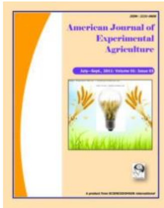

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Efficacy of Organic Manures on the Productivity, Shelf-life and Economic Efficiency of Tomato Varieties in a Long-term Fertilized Field by Chemical Fertilizers

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Author's contributions

This work was carried out in collaboration between all authors. Author AHMS designed the study, wrote the protocol and wrote the first draft of the manuscript. Author TN reviewed the experimental design and all drafts of the manuscript. Authors TN and TSR managed the analyses of the study. Authors AHMS and TN performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

The study was undertaken to identify the effect of organic manures (OMs) on the productivity, shelf-life, and economic efficiency of tomato varieties for minimizing the continuous application of chemical fertilizers in Bangladesh. The 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 treatment viz. cow dung (CD), poultry manure (PM), and vermicompost (VC) containing 170 kg ha^{-1} of N_2, and the results were compared with non-fertilized plots (control). The harvested fruits were kept at an ambient temperature without bagging, kept at an ambient

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temperature in a polyethylene bag, or kept at 10ºC in a polyethylene bag, and the shelf-life of each fruit was monitored. Moreover, cost-effectiveness was calculated based on common tomato production practices of Bangladesh. The effect of OMs on the vegetative growth was largely depend on the cultivars. Differing from the 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 varied 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 low. 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 showed the best result not only from the viewpoint 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 on Bangladesh 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 largest vegetables in Bangladesh [1], approximately 80% are grown in fields located in areas experienced with floods caused by four major rivers: Padma (Ganges), Meghna, Brahmaputra, and Jamuna, during the rainy season [2]. 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 or nitrite 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 nitrosamines that can cause gastric cancer [3]. Nevertheless, tomatoes have been successively produced for many years using only CF mainly due to their ease handling [4]. One of the solutions for avoiding such an over-accumulation of nutrients like N, P and K after fruit harvest is to absorb the remaining nutrients in the soil using other crops and keep them in the soil as an organic compound or remove 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 rapidly reduces 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 substitute for CFs will be a more promising technique not only for improving soil physical properties and the environment, but also for reducing runoff [6]. Among OMs, types of manure such as cow dung (CD), poultry manure (PM) and vermicompost (VC) are suitable substitutes for CFs, because farmers in Bangladesh can avail 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 yield, high disease susceptibility, and a short shelf-life [4,7]. To improve such a difficult situation, the Bangladesh Agricultural Research Institute (BARI) developed a few promising tomato varieties: BARI Tomato 15, BARI tomato 14, and BARI tomato 2. These varieties show a high fruit yield (approximately 80 t ha^{-1}), high disease tolerance and long shelf-life, but the results were obtained using only CFs [8].

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

However, utilization of OMs cannot be employed easily as an applicable technique from an economical perspective, because the price of OMs is often higher than 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 cultivation 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 (23.75º N to 90.34º 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).

Based on the chemical analysis of soil, 700 mg kg^{-1} of N remained in the soil. The standard amount of N 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 N in all the three plots (Table 2).

The experiment was laid out with 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 size of a single plot was 2.4 × 2.4 m and the distances between the plots and blocks were 0.5 and 1.0 m, respectively.

The average temperature, total precipitation, and average humidity during the experimental period were 23.1ºC, 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. 24ºC) without bagging, put in a perforated polythelene bag (0.08-mm thickness) and kept at ambient temperature, or put in a polyethylene bag and kept at 10ºC. The shelf-life of each fruit was estimated by eye to assess whether any physical or physiological changes had taken place.

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 taken into consideration for computing the production cost. The bank interest was computed at 13% per year for six months as per the rules of bank. 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: $\mathrm{BCR} = \frac{\text{gross return}}{\text{Total cost of production}}$

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 $P \leq 0.05$ [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. El-Fakhrani [11] also showed that PM (10 t ha-1) promoted the vegetative growth of Solanaceous crops more than any other organic sources, because it contained the maximum macro- and micro-nutrients.

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 (Figs. 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.

Among the three OMs, the P content in CD was the lowest (Table 2) suggesting that the minimal 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.

3.3 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 OMs, 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 10ºC, the effect of the shelf-life on OMs 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 N_2 higher than 180 kg ha^{-1} was applied in the form of nitrate. In our experiment, 1.46 kg ha^{-1} of N_2 remained in the soil before plant cultivation, and OMs containing 170 kg ha^{-1} N_2 were applied prior to the start of the experiment.

