International Journal of Agricultural Technology 2026 Vol. 22(6):2927-2938
DOI: https://doi.org/10.63369/ijat.2026.22.6.2927-2938
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Optimizing sweet pepper yield and quality through integrated nutrient management

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Marufa Sultana, Masud, M. M., Sarker, Md. A. and Naser, H. M. (2026). Optimizing sweet pepper yield and quality through integrated nutrient management. International Journal of Agricultural Technology 22(6):2927-2938.

Abstract The results highlighted that 75% of the recommended chemical fertilizer combined with 3 tons of PM (Poultry Manure) Slurry per hectare, produced the most favorable outcomes. This treatment is exhibited the highest fruit yield (26.15 t/ha), pericarp thickness (6.91 mm), shelf life (12 days), pH level (5.86), Total Soluble Solids (TSS) at 5.4 oBrix, Vitamin C content at 107.83 mg per 100g, and firmness at 0.34 kgf/cm². Conversely, the control displayed lower fruit yield (11.08 t/ha), thinner pericarp (5.14 mm), shorter shelf life (8 days), lower pH (5.48), TSS at 4.0 oBrix, Vitamin C content at 54.99 mg per 100g, and lower firmness at 0.28 kgf/cm². Furthermore, the inclusion of 3 tons of PM Slurry per hectare with 75% RD demonstrated the potential to reduce chemical fertilizer usage by 25% while enhancing soil fertility. This integrated approach was found to be the most effective in improving sweet pepper yield and enriching soil organic matter. In conclusion, this experiment revealed that PM slurry has the potential to positively influence sweet pepper cultivation, offering a dependable organic alternative to traditional fertilizers.

Keywords: Sweet pepper, Chemical fertilizer, Organic amendments, Yield and quality

Introduction

Sweet pepper (*Capsicum annuum* L.) belongs to the solanaceous group of fruity vegetables and is commonly known as Bell pepper or Green pepper. It holds considerable economic value due to its nutritional qualities (Martínez-Ispizua, 2021). In the context of Bangladesh, sweet pepper cultivation primarily focuses on peri-urban areas with the aim of supplying urban markets. However, local farmers in Bangladesh often face challenges in achieving yields and quality comparable to those in other countries. Sweet pepper is a significant greenhouse cash crop known for its delightful flavor, pungency, high ascorbic acid, and mineral content (Kumar *et al*., 2016). Its immature green stage is particularly prized for its pleasant fruity aroma, making it suitable for use in condiments (Manikharda *et al*., 2018).

The current state of fertilization to boost crop yields is a topic of concern as excessive reliance on chemical fertilizers has led to a host of

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environmental problems, soil fertility loss, and reduced productivity. Furthermore, the widespread use of fertilizers lacking nutrient diversity exacerbates these issues, posing a significant threat to sustainable agriculture. Synthetic chemical fertilizers are the conventional choice for agriculture, aimed at increasing crop production and soil fertility. However, an increasing awareness of the detrimental impact of chemical fertilizers on both human health and the environment has sparked a transition towards organic fertilizers.

The utilization of organic resources, such as cow dung, poultry manure, organic waste, crop residues, and compost, not only boosts yields but also enhances the efficiency of applied nutrients. These changes have a positive effect on soil structure, microbial populations, and moisture-holding capacity, ultimately leading to improved crop production (Hussainy, 2019). The use of organic fertilizers in crop production shows promise in reducing carbon emissions, promoting soil carbon sequestration, and minimizing the agricultural carbon footprint. Organic fertilizers offer environmental advantages by mitigating erosion, reducing chemical leaching, and improving soil fertility, contributing to a more sustainable future. Moreover, research by Al-Harbi *et al.* (2020) highlights the positive impact of incorporating carbon in sweet pepper cultivation. This approach has resulted in substantial improvements in fruit quality, particularly in terms of dry matter, vitamin C, total soluble solids, total acidity, and total sugar content. These findings underscore the potential for enhancing agricultural practices and elevating the quality of sweet peppers in Bangladesh.

In this context, maintaining soil fertility and crop productivity in agricultural systems depends on a balanced approach. Unfortunately, there is often an imbalance in the use of chemical fertilizers in vegetable and crop production in Bangladesh. Most cultivated soils in the country contain less than 1.5% organic matter, whereas a good agricultural soil should ideally contain at least 2% organic matter. This deficiency is further exacerbated by minimal organic matter supply to crop fields in continuous cropping areas. Consequently, various beneficial soil microorganisms are adversely affected.

