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ORGANIC FARMING ON NUTRITIONAL QUALITY, BIOACTIVE COMPOUNDS AND YIELD OF TOMATO

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SUBMITTED TO:

Course Instructors	Major Professor
1. Prof. Dr. A. K. M. Aminul Islam Department of GPB BSMRAU, Gazipur 2. Dr. Md. Abdullahil Baki Bhuiyan Assistant Professor Department of Plant Pathology BSMRAU, Gazipur	Dr. Md. Manjurul Haque Associate Professor Head of the Department Department of Environmental Science BSMRAU, Gazipur

SUBMITTED BY:

Md. Sohel Rana

MS Student

Reg. No.: 16-11-4150

Department of Environmental Science

BANGABANDHU SHEIKH MUJIBUR RAHMAN AGRICULTURAL UNIVERSITY

SALNA, GAZIPUR 1706

Organic Farming on Nutritional Quality, Bioactive Compounds and Yield of Tomato[1]

Md. Sohel Rana[2]

ABSTRACT

The application of chemical fertilizer is the accepted method of intensive agriculture despite the apprehension of environmental pollution. Movement of nitrogen (N) and phosphorus (P) from agricultural fields to surface water may cause eutrophication of aquatic ecosystems. Application of P fertilizers can also introduce cadmium into the soil and, thereby, to the crops. Organic farming, which strictly limits the use of chemical fertilizers, provides an alternative that minimizes the negative effects of chemical fertilization. Unfortunately, organic farming almost always means a lower yield and increasing cost of production. Integrated nutrient management systems do not aim to entirely remove chemical fertilizers but suggest the use of microbial inoculants or "biofertilizers" (products containing living cells of microorganisms), or plant growth promoting microbes (PGPM), to reduce the amount of the chemical fertilizers applied. Among PGPM, *Trichoderma* species are filamentous fungus widely used as biopesticides. *T. hazianum* strain T203 was shown to increase the concentrations of P, Fe, Mn, Cu, Zn, and Na in cucumber roots grown in hydroponic system whereas *T. asperellum* strain T34 was shown to decrease the concentration of Cu, Zn and Mn in aerial part of wheat plants grown in a ferrihydrite-enriched calcareous medium.

Key words: Organic Farming, TEB, Nutritional Quality, Bioactive Compounds.

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[1] A seminar paper presented at the graduate seminar course on 21 December 2017.

[2] M.S Student, Department of Environmental Science, BSMRAU, Gazipur-1706.

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CHAPTER 1

INTRODUCTION

Tomato (*Solatium lycopersicum* L. syn. *Lycopersicon esculenlum* Mill.) is one of world's most popular vegetable, being consumed either fresh or utilized in preparation of wide range of process products such as juice, ketchup, sauce, paste, chutney and salsa. Tomato is the second most produced vegetable in the world (FAOSTAT, 2014). Due to wider adaptability, it is also grown in Bangladesh. In 2012, tomato crop cultivated area in Bangladesh was 25672 ha and produced about 255430 tons (FAOSTAT, 2013). It is an excellent source of minerals (notably potassium, calcium and magnesium), carboxylic acids, including ascorbic, citric, malic, fumaric and oxalic acids (Caputo *et al*., 2004; Herndndez-Suirez *et al*., 2007), antioxidants, such as lycopene, β-carotene, lutein, phytoene, phytofluene, vitamin C and E (Hemandez-Suarez *et al*., 2007; Capanoglu *et al*., 2010; Ray *et al*., 2011; Nour *et al*., 2013), phenolic compounds, such as flavonoids and hydroxyinnamic acid derivates, including quercetin. kaempferol, rutin, myricetin and naringenin (Hernandez-Suarez *et al*., 2007; Ray *et al*., 2011), vitamins, such as vitamin C, E, folic acid, niacin, and trace elements, e.g. selenium, copper, manganese, iron and zinc (Luthria *et al*., 2006; Molla *et al*., 2012). Surprisingly, tomato is low in fat, as well as cholesterol-free. Therefore, consumption of tomato and tomato products reduced the risk of cardiovascular disease and certain types of cancer, such as cancers of prostate, lung and stomach (Canene-Adams *et al*., 2005). However, minerals and phytochemical contents of tomato are dramatically affected by the environmental factors and agronomic practices (Dumas et al., 2003; Hernandez Suarcz *et al*., 2007; Nour et al., 2013).

