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Nutritional Quality of Tomato as Affected by Integrated Use of Poultry Manure and Inorganic Fertilizers

M. Islam[1], M.G. Kibria[2] and K.T. Osman[3*]
[1,2,3] Department of Soil Science, University of Chittagong, Chittagong-4331, Bangladesh

Abstract
In order to study the nutritional quality of tomato as affected by integrated use of poultry manure (PM) and inorganic fertilizers, a field experiment was conducted at the Research Field of the Department of Soil Science, University of Chittagong, Bangladesh. Two tomato (Lycopersicon esculentum Mill.) varieties BARI-14 and BARI-15 were used in this experiment. There were six treatments- T1(control; no poultry manure + no fertilizer), T2 (100% RDF; i.e. recommended doses of fertilizers NPK@ 120 kg N ha^{-1}, 60 kg P ha^{-1} and 80 kg K ha^{-1}, T3 (30 t ha^{-1} PM i.e. poultry manure), T4 (75% RDF+ 7.5 t ha^{-1} PM), T5 (50% RDF + 15 t ha^{-1} PM) and T6 (25% RDF + 22.5 t ha^{-1} PM). The treatments were arranged in a randomized block design with three replications. Nutritional quality of tomato in terms of reducing sugar, non-reducing sugar and total soluble sugar, lycopene, vitamin C and protein content of tomato were determined at ripe stage. The results showed that application of poultry manure or recommended doses of fertilizer alone and their different combinations significantly increased reducing sugar, total soluble sugar, lycopene, vitamin C and protein content of tomato compared to control. Lycopene and vitamin C contents of BARI-15 were lower but protein content was higher than those of BARI-14 variety. The combined use of NPK fertilizers and poultry manure was found more effective in increasing the different quality parameters of tomato compared to NPK fertilizers or poultry manure alone.

Key words: *Nutritional quality, tomato, poultry manure, fertilizer.*

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I. Introduction

Tomato (*Lycopersicon esculentum Mill.*) is an important crop cultivated and consumed worldwide. Due to the nutritional value of tomato to human diet and subsequent importance in human health and its economic importance, tomato has become an important cash and industrial crop in many parts of the world [1]. Tomatoes production accounts for about 4.8 million hectares of harvested land area globally with an estimated production of 162 million tones [2]. In regions where it is being cultivated and consumed, it constitutes a very essential part of people's diet. It can be consumed fresh in salads, cooked in other dishes or processed into other food products [1, 3, 4, 5]. Tomatoes and tomato-based foods provide a wide variety of nutrients and many health-related benefits to the body. Lycopene is a type of carotenoid with anti-oxidant properties [6] which is present in tomato in higher amounts and is beneficial in reducing the incidence of some chronic diseases [7] like cancer and many other cardiovascular disorders [8]. Consumption of tomatoes and tomato-base foods can reduce incidence of a variety of cancers in general, including pancreatic, lung, stomach, colorectal, oral, bladder, breast and cervical cancers [9]. The old-age related diseases like dementia, osteoporosis, Parkinson's and Alzheimer's can be prevented by consumption of tomatoes [8]. Tomatoes have high sources of vitamin C and vitamin A which are vital in warding off muscular degeneration and improve eyesight. It is also believed to be powerful blood purifier and clear up urinary tract infections. The main functions of vitamin C are in the prevention of scurvy and maintenance of skin and blood vessels [10]. Franceschi *et al.*[11] and Frusciante *et al.*[12] reported that the consumption of the tomato and its sub products (i.e., ketchup, paste) is negatively correlated with the development of tumors in the digestive tract and prostate cancer. Tomatoes are high in fibre which aids easy digestion and can assist in weight loss. These numerous health benefits of tomatoes and tomato-based foods may be linked to its high production globally. The tomato is now grown worldwide for its edible fruits. Tomato fruit quality can be affected by many factors including genetic, environmental, pre- and postharvest factors. The intensive nature of vegetable production necessitates fertilizer management aimed at maximizing yield and quality[13] There is great interest in organic crop production [14], particularly in adding organic matter to the soil, which liberates nutrients in a gradual and controlled way, allowing a great production of vegetables with minor environmental impact [15, 16]. The need to use renewable forms of energy and reduce costs of fertilizing