Presently, there is a growing focus on organic and environmentally friendly agriculture, with consumers seeking healthier and more nutritious products. When it comes to crop quality, research has shown that the use of chemical fertilizers can reduce antioxidant levels in crops. Vegetables like cabbage, spinach, and peppers have been found to contain more antioxidants when cultivated with organic fertilizers. Akiyama *et al.* (2008) demonstrated that tomatoes grown with organic fertilizers had higher nutritional values than those amended with chemical fertilizers. While specific studies have shown that organic fertilizers improve vegetative growth, total yield, and germination of sweet peppers, there is limited information available on how organic fertilization affects the quality of sweet peppers, particularly in terms of bioactive compounds and aromatic profiles.

The choice between organic and inorganic fertilizers can have both positive and negative effects on plant growth, development, and soil quality (Roba, 2018). Research findings emphasize that relying solely on organic manures may not meet crop nutrient requirements (Deore *et al.*, 2010). To achieve soil health and crop productivity, a balanced approach involves integrating both organic and inorganic fertilizers. Furthermore, the sustained use of organic and inorganic fertilizers positively impacts soil quality and microbial diversity, resulting in significant changes in soil's chemical and biological characteristics. The application of both organic and inorganic fertilizers, particularly compost, is well-documented in improving soil's chemical, physical, and biological properties, leading to increased crop productivity (Ho *et al.*, 2022). These mechanisms improve nutrient synchrony and overall fertility (Brempong and Addo-Danso, 2022). However, research underscores that using organic and inorganic fertilizers in combination is the most effective approach for maintaining healthy and sustainable soil while increasing crop productivity (Biramo, 2018), as relying solely on either may not be profitable or sufficient for sustaining high-yielding crop varieties.

Various experiments, both in greenhouses and experimental fields, have highlighted the benefits of organic resources on plant growth and yield. For instance, composted sludge was found to improve leaf, shoot, root dry matter, and fruit yield in capsicum plants (Pascual *et al*., 2010). In addition, the treatment with poultry manure was recommended for the cultivation of chili (Soreng and Kerketta, 2017). In a pot experiment exploring the impact of various sources of organic manure on sweet pepper growth and yield, treatments such as chemical plant food, vermi-compost, poultry manure, farmyard manure, goat manure, and industrial plant food had significant effects on growth and yield (Adhikari *et al*., 2016). The objectives of this study were to measure the impact of organic fertilizers on the yield and quality of sweet pepper. and to reduce the dependency on chemical fertilizers in sweet pepper cultivation, promoting sustainability and environmental health.

Materials and Methods

Soil and organic fertilizer collection

The study was performed at Central farm, BARI, Gazipur in the *Rabi* season. The initial collected soil samples (0-30 cm depth) were used auger after prepared cultivation. Four types (CD, CD slurry, PM, PM slurry) of organic fertilizer used in this experiment were collected form suburb of Gazipur. The field experiment was prepared and divided to be in each plot. Sweet pepper seeds (*Capsicum annuum* L. var. BARI Misti Morich-1) were established in a greenhouse in large trays with a 1:1 mixture of sand and peat (1:1 v/v). Irrigation was managed after sowing. Five-week-old of pepper

seedling plants were transplanted to prepared beds. The experiment was performed using Randomized Complete Block Design (RCBD) with three replicates. The plot size unit was managed as 3m×1m and spacing of 50cm×50cm. The cultural practice management including plant protection were uniformly done throughout the experimental period.

Table 1. Analytical data of the experimental soils of Central farm, BARI, Gazipur

Location	pH	OM(%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Mn	Zn
			meq 100g^{-1}				µg g^{-1}						
Central farm, BARI	6.1	1.21	4.4	2.1	0.14	0.059	11	10	0.22	3.2	90	11	0.7
Critical level	-	-	2.0	0.5	0.12	0.12	7	10	0.2	0.2	4	1	0.6

Table 2. The status of nutrient for cow dung, cow dung slurry, poultry manure and poultry manure slurry applied in the experiment