The application of chemical fertilizer is the accepted method of intensive agriculture. In fact, increased use of chemical fertilizer, played an important role in the immense success in food productivity. However the recovery rates of chemical fertilizers by plant are usually as low as less than 30%, which increases farmers investment in crop production and pollutes environments. For example, applied phosphorus (P) may cause eutriphication of aquatic ecosystems, leading to anoxic areas called dead zones (Simpson *et al*., 2011). Nevertheless, P fertilizers used in conventional agriculture can introduce cadmium into the crops (Rembialkowska, 2007). Nitrogen (N) fertilizer has been linked to leaching of nitrate into ground water and increased denitrification, resulting in elevated emission of nitrous oxide (N_2O) to the atmosphere (Galloway *et al*., 2003). N_2O is considered an important factor in ozone layer depletion, global warming and acid rain (Ma *et al*., 2007; Burger and Ventera, 2011). Application of N fertilizers may also deplete soil organic carbon (Khan *et al*., 2007). Nitrate is relatively non-toxic, in the digestive system it is readily converted to nitrites, which can react with amines and amides to produce N-nitroso compounds that are toxic and these have been associated with the potentially fatal methemoglobinemia (also known as blue baby syndrome) (Chan, 2011).

Objectives:

1. To study the effects of BioF/compost alone or in combination with reduced rates of N fertilize , on growth, yield attributes and yield of tomato.
2. To know the effects of BioF/compost alone or in combination with reduced rates of Nitrogen fertilizer on nutritional quality and bioactive compounds in tomato.
3. To study the impacts of BioF/compost alone or in combination with reduced rates of Nitrogen fertilizer on improvement of soil health.

CHAPTER 2

MATERIALS AND METHODS

This seminar paper is exclusively a review paper. So, no specific methods of studies are followed to prepare this paper. All data and information were collected and used from secondary sources. This seminar paper has been complied through reading of different books, journals, booklets, proceeding, newsletters, souvenir, consultancy report that are available in the libraries of BSMRAU, BRRI. Maximum necessary supports were taken from internet searching. Finally, this seminar paper was prepared with the consultation of my respective major professor and honorable seminar course instructors.

CHAPTER 3

REVIEW OF FINDINGS

3.1 Organic Farming

Organics, or the ‘O-word’ as Mark Lipson (1997) has wryly called organic agriculture in recognition of the ambiguous nature of the word, is a problematic label that can be interpreted to mean a wide range of things. The term ‘organic’ was first used in relation to farming by North-bourne (1940) in the book Look to the Land: ‘the farm itself must have a biological completeness; it must be a living entity, it must be a unit which has within itself a balanced organic life’. Clearly, Northbourne was not simply referring to organic inputs such as compost, but rather to the concept of managing a farm as an integrated, whole system (Lotter 2003). The use of ‘organic’ in reference to agricultural production and food is legally constrained in many countries, and some certification agencies have more stringent compliance requirements than others. Many farmers in less developed countries may practice organic agriculture by default based on their traditional methods of production. However, it is useful to provide a general definition of organic agriculture to indicate briefly what the production systems are designed to achieve.

Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasises the use of management practices in preference to the use of off farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfill any specific function within the system (FAO 1999).

Difference between onganic farming and conventional farming

Sl No	Organic Farming	Conventional Farming
1.	It is based on ecological orientation.	It is based on economical orientation.
2.	GMOs are not used.	GMOs are used.
3.	Synthetic fertilizers are not used.	Synthetic fertilizers are used.
4.	Manually weeds are removed here.	Weeds are controlled through herbicides.
5.	Pest and diseases are controlled biologically.	Pesticides and fungicides are used to control pest and diseases.
6.	Air, water and soil pollution is not common here.	Air, water and soil pollution is common here.
7.	Soil fertility is maintained on long term basis.	Soil fertility is maintained for short period.

Source: FAO (1999)

3.2 Organic Farming in Agriculture

In 2004, 80% of organically managed land is located in only ten countries, with more than 50% in two countries, Australia and Argentina (Yussefi 2004). However, the most intensive adoption of organic agriculture has occurred in western Europe, especially in the German-speaking countries and Scandinavia, with three countries achieving at least 10% of organic agriculture and five more countries with over 5% organic agriculture (Table 1). The highest numbers of organic farms are reported to be in many non-European countries, although some European countries also have over 15,000 organic farms (Table 2).