Table 1. 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						
Nutrient content in soil(mg kg^{-1})				**pH**	**CEC**	**Organic C (%)**
Total N	**Available P**	**Available K**	**Available S**	**(1:2.5)**	**(cmol kg^{-1})**	
700	20	152	45	5.5	26.5	0.45

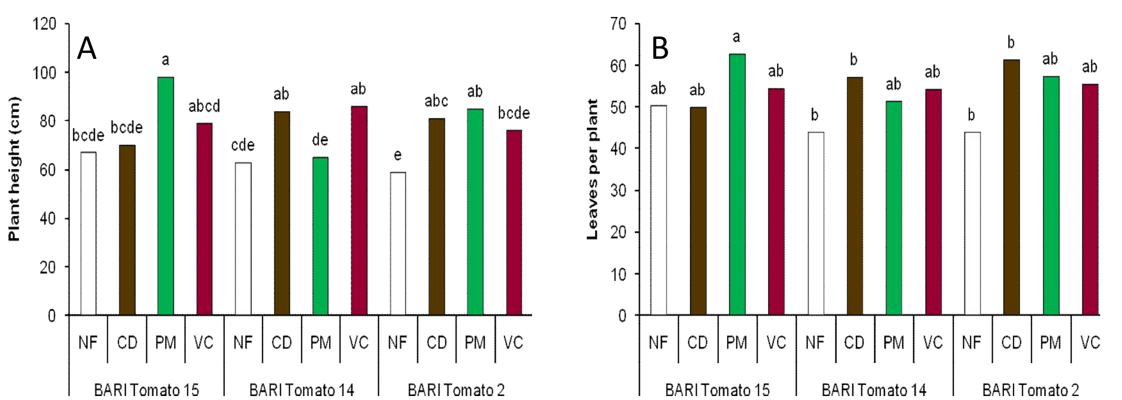

Fig. 1. Plant height (A) and number of leaves (B) of tomato seedlings as affected by the combinations of manure and varieties

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≤0.05

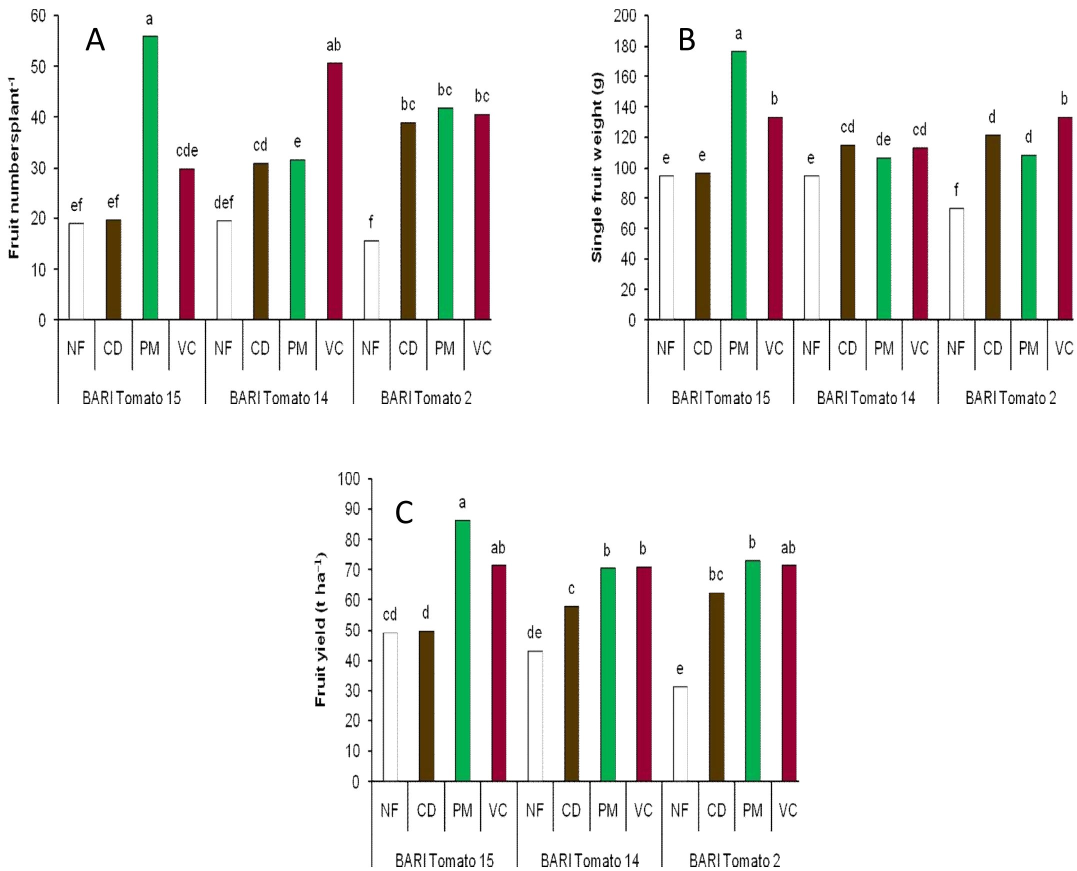

Fig. 2. Fruit number (A) and single fruit weight (B) and yield (C) of the tomato seedlings as affected by the combination of manures and varieties

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≤0.05

Table 2. Amount of major nutrients contained in the OMs used in the experimental field

Components	Cow dung (CD) (20 t ha^{-1})	Poultry manure (PM) (14 t ha^{-1})	Vermicompost (VC) (11 t ha^{-1})
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

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

3.4 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, as per 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.