[*] Deceased

crops has revived the use of organic fertilizers worldwide [17]. Poultry manures provide organic matter to soil and nutrients to crops [18]. Poultry manure is an excellent organic fertilizer, as it contains high nitrogen, phosphorus, potassium and other essential nutrients [19]. Lee et al. [20] showed that the amount of added nitrogen could be reduced by 40% with the addition of poultry manure. Poultry manure is an effective source of nutrients for vegetables such as tomato [21]. Although, the effects of poultry manure on growth and yield s of some vegetable and grain crops have been reported by some workers[22, 23] but research information on response of crop quality to application of poultry manure (BPR) is scarce. In the light of these issues, a study was conducted to determine the growth, yield and nutritional quality of tomato as influenced by different levels of poultry manure, NPK fertilizer and integrated use of NPK fertilizer and poultry manure. The results of the study in relation to effects of poultry manure and NPK fertilizer on growth and yield of tomato have been reported in our previously submitted paper for publication. The nutritional qualities of tomato as influenced by poultry manure and NPK fertilizer have been presented in this paper.

II. Materials and Methods

2.1 Pot experiment

A field experiment was conducted to study the effects of poultry manure and NPK fertilizers on growth and yield of tomato at research field of the Department of Soil Science, University of Chittagong. The treatments consisted of as the following:

T1 = Control (No fertilizer + No poultry manure)

T2 = 100% RDF (100% recommended dose of fertilizers NPK @ 120 kg N ha^{-1}, 60 kg P ha^{-1} and 80 kg K ha^{-1}) according to BARC (2005)

T3 = PM (poultry manure) @30 ton ha^{-1}

T4 = 75% RDF (NPK @ 90 kg N ha^{-1}, 45 kg P ha^{-1} and 60 kg K ha^{-1}) + 7.5 ton ha^{-1} PM

T5= 50% RDF (NPK @ 60 kg N ha^{-1}, 30 kg P ha^{-1} and 40 kg K ha^{-1})+ 15 ton ha^{-1} PM, and

T6= 25% RDF (NPK @ 30 kg N ha^{-1}, 15 kg P ha^{-1} and 20 kg K ha^{-1}) + 22.5 ton ha^{-1} PM

The whole experimental land was divided into unit plots maintaining the desired spacing. The whole area of the experimental land was divided into 3 blocks and each block was again subdivided into 12 unit plots (for 2 varieties× 6 treatments). Thus the total number of plots was 36. The experiment was laid out in a randomized complete block design with three replication of each treatment. The unit plots were 2 m×2 m size separated by 0.5 m margin. Seeds of two tomato varieties of BARI-14 and BARI-15 were collected from Bangladesh Agricultural Research Institute and the seedlings of the two tomato cultivars were raised in nursery bed. Thirty days old seedlings were transplanted in the main plots. The space between rows to row was 50 cm and seedling to seedling within a row was 40 cm. Poultry manure (PM) was collected from a poultry farm at Fatehpur in Chittagong. Poultry manure was applied in the plots before 3 weeks of transplantation. According to the recommendation of Bangladesh Agricultural Research Council [24], nitrogen and potassium was applied in two equal installments at 15 and 35 days after transplanting as ring method around the plants followed by irrigation. Full phosphorus was broadcast and incorporated during final land preparation.

2.2 Properties of soil and poultry manure

Surface soil sample was collected before conducting the experiment from the experimental site. Poultry manure (PM) was collected from a poultry farm at Fatehpur in Chittagong and separated some amount of poultry manure for laboratory analysis. Soil texture was determined by hydrometer method of Day [25], pH in a 1:2.5 soil/water suspension with glass electrode pH mater, organic carbon by wet-oxidation method [26], total nitrogen by Micro-Kjeldahl digestion and distillation and CEC by 1N NH_4OAC saturation [27], and available phosphorus by Bray and Kurtz II method [28]. Properties of soil and poultry manure are given in Table.1.

Table 1 Properties of soil and poultry manure

Properties	Value
Soil	
Texture	Clay loam
Sand	33%
Silt	19%
Clay	48%
pH	5.10
Cation exchange capacity(CEC)	8.76 cmol kg^{-1},
Total nitrogen	0.12%
Available P (Bray & Kurtz II)	12 mg kg^{-1}
Poultry manure	
pH	7.65
Total nitrogen	0.28%
Available P (Bray & Kurtz II)	14.17 mg kg^{-1}

2.3 Determination of tomato quality

Soluble reducing and non-reducing sugars, total soluble sugars were determined by Shahnawaz *et al.* [29] and vitamin C by Jideani and Onwubali [30]. Lycopene in the tomato samples was extracted by hexane: acetate: ethanol (2:1:1, v. v. v) mixture following the method of Sharma and Le Maguer [31]. The absorbance of hexane solution containing lycopene was measured at 472 nm on a spectrophotometer using hexane as a blank. The lycopene concentration was calculated using its specific extinction coefficient (E1%, 1 cm) of 3450 in hexane at 472 nm [32]. Oven dried (65^0 C constant weights) and ground ripe fruit samples were digested with a mixture of H_2SO_4, H_2O_2 and lithium sulfate for the determination of N in the fruit tissues [33]. Micro- Kjeldahl method as described by Jackson [27] was used for the determination of nitrogen. Protein content of plant material was obtained by multiplying the nitrogen value by 6.25.