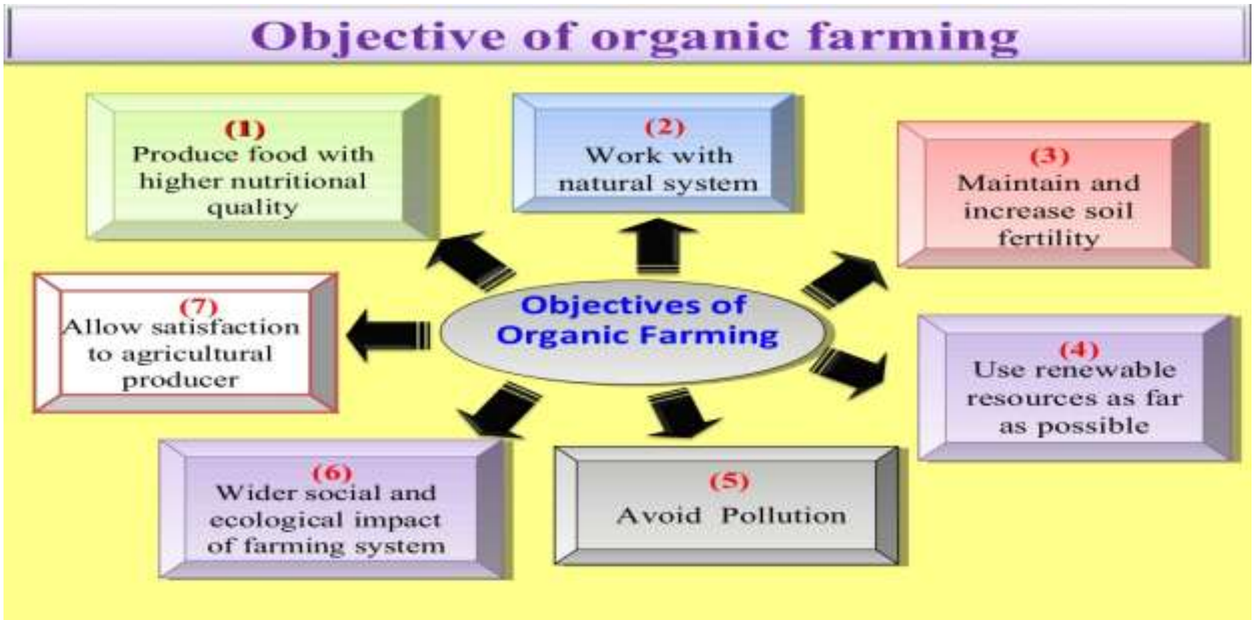

Figure 1: Objectives of Organic Farming

Source: Yedidia *et al* (2001)

Figure 2: Components of Organic Farming

Source: Santiago *et al* (2011)

Table 1: Percentage of national agricultural land under organic management

Country	Percentage (%)
Liechtenstein	26.4
Austria	11.6
Switzerland	10
Italy	8
Finland	7
Denmark	6.7
Sweden	6.1
Czech Republic	5.1
United Kingdom	4.2
Germany	4.1

Source: Yussefi (2004)

Table 2: Number of farms under organic management

Country	No. of farms
Mexico	53,577
Italy	49,489
Indonesia	45,000
Uganda	33,900
Tanzania	26,986
Peru	23,057
Brazil	19,003
Austria	18,576
Turkey	18,385
Spain	17,751

Source: Yussefi (2004)

3.3 Organic Farming in Tomato Cultivation

The society has been increasingly concerned about environmental damage caused by agricultural activities, especially with regard to health hazards resulting from the use of agrochemicals. On the other hand, growing phytosanitary problems and ever-increasingly de-pauperate soils lead to an all time high utilization of these products. Sustainability of conventional agriculture started being questioned, and the agricultural scene experienced changes (Van Bruggen, 1995). The emergence of market segments interested in differentiated products lead farmers to search for alternative cropping systems, enabling the production of food crops at lower environ-mental and economic costs.

The adoption of the new practices brought, how-ever, the need for comparison between low-input against conventional systems. In addition, recovering the principles and mechanisms that operate in the nature to be utilized as replacement for the traditional input, will only be achieved if a broad base of knowledge of the complex relationships between organisms and their relationship with the environment is available (Edwards, 1989; Ghini & Bettiol, 2000). To that effect, interdisciplinary studies are needed to verify whether or not the sustainability of the agro-ecosystems can be achieved. Although the development of ecologically sound agriculture systems is rapidly emerging as a priority, few research papers have detailed the effects and interactions of the new proposed practices.

Tomato cropping is an excellent model for comparisons between the conventional and the organic systems for reasons like the intense use of agricultural in-put and the risk of contamination of consumers, farmers and ground water by agrochemicals (Drinkwater *et al*., 1995). In an interdisciplinary study, Drinkwater et al. (1995) evaluated several agronomical and ecological indicators in the organic and conventional tomato cropping systems in California (USA), and concluded that biotic agents are essential to make up for the absence of synthetic input. However, the involved mechanisms are much more complex than a mere replacement.

Creamer *et al*. (1996) compared in two locations the conventional, integrated, organic and no-input systems tomato cropping systems; the last three systems were associated to a cover crop. The number of fruits and flower clusters were higher in the conventional system during the initial assessments, becoming equivalent to the other systems later. No differences were observed with regard to the occurrence of pests and diseases among the treatments.