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.

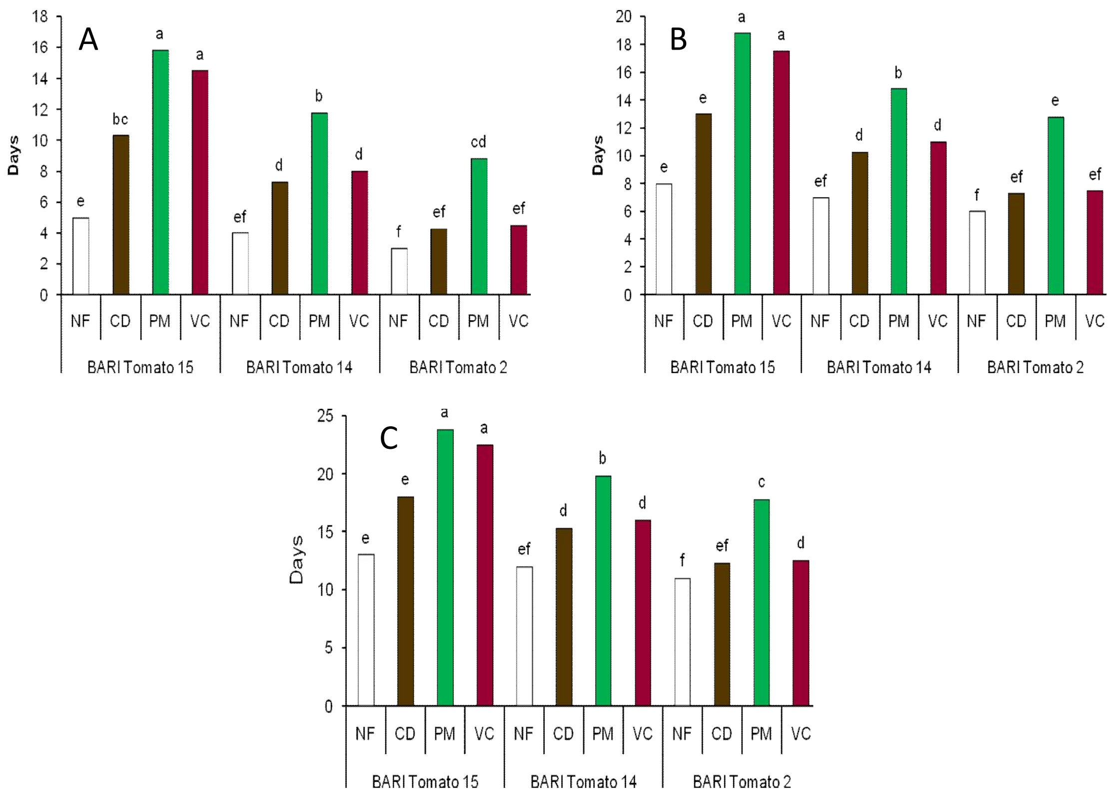

Fig. 3. Shelf-life of stored tomato fruits as affected by the combination of manures and varieties. Harvested fruits were stored at (A): ambient temperature without bagging, (B): ambient temperature with a polyethylene bag, and (C): 10ºC with a polyethylene bag

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≤0.05

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×BARI Tomato 14	NF×BARI Tomato 2	CD×BARI Tomato 15	CD×BARI Tomato 14	CD×BARI Tomato 2	PM×BARI Tomato 15	PM×BARI Tomato 14	PM×BARI Tomato 2	VC×BARI Tomato 15	VC×BARI Tomato 14	VC×BARI Tomato 2
[z]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
[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	141.7
[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	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

NF, CD, PM and VC are non-fertilized control, cow dung, poultry manure, and vermi-compost, respectively; [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}

4. CONCLUSION

Among the treatment combinations, PM x BARI Tomato 15 showed the most favorable results with respect to all factors like soil, plant height, number of leaves and fruits per plant, single fruit weight, fruit yield and shelf-life. Since continuous application of CFs is detrimental to soil health, therefore, this combination would be an effective alternative to improve the soil condition in Bangladesh which may ensure a sustainable crop yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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