2.4 Statistical analysis

The collected data were subjected to analysis of variance, and treatment means were compared using Duncan's Multiple Range Test (DMRT) at a 5% probability level. The statistical software Excel [34] and SPSS version 12[35] were used for these analyses.

III. Results and Discussion

3.1 Reducing sugar, Non reducing sugar and Total soluble sugar content

Data on reducing sugar, non-reducing sugar and total soluble sugar are presented in Table 2. The reducing sugar content of tomato among the treatments of this study varied significantly from 2.30 to 2.65 % in BARI-14 and from 2.26 to 2.59% in BARI-15 variety. The highest reducing sugar content of tomato was found in treatment T6 (25% RDF + 22.5 ton ha^{-1} PM) and the lowest reducing sugar content was found in control treatment T1 in both the tomato varieties. Reducing sugar content of tomato in BARI-14 and BARI-15 with the treatments T2 (100% RDF), T4 (75% RDF+7.5 ton ha^{-1} PM) and T5 (50% RDF+ 15 ton ha^{-1} PM) was not significantly different from that with the control treatment T1. Reducing sugar content of two tomato varieties found with applied treatments was similar.

The non-reducing sugar content of tomato in BARI-14 were in the ranges between 0.83% in treatment T2 (100% RDF) and 0.92 % in treatment T3 (30 ton ha^{-1} PM). The values of non- reducing sugar content in BARI-15 varied from 0.78% in T2 (100% RDF) to 0.89% in T3 (30 ton ha^{-1} PM). The non-reducing sugar contents did show significant variation among the treatments neither in BARI-14 nor in BARI-15.

Table 2 Effects of poultry manure and NPK fertilizers on reducing sugar, non-reducing sugar and total soluble sugar content of tomato.

Variety	Treatment	Reducing sugar (%)	Non-reducing sugar (%)	Total soluble sugar (%)
BARI-14	T1	2.32 de	0.85 a	3.33 d
	T2	2.42 bcde	0.83 a	3.35 d
	T3	2.62 ab	0.92 a	3.60 ab
	T4	2.42 bcde	0.89 a	3.35 d
	T5	2.50 abcd	0.91 a	3.44 bcd
	T6	2.65 a	0.87 a	3.63 a
BARI-15	T1	2.26 e	0.82 a	3.29 d
	T2	2.36 cde	0.78 a	3.31 d
	T3	2.56 abc	0.89 a	3.55 abc
	T4	2.36 cde	0.87 a	3.32 d
	T5	2.44 abcde	0.86 a	3.41 cd
	T6	2.59 ab	0.86 a	3.58 ab

Mean values in a column followed by the same letter(s) are not significantly different by DMRT ($p<0.05$)

The total soluble sugar content of tomato was found to be varied between 3.33 and 3.63% in BARI-14 and between 3.29 and 3.58 % in BARI-15 on dry matter basis. There was a significant variation in total soluble sugar content of tomato among the treatments. The treatments T2 (100% RDF), T4 (75% RDF+7.5 ton ha^{-1} PM) and T5 (50% RDF+ 15 ton ha^{-1} PM) did not significantly increase total soluble sugar content of tomato in both BARI-14 and BARI-15 from that of the control. The total soluble sugar contents of tomato in treatments T3 (30 ton ha^{-1} PM) and T6 (25% RDF + 22.5 ton ha^{-1} PM) were significantly higher than that of the control but they were statistically similar with each other. Total soluble sugar content was similar between two tomato varieties.

3.2 Lycopene content of tomato

Lycopene content of tomato varied significantly with the treatments in both the varieties BARI-14 and BARI-15. Levels of lycopene ranged from 137.00 to 297.00 mg kg^{-1} in BARI-14 and 128.33 to 287.33 mg kg^{-1} in BARI-15 (Table 3). Application of NPK fertilizers or poultry manure alone and their different combinations significantly increased the level of lycopene over that with control in both the tomato varieties. The highest level of lycopene content of tomato was found with 30 ton ha^{-1} PM (T3) that was statistically similar to that with 25% RDF + 22.50 ton ha^{-1} PM application. Similar increase in lycopene in organically grown tomato was reported by Lumpkin [36]. In agreement with the present study, Adeniyi and Ademoyegun [37] also reported the more influence of organic fertilizers than inorganic fertilizer on the level of lycopene content of tomato. Between two tomato varieties, lycopene content was higher in BARI-14 than BARI-15 with each treatment.