3.4 Vegetative Growth of Tomato

Vegetative growth, such as plant height, number of leaves and branches per plant was significantly influenced by the application of bio-fertilizer alone or in combination with N:P:K (Table 3). Treatments T2,T4, and T7 offered significantly (P B 0.05) higher plant height and number of leaves per plant. However, moderate plant height was recorded in treatments T3 and T8. The maximum number of branches per plant achieved by the standard dose of N:P:K (T2) followed by the treatments T7 and T4. BioF/compost (T3) produced significantly higher plant height, number of leaves and branches per plant as compared to the BioF/liquid (Heeb *et al*., 2006). Furthermore, application of 50 % BioF/compost or 50 % BioF/liquid combined with 50 % N:P:K (i.e., treatments T4 and T7) enhanced significantly higher plant height, number of leaves and branches per plant over the treatments T3 and T6. The lowest plant height, number of leaves and branches per plant were recorded in treatments T1 and T6.

Enhanced growth response of several plants, such as bean (Inbar *et al*.,1994), cucumber (Kleifeld and Chet.,1992), maize (Bjorkman *et al*.,1994), and tomato (Ozbay et al., 2004) were also noticed by the application of *Trichoderma* spp. And other biofertilizers. The increased plant growth by *Trichoderma* (*T. harzianum* strain T22, T39, and A6) may be due to production of secondary metabolites which may act as an auxin like compound (Vinale *et al*., 2008). Secondary metabolites such as harzianolide, anthraquinoues, T39 butenolide isolated from *Trichoderma* spp. was shown to increase growth of wheat while harzianic acid increased the growth of canola. Conversely, at higher concentrations, several secondary metabolites inhibited the plant growth. It has been shown that *Trichoderma* spp. increased nutrient uptake through enhanced root growth or promoted availability of necessary nutrients leading to growth of the plants (Harman *et al*., 2004). Moreover, *Trichoderma* reduced the concentrations of substances in soil that are inhibitory to plant growth. It has also been reported that *T. harzianum* 1295-22 could improve nitrogen use efficiency and could solubilize a number of poorly soluble nutrients, such as Mn4+ ,Fe3+ , and Cu2+ , etc., leading to better plant growth and development. Thus, one or several mechanisms may be involved in regulation of growth of tomato by *Trichoderma*-enriched biofertilizer alone or in combination with N:P:K.

Table 3. Impact of *Trichoderma*-enriched biofertilizer (BioF) on vegetative growth of tomato as sole and combination with N:P:K application at field condition

Treatments	Plant height (cm)	Number of leaves/plant	Number of branches/plant
T1 (control, without BioF and NPK)	66.33 c	34.60 f	6.33 e
T2 (standard dose of N:P:K)a	95.06 a	105.96 a	13.10 a
T3 (BioF/compost)b	80.53 b	53.40 e	8.20 de
T4 (50 % BioF/compost, i.e., T3 + 50 % N:P:K, i.e., T2)	93.80 a	104.50 a	11.20 abc
T5 (75 % BioF/compost, i.e., T3 + 25 % N:P:K, i.e., T2)	84.06 ab	76.66 cd	9.26 cd
T6 (BioF/liquid)c	69.33 c	34.46 f	6.53 e
T7 (50 % BioF/liquid, i.e., T6 + 50 % N:P:K, i.e., T2)	95.06 a	106.10 a	12.26 ab
T8 (75 % BioF/liquid, i.e., T6 + 25 % N:P:K, i.e., T2)	82.60 b	72.36 d	10.30 bcd
CV (%)	7.04	8.73	15.05
LSD ($P \leq 0.05$)	10.27	10.61	2.54

NB: [Different letters in column imply significant difference at ($P \leq 0.05$),a 120:108:10 kg ha-1 for N:P:K, b BioF/compost (composted kitchen wastes by T. harzianum T22), c BioF/liquid (Broth of spores suspension of T. harzianum T22)]. Source: Molla *et al*. (2012)

3.5 Dry Matter Production of Tomato

Shoot and root dry matter weight (per plant) was significantly (P B 0.05) influenced by combined application of bio-fertilizer and N:P:K (Table 4). Treatments T7 and T4 produced maximum root and shoot dry matter weight. The second highest root and shoot dry weight was found in treatments T8 and T2 and T5, respectively. However, the treatments T2,T3, and T6 presented similar root dry matter weight. Like vegetative growth, the lowest root (2.87 g) and shoot (30.55 g) dry matter weight was recorded in control treatment (T1). These results clearly illustrated that the dry matter of tomato plant was boosted by the combined use of bio-fertilizer and N:P:K. The increased root dry matter weight of plant could increase the chance for nutrients uptake through maximum exploitation of soils. The obtained results corroborate earlier findings (Bjorkman *et al*.,1994) that the application of *Trichoderma* spp. increased both root and shoot growth of corn. Shoot and root dry matter weight of tomato was also increased by 120.6 and 78.6 % when treated with other microbe, Rhodopseudomonas sp.

