield of VC was as high as that of PM in V2 and V14 (Fig. 2), BCR was lower than PM because of the high price. Fruit yield of CD was the lowest among the applied OFs, 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 OFs is more promising than non-fertilizing cultivation from an economic aspect, even if excess nutrients remain in the soil.

On V2, V14, and V15 production, 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 macro-

nutrients are applied as chemical fertilizers, 450 kg·ha⁻¹ of urea (US\$ 0.23 kg⁻¹), 250 kg·ha⁻¹ of triple super phosphate, (US\$ 0.32 kg⁻¹), and 260 kg·ha⁻¹ of muriate 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 V15 (US\$ 3675.7 and 2.98, respectively), but BCR is similar with PM x V2 and PM x V14, 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 OFs were applied at the same time, but we found that only OFs were often sufficient to achieve better results.

4. CONCLUSION

Among the combinations, PM x V15 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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