3.3 Vitamin C content of tomato

The vitamin C (ascorbic acid) content of tomato was found to be significantly varied from 230.17 to 256.13 mg kg^{-1} in BARI-14 and from 209.50 to 241.53 mg kg^{-1} in BARI-15 with the treatments of the present study (Table 3). The highest vitamin C content was found with the treatment T3 (30 ton ha^{-1} PM) and the lowest vitamin C content was found with the treatment T1 (control) in both the tomato varieties. Although application of 100% RDF did not increase vitamin C content of tomato from the control but its combination with poultry manure in treatment T4 (75% RDF+7.5 ton ha^{-1} PM), T5 (50% RDF+15 ton ha^{-1} PM) and T6 (25% RDF + 22.5 ton ha^{-1} PM) or poultry manure alone @ 30 kg ha^{-1} (T3) significantly increase vitamin content from the control. However, there was no significant difference between T3 and T6 and between T4 and T5 in producing vitamin C in tomato variety BARI-14. In variety BARI-15, the treatments T3, T4, T5 and T6 were statistically similar with each other. The results of the present study are in agreement with the finding of Shankar and Sumathi [38] that vitamin C content of tomatoes was found to be significantly higher in organically grown compared to conventionally grown vegetables. The tomato variety BARI-14 contained significantly higher amounts of vitamin C than BARI-15 variety with each treatment except T5 (50% RDF+15 ton ha^{-1} PM).

3.4 Protein content of tomato

Protein content of tomato varied significantly from 1.81 to 2.37 % in BARI-14 and 2.27 to 2.86 % in BARI-15 by the treatments of the present study (Table 3). The highest protein content was found with treatment T3 (30 ton ha^{-1} PM) and the lowest protein content was found with control treatment T1 in both BARI-14 and BARI-15. Application of 100% RDF (T2) and 30 ton ha^{-1} poultry manure (T3) alone or their different combinations in treatment T4 (75% RDF+7.5 ton ha^{-1} PM), T5 (50% RDF+15 ton ha^{-1} PM) and T6 (25% RDF + 22.5 ton ha^{-1} PM) significantly increased protein content in tomato compared to control treatment T1. Protein content of tomato in treatments T3 (30 ton ha^{-1} PM) and T6 (25% RDF + 22.5 ton ha^{-1} PM) were statistically similar with each other but are significantly higher than that with all other treatments. The observation of the present study is corroborated with the findings of Odoemena [39] who reported that protein content of tomato increased with increased application of poultry manure compared to the control. Between two tomato varieties, protein content of BARI-15 was significantly higher than that of BARI-14 with each treatment.

Table 3 Effects of poultry manure and NPK fertilizers on lycopene, vitamin C and protein content of tomato.

Variety	Treatment	Lycopene (mg kg^{-1})	Vitamin C (mg kg^{-1})	Protein (%)
BARI-14	T1	137.00 g	230.17 cde	1.81 i
	T2	173.33 e	239.90 bcd	1.89 h
	T3	297.00 a	256.13 a	2.37 d
	T4	192.33 d	240.90 bc	2.10 g
	T5	285.33 b	244.93 ab	2.22 f
	T6	296.33 a	255.83 a	2.32 de
BARI-15	T1	128.33 h	209.50 f	2.27 ef
	T2	165.00 f	218.17 ef	2.35 d
	T3	287.33 b	241.53 bc	2.86 a
	T4	180.00 e	226.03 de	2.59 c
	T5	276.66 c	233.60 bcd	2.71 b
	T6	284.00 b	236.40 bcd	2.81 a

Mean values in a column followed by the same letter(s) are not significantly different by DMRT ($p<0.05$)

IV. Conclusion

Application of poultry manure alone or in combination with NPK fertilizers significantly increased reducing sugar, total soluble sugar, lycopene, vitamin C and protein content of tomato compared to the control in valley soils of Chittagong. Lycopene and vitamin C contents of BARI-15 were lower but protein content was higher than those of BARI-14 variety. Integrated use of poultry manure with NPK fertilizer is recommended for improving the nutritional quality of tomato.

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