Table 4. Impact of *Trichoderma*-enriched bio-fertilizer (BioF) on dry matter production of tomato as sole and combination with N:P:K application at field condition

Treatments	Dry matter weight/plant (g)	
	Root	Shoot
T1 (control, without BioF and NPK)	2.87 e	30.55 e
T2 (standard dose of N:P:K)a	3.77 d	83.31 b
T3 (BioF/compost)b	3.90 d	45.35 d
T4 (50 % BioF/compost, i.e., T3 + 50 % N:P:K, i.e., T2)	6.38 a	93.20 a
T5 (75 % BioF/compost, i.e., T3 + 25 % N:P:K, i.e., T2)	4.67 c	83.54 b
T6 (BioF/liquid)c	3.95 d	42.05 d
T7 (50 % BioF/liquid, i.e., T6 + 50 % N:P:K, i.e., T2)	6.66 a	95.28 a
T8 (75 % BioF/liquid, i.e., T6 + 25 % N:P:K, i.e., T2)	5.08 bc	62.88 c
CV (%)	5.56	6.38
LSD ($P \leq 0.05$)	0.44	7.33

NB: [Different letters in column imply significant difference at ($P \leq 0.05$),a 120:108:10 kg ha-1 for N:P:K, b BioF/compost (composted kitchen wastes by *T. harzianum* T22), c BioF/liquid (Broth of spores suspension of *T. harzianum* T22)]. Source: Molla *et al*. (2012)

3.6 Promotion of plant growth by *T. harzianum* root colonization of Tomato

Plant-growth promotion by *T. harzianum* CECT 2413 was assayed under sterile conditions after 20 days of incubation. Effects due to the solubilization of soil nutrients were excluded by the use of complete specific plant-culture medium. Plants inoculated with *T. harzianum* developed better than control plants (Fig. 3A), as evidenced by a three-fold increase in foliar area (5.32 ± 1.88 for control vs. 17.72 ± 9.82 for *T. harzianum*; Fig. 3E), a 1.4-fold increase in the number of true leaves (3.34 ± 0.45 for control vs. 4.74 ± 0.40 for *T. harzianum*; Fig. 3B), a three-fold increase in the number of secondary roots (1.3 ± 0.37 for control vs. 3.89±1.20 for *T. harzianum*; Fig. 3D), and a 1.4-fold increase in fresh weight (16.5 ± 5.6 for control vs. 23.2 ± 6.6 for *T. harzianum*; Fig. 3C). A comparison between plants treated with *T. harzianum* and untreated plants yielded P values of 0.0183 for fresh weight, 0.0001 for secondary root number, 0.0001 for foliar area, and 0.0001 for the number of true leaves. Although in some cases the standard deviations reached these values, ANOVA test results and the low SEM values (bars in Fig.3) indicated significant differences between *T. harzianum* and control treatments. Hence, *T. harzianum* CECT 2413 promoted tobacco plant growth by increasing the foliar area, the number of leaves and secondary roots, and the plant fresh weight. These effects were clearly not due to nutrient solubilization or to the control of plant pathogenic microorganisms. Experiments with tomato plants showed that inoculation with *T. harzianum* yielded effects on growth promotion similar to those detected in tobacco plants inoculated with the fungus (data not shown). Furthermore, compared to tobacco plants, tomato seeds germinated more synchronously, plant sizes were more homogeneous, and the root system grew more profusely. For these reasons, further experiments were carried out with tomato plants.