Name of manure	pH	OM	Ca	Mg	K	Total N	P	S	B	Zn	Pb	Cd	As
		%									µg g^{-1}		
CD	6.8	21	1.20	0.56	0.54	1.07	0.57	0.32	0.012	0.014	2.94	0.8	1.16
CD Slurry	7.1	22	1.25	0.62	0.61	1.14	0.62	0.34	0.012	0.016	2.81	0.9	1.08
PM	7.6	24	4.50	1.84	0.83	1.35	0.76	0.40	0.014	0.018	8.10	2.4	1.67
PM Slurry	7.9	24	4.92	1.97	0.89	1.43	0.80	0.42	0.015	0.019	7.92	2.3	1.58

Note: Moisture content of CD = 13.49%, CD slurry = 15.86%, PM = 13.06% & PM slurry = 15.24%

Experimental layout and data collection

Fruit maturity was harvested for four times. Data were gathered from 5 randomly selected plants which were plant height, fruit diameter, fruit length, fruit numbers plant^{-1}, pericarp thickness, fresh weight, yield (tha^{-1}), fruit quality of pH, TSS, Vit-C and fruit firmness. Data were subjected to analyze statistically and compared with Least Significant Difference (LSD) at 5% level.

pH, total soluble solids and ascorbic acid c

Sweet pepper fruits from each treatment were cut into small slices and pooled. Samples were homogenized in a blender and portions of the homogenate were taken to determine the fruit quality. The pH value of fruit was measured with a pH meter at 20 ^{0}C. Total soluble solids content (TSS) was determined at 20 ^{0}C with a refracto meter and reported as ^{0}Brix.Ascorbic acid contents (vitamin C) was measured by classical titration method using 2, 6-dichlorophenol indophenol (DCPIP)solution and expressed as mg 100 g $^{-1}$ of fresh weight (Pisoschi *et al.,* 2008).

Fruit firmness

The firmness of fruits was recorded from 5 fruits in each sample by Chattillon hand penetro meter (Model DPP 1000) with a 0.6 mm probe. The center of each fruit was measured, and the bio yield point was recorded by maximum force (N).

Methods of chemical analysis

Soil pH was determined using

Metler Toledo S220 used to determine soil pH with a combine electrode in a soil and water ratio of 1:2.5 (w/w) followed method of Mehmood *et al*., 2018. Wet oxidation method was used to determine organic carbon (Walkley and Black, 1934). The modified Kjeldhalm method was determined total N. Extraction the base cations (Ca^{2+}, Mg^{2+} and K^{+}) was performed using 1 M ammonium acetate (pH 7.0) followed by Pansu and Gautheyrou (2006). DTPA extraction was done to determine Cu, Fe, Mn, Zn and followed by atomic absorption spectrophotometer (AAS). $CaCl_2$ extraction method was used to determine Boron. Bray and Kurtz method while S was used to determine Phosphorus by turbidimetric method with $BaCl_2$. The organic samples were cleaned, air-dried and placed in an electric oven, dried at 105ºC for 24h. The nutrient dried samples of N, P, K, Ca, Mg, S, B and Zn, were determined followed the method of Jones and Case (2018).

The experiment was performed with six treatment combinations for sweet pepper cultivation. Treatment T_1 represented the application of 100% recommended dose of fertilizers, namely N_{115}, P_{70}, K_{125}, S_{20}, and Zn_2 kg ha^{-1}. Treatment T_2 represented 75% of the recommended dose (N_{88}, P_{53}, K_{94}, S_{15}, $Zn_{1.5}$ kg ha^{-1}) with 5 t ha^{-1} cow dung (CD). Treatment T_3 represented =75% recommended dose combined with 5 t ha^{-1} cow dung slurry. Treatment T_4 represented 75% recommended dose with 3 t ha^{-1} poultry manure (PM). Treatment T_5 represented 75% recommended dose along with 3 t ha^{-1} poultry manure slurry, Treatment T_6 represented native soil fertility without any additional fertilizer or organic amendment.

Results

Effects of organic and inorganic fertilizer on pepper height are presented in Table 3. Pepper heights observed in organic and inorganic were not significantly different except control experiment. However, plant height at maturity varied from 71.53 to 81.94 cm where the highest result was found in 75% RD + 3 t PM slurry ha^{-1} and lowest in native fertility. The highest number of fruits per plant was recorded in the poultry manure slurry with 75% RD applied plots while the least was observed in the control plots. Fruit

length and fruit diameter obtained from poultry manure slurry with 75% RD treated plots and those of organic and inorganic were identical but higher than the ones obtained from the control plots. Table 3 shows the effects of integration of organic and inorganic fertilizer on pepper yield.