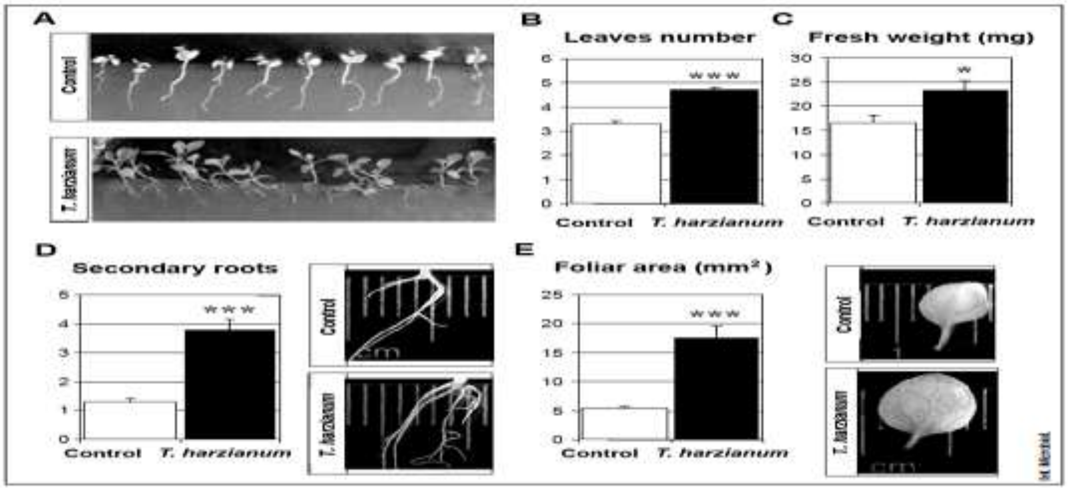

Figure 3: Plant growth promotion assay. (A) Tomato germlings planted in Petridishes inoculated with T. harzianum (10 spores per root) or non-inoculated. The promotion of plant growth was quantified after 20 days (B), fresh weight (C), length of secondary roots (D), and foliar area (E). The results are based on at least two independent experiments. Data are expressed as mean values ± standard error of the mean (SEM). Asterisks indicate results of ANOVA test (B–E): *P < 0.05 and ***P < 0.001. D and E are sample representative images. Source: Mariola *et al*. (2007)

3.7 Leaf greenness

Chlorophyll content of leaves showed an increasing trend from vegetative to flowering stage, reaching a peak value at 60 DAT, thereafter declining (Fig. 4-A). At 40 and 50 DAT, chlorophyll content did not differ significantly among the treatments. At 60 DAT, the treatments T2 and T3 offered significantly ($P \leq 0.05$) higher chlorophyll content compared to the other treatments. Interestingly, at 70 and 80 DAT, significantly higher chlorophyll was recorded in T3 treatment. Lower chlorophyll content in T3 treatment at 30, 40, and 50 DAT may be due to slow release of nutrients from the bio-fertilizer. Conversely, chemical fertilizer might have been instantly supplying adequate amounts of nitrogen ions to increase the chlorophyll content at 30, 40 and 50 DAT. We also estimated leaf chlorophyll (chlorophyll a, chlorophyll b and carotinoid) content biochemically only at 80 DAT (Fig. 4-B). Chlorophyll a content was significantly (P≤0.05) higher in T3 treatment followed by the treatment T2. Chlorophyll b content was also significantly (P≤0.05) higher in T3 treatment followed by the treatments T2 and T6. Carotenoid content was statistically similar in treatments T2, T3, T4, T5 and T6, but they were significantly higher than the control treatment (T1). However, the lowest chlorophyll a, chlorophyll b and carotenoid were always detected in control treatment.

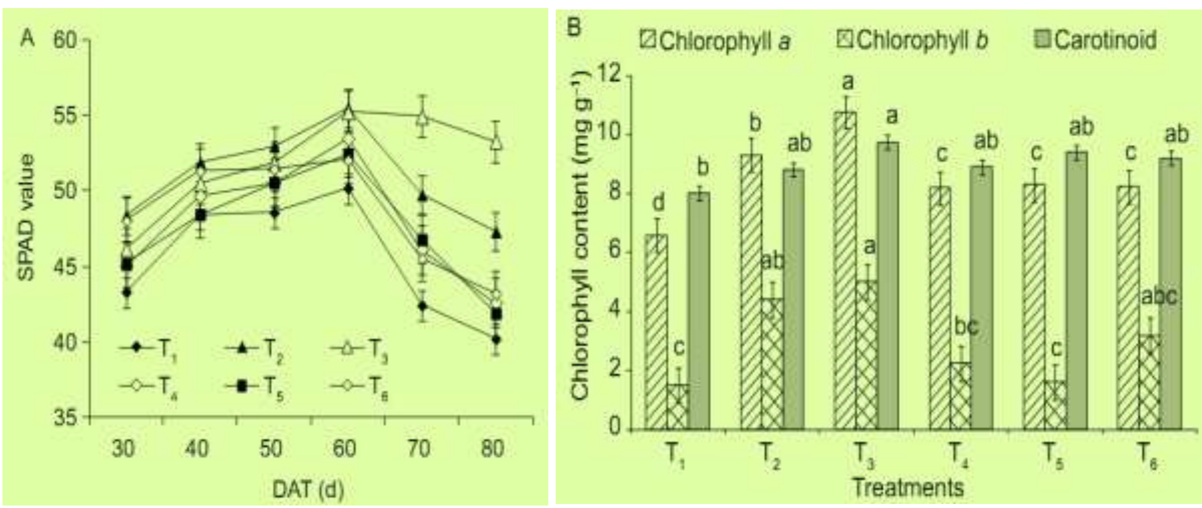

Figure 4: Chlorophyll content of tomato leaves. A, measurement of chlorophyll content by single-photon avalanche diode (SPAD) meter at different days after transplanting (DAT). B, chlorophyll contents determined biochemically at 80 DAT. T1, control, without BioF/compost and NPK; T2, recommended dose of NPK; T3, 100% BioF/compost; T4, 75% BioF/compost+25% N; T5, 50% BioF/compost+50% N; T6, 25% BioF/compost+75% N. Error bar indicates standard error. Different letters in column imply significant difference at P≤0.05. Source: Yeakub *et al*. (2017)

3.8 Impact of *Trichoderma*-enriched bio-fertilizers on yield of Tomato

Fruit yield of tomato per plant varied significantly among the treatments (Table 5). The maximum individual fruit weight was obtained in T8, which did not differ significantly from treatment T7 but was identical to T2. The minimum individual fruit weight was recorded in control treatment (T1). The highest fruit yield per plant (1.67 kg) was recorded in T8, which was significantly ($P \leq 0.01$) different from with rest of the treatments. N fertilizer supplemented treatments T6 and T7 gene the second highest yield, which was significantly lower than the T8 treatment, but significantly higher than the other treatments including T2. The lowest fruit yield per plant (0.55 kg) was found in the control treatment. Yield increase of 203% was recorded in the treatment T8, whereas 125 and 156% yield increase were observed in T6 and T7 treatments, respectively over control. The yield increase of 61.82% was observed in T2 over control However, 56, 31 and 9% were observed in sole bio-fertilizers i.e. T3, T4 and T5 treatments, respectively over the control. The yields were significantly influenced by the combined treatments i.e. T6-T8 by supplementation of N fertilizer to the bio-fertilizers. These results implied that yield of tomato was significantly increased when *Trichoderma*-enriched bio-fertilizers were combined with chemical N fertilizer (Table 5). The combined treatment gave significantly higher yield of tomato than the treatment T2 i.e. standard dose of NPK fertilizer.

Table 5. Effect of *Trichoderma*-enriched bio-fertilizer (BioF) alone or in combination with chemical fertilizers on yield of tomato

Treatments	Individual fruit wt.(g)	Fruit yield (kg/plant)	Percent yield increased
T1 (Control)	62.27 d	0.55 d	-
T2 (NPK fertilizers only)	82.00 ab	0.89 c	61.82
T3 (BioF/compost)	71.87 c	0.86 c	56.36
T4 (BioF/pellets)	71.03 c	0.72 cd	30.90
T5 (BioF/suspension)	72.50 c	0.60 d	9.09
T6 (50% N + 50% BioF/compost)	74.43 bc	1.24 b	125.45
T7 (50% N + 50% BioF/pellets)	86.57 a	1.41 b	156.36
T8 (50% N + 50% BioF/suspension)	87.17 a	1.67 a	203.63
CV (%)	4.49	9.0	-
LSD ($P \leq 0.01$)	8.14	0.21	-

In column common letters are not significantly differed at LSD ($P \leq 0.01$) level.

Source: Haque *et al*. (2012)

3.9 Bioactive compounds in Tomato fruit

TSS did not differ significantly among the treatments (Table 6). As expected, protein content (17.17%) was significantly ($P \leq 0.05$) higher in T2 treatment, followed by T6, T3, T4 and T5 (Table 6). Total sugar content was decreased in T2 treatment (38.9 g kg–1) compared to the T3 treatment (40.8 g kg–1). Ascorbic acid content (122.3 mg kg–1) was significantly ($P \leq 0.05$) higher in ripe tomato fruits fertilized with 100% BioF/compost, followed by plants receiving the recommended doses of NPK. β-Carotene, a precursor of vitamin A, was also found significantly ($P \leq 0.05$) higher in T3 treatment (1.10 mg kg–1), followed by treatments T1 (0.60 mg kg–1) and T5 (0.60 mg kg–1). However, the lowest β-carotene (0.20 mg kg–1) was detected in treatments T2, T4 and T6 (Table 6). The lycopene content is not only antioxidant but also the main factor on which the red color of tomatoes depends on. It was significantly ($P \leq 0.05$) higher in treatment T2 (0.70 mg kg–1), followed by the treatments T3 (0.60 mg kg–1) and T1 (0.60 mg kg–1).

These results are indicative of the fact that BioF/compost increases the quality and the functionality of tomatoes.