Table 3. Yield, yield components and quality of capsicum as influenced by organic and inorganic fertilizer at Gazipur

Treatment	Plant height (cm)	No. of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (cm)	Pericarp thickness (mm)	Fresh fruit wt. (g)	Dry wt. (g)	Shelf life (days)	Yield (t ha^{-1})	pH	TSS (^{0}Brix)	Vit-C mg 100 g^{-1}	Firmness kgf cm^{-2}
T_1	78.67 a	13.00ab	9.45	6.99ab	6.16b	141.27	10.87 a	6c	21.72b	5.86	4.35bc	80.22	0.32
T_2	79.17 a	13.00ab	9.34	7.15ab	6.22b	142.70	9.18bc	10b	24.66ab	5.79	4.42bc	83.37	0.30
T_3	81.72 a	11.00b	8.83	7.34a	6.07b	136.43	9.63b	11ab	21.62b	5.72	4.65bc	91.26	0.29
T_4	79.87 a	13.00ab	9.44	7.01ab	6.46ab	143.73	9.03bc	12a	24.95ab	5.63	4.75ab	105.20	0.31
T_5	81.94 a	14.00a	9.79	7.33a	6.91a	152.30	10.94 a	12a	26.15a	5.61	5.40a	107.83	0.34
T_6	71.53 b	8.00c	9.26	6.86b	5.14c	127.30	8.72c	8c	11.08c	5.48	4.00c	54.99	0.28
CV (%)	4.21	8.36	5.85	3.61	6.03	13.33	4.53	9.50	8.83	7.10	6.33	25.43	11.67

Maximum fresh fruit weight was recorded in T_5 (152.30 g) and minimum fresh fruit weight was recorded in T_6 (127.30 g). Result revealed that dry matter content in fruits was significantly influenced with the increase in application of nutrients through organic sources and inorganic fertilizers. The treatment 5 was recorded the highest dry weight of 10.94g. and minimum dry weight was recorded in T_6 (8.72 g). It was statistically significant in variation among dry wt. of fruits. At 90 DAT maximum shelf life (12) was shown in T_5 and minimum shelf life (6) was recorded in T_1. It was statistically significant variation among fruit shelf life. Maximum pericarp thickness was recorded in T_5 (6.91 mm) and minimum pericarp thickness was recorded in T_6 (5.14 mm).

The combination of organic and inorganic fertilizer effects was significantly variated on the yield of sweet pepper (Table 3). The highest yield 26.15 tha^{-1} was found in T_5 (75% RD + 3 t PM slurry ha^{-1}) and in the lowest in native fertility (T_6). The result showed that T_4 and T_2 were 24.95 and 24.66 tha^{-1}, respectively. To apply 3 t PM slurry ha^{-1} increased the soil physical properties which enhanced by using 75% RD. Growth and yield parameter of sweet pepper were increased in the mentioned treatment. It is found that the experiment in combined application of organic and chemical fertilizers is shown to be effective for sweet pepper cultivation. However, the average lowest yield (11.27 t ha^{-1}) was obtained from native fertility treatment. T_1 treatment showed the highest fruit pH, while T_5 was the lowest fruit pH. It was not significantly differed among treatments. Application of various kinds of inorganic with organic manure was significantly increased a

total soluble solid (Table 3). The 3 tha^{-1} PM slurry treatment was found to be the most total soluble solid (5.4 ^{0}Brix) and the least value related to the native fertility (4.0 ^{0}Brix). Result showed the different combination of organic treatments affected vitamin C content in fruits (Table 3). The highest vitamin C content was shown in T_5 which was 107.83 mg 100 g^{-1}.
The highest value of fruit firmness was found in 3 tha^{-1} PM slurry with 75% RD application with 0.34 kgf cm^{-2}, while the least fruit firmness was found in native fertility with 0.32 kgf cm^{-2}.