Table 6. Bioactive compounds in ripe tomato fruits influenced by Trichoderma-enriched biofertilizer (BioF/compost) alone or in combination with reduced rates of N

Treat-ments	Total soluble solid (g 100 g–1)	Protein (%)	Reducing sugar (g kg–1)	Total sugar (g kg–1)	Ascorbic acid	β-Carotene	Lycopene
T1	5.07±0.009	10.08±0.04 c	16.4±0.012 c	34.4±0.01 c	90.02±0.060 e	0.60±0.01 ab	0.60±0003 ab
T2	4.70±0.025	17.17±0.04 a	20.7±0.018 a	38.9±0.03 b	110.79±0.023 ab	0.20±0.0001 b	0.70±0.002 a
T3	4.96±0.009	13.86±0.08 b	21.7±0.006 a	40.8±0.05 a	122.3±0.023 a	1.10±0.003 a	0.60±0.003 ab
T4	4.90±0.006	13.15±0.14 b	18.7±0.018 abc	34.8±0.03 c	110.35±0.023 bc	0.20±0.00 b	0.50±0.00 bc
T5	4.85±0.090	11.26±0.14 c	20.4±0.038 ab	41.3±0.04 a	100.96±0.012 c	0.60±0.01 ab	0.50±0.00 c
T6	4.75±0.012	14.41±0.14 b	17.5±0.006 bc	34.8±0.02 c	100.38±0.046 d	0.20±0.00 b	0.60±0.00 bc
CV (%)	3.75	4.31	6.16	1 .79	1.84	61.83	8.45

T1, control, without BioF/compost and NPK; T2, recommended doses of NPK (135.5, 45.6 and 22.9 kg ha–1, respectively); T3, 100% BioF/compost; T4, 75% BioF/compost+25% N; T5, 50% BioF/compost+50% N; T6, 25% BioF/compost+75% N. Data are means±standard error. Different letters in column imply significant difference at P≤0.05. Source: Yeakub *et al*. (2017)

3.10 Nutritional quality of Tomato fruits

Tables 7 show the nutritional quality of tomato as affected by *Trichoderma*-enriched biofertilizer alone or in combination with N:P:K. The higher mineral content, such as Ca, Mg, K, Fe, Zn and Cu was found in tomato fertilized with 50 % BioF/compost + 50 % N:P:K (T4 treatment) and the lowest value was recorded in control treatment. Manganese and phosphorus contents were obtained higher in treatment T3. These results suggested that biofertilizer alone or in combination with N:P:K may influence the nutritional quality of tomato.

Table 7. Influence of *Trichoderma*-enriched biofertilizer (BioF) on mineral content of tomato (per 100 g of tomato) grown in field condition

Treatment	Ca (mg)	Mg (mg)	Na (mg)	K (mg)	Fe (mg)	Zn (mg)	Cu (mg)	Mn (mg)	P (mg)
T1	21.23 d	2.86 c	5.77 a	70.93 d	0.65 f	0.22 e	0.13 c	0.07 ef	7.83 cd
T2	26.76 b	10.76 d	5.23 b	98.06 a	0.88 de	0.30 cd	0.14 c	0.09 cde	7.63 cd
T3	25.93 bc	15.47 b	5.23 b	77.86 c	0.95 d	0.28 d	0.13 c	0.15 a	10.83 a
T4	32.40 a	16.63 a	4.73 c	94.73 a	1.32 a	0.39 a	0.19 a	0.11 bc	8.20 c
T5	18.50 e	13.13 c	4.20 d	80.53 bc	1.33 a	0.34 b	0.17 ab	0.08 def	9.87 b
T6	25.10 c	16.00 ab	5.17 b	81.83 bc	1.07 c	0.32 bc	0.15 bc	0.06 f	9.77 b
T7	33.80 a	12.36 c	5.57 a	85.56 b	0.87 e	0.34 b	0.16 bc	0.09 cd	7.50 d
T8	22.03 d	16.63 a	4.27 d	76.73 c	0.72 f	0.28 d	0.13 c	0.13 ab	10.30ab
CV (%)	3.21	3.31	3.13	3.89	4.17	5.20	10.10	12.80	4.10
LSD ($P \leq 0.05$)	1.45	0.79	0.28	5.67	0.07	0.027	0.027	0.023	0.64

T1—control (without BioF and N:P:K), T2—recommended dose of N:P:K (120:108:10 kg ha-1), T3—BioF/compost (household/ kitchen wastes composted with *T. harzianum* T22), T4—50 % BioF/compost + 50 % N:P:K, T5—75 % BioF/compost + 25 % N:P:K, T6—BioF/liquid (broth containing spores and mycelia of *T. harzianum* T22 grown in liquid media), T7—50 % BioF/liquid + 50 % N:P:K, and T8—75 % BioF/liquid + 25 % N:P:K. NB: [Different letters in column imply significant difference at ($P \leq 0.05$), a-120:108:10 kg ha-1 for N:P:K, b-BioF/compost (composted kitchen wastes by *T. harzianum* T22), c-BioF/liquid (Broth of spores suspension of *T. harzianum* T22)]. Source: Molla *et al*. (2012)