Discussion

Yield attribution

The recorded data were significantly highest number of fruits per plant, fruit length, fruit diameter, fresh fruit weight, dry weight, pericarp thickness, shelf life and fruit yield ton/ ha. Combination of inorganic sources and poultry manure slurry increased in yield which related to Capsicum. It may due to availability of native and applied macro and micro-nutrients, a balanced C/N ratio, decomposition, and mineralization. These results were related to the findings of Magray (2002) in capsicum, Harikrishna *et al.* (2002) in tomato, Malawadi *et al.* (2004) in chilli. Fruit yield was statistical significantly influenced by increasing fertilizers application (inorganic fertilizer and organic PM slurry). The inorganic fertilizer efficacy is pronounced when mixed with organic manures. The increased growth and balanced C/N ratio related to increase the synthesis of carbohydrates which promoted high yield. These results were related to the findings of Malewar *et al.* (1998) in chilli, Magray (2002) in capsicum.

Quality parameters

Results indicated that compost was significantly affected the pH of fruit which related to compost application. It is shown that the highest fruit pH related to the lowest organic and inorganic application with 5.61, while the lowest fruit pH found in control which was 5.48. It was not significantly differed between treatments. The result is related to the findings of Toor *et al.* (2006) and Mauromicale *et al.* (2011). The fruit pH is reported to correlate with acid content and citric acid which is the primary organic acid found in the most fruits (Wang and Lin, 2002). Fruits with low pH value gathered from growing with organic fertilizers reported to be more citric acid, which is beneficial for human health (Wang and Lin, 2002). The fruit with low pH is reported to be more suitable for ripening, while it is improved the shelf life (Hernandez-Perez *et al.,* 2005). Application of compost was significantly increased a total soluble solid. The PM slurry 3 tha^{-1} application found to be the most total soluble solid (5.40 ◦Brix) and the least value was shown in the

control (4.00 ◦Brix). Similar results were found by Toor *et al.* (2006) and Santiago *et al.* (2009) who reported that the harvested fruits from applying manure and mineral fertilizer was significantly greater a total soluble solid (TSS) than the harvested fruits applying mineral fertilizer alone. The fruit quality improvement may be related to better plant growth and fruit quality at various application rate of organic fertilizer, which might favor crop production (Rajbir *et al.*, 2008). The research finding indicated that organic and inorganic combination affected to vitamin C of fruits. The greatest vitamin C content was found to produce the lowest level of organic and inorganic application (PM slurry 3 tha^{-1}+75% RD) with 107.83 mg 100 g^{-1}, while the least vitamin C in fruits was revealed in control with 54.99 mg 100 g^{-1}. Level of Vitamin C in vegetables depend on various related factors including cultivar, plant nutrition, production practice and fruit maturity (Antonio *et al*., 2007). The research finding agreed with Taiwo *et al.* (2007) who reported that manure application at various concentrations improved vitamin C in fruits. Organic fertilizer is reported to be a low yield of tomatoes with high ascorbic acid content, whereas mineral and organic fertilizer combination resulted to high yield of fruits with lower ascorbic acid content (Dumas *et al.,* 2003). Therefore, the finding confirmed the previous studies that the level of vitamin C in fruits from organically grown peppers was higher than in conventionally grown peppers. Fruit firmness was significantly greater in compost application than the non-treated control. The highest value of fruit firmness was observed at 15 t ha^{-1} application t with 8.5 N, while the least fruit firmness was found in control with 5.8 N. It is agreed with Mccollum *et al.* (2005) and Riahi *et al*. (2009) who stated that organic tomato fruits were generally firm which it do not lose much juice when sliced and less susceptible to physical damage during shipping.

It is summarized that applying organic fertilizer is maintained soil fertility. The combination of 3 tha^{-1} PM slurry along with 75% recommended dose of chemical fertilizer showed significantly higher yield of sweet pepper (cv. BARI Misti morich-1) enhanced crop growth and sweet pepper quality. Among the four organic manures, it is proved that poultry manure slurry was the most successfully result to be greater amount of plant nutrients than the other organic fertilizers. PM slurry is found to be locally available and environmentally friendly. The integrated application of chemical fertilizer and PM slurry was recorded to be the best for sweet pepper cultivation and followed by poultry manure, cowdung slurry and cowdung applications.

Acknowledgements

Authors are extremely grateful to Ministry of Agriculture, Bangladesh for their funding support to Bangladesh Agricultural Research Institute (Grant ID: 143/4301/1430101/131014800) and also thanks to laboratory personnel of analytical service laboratory, Soil Science Division, Bangladesh Agricultural Research Institute.

Conflicts of interest

The authors declare no conflict of interest.

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(Received: 26 March 2025, Revised: 9 July 2026, Accepted: 13 September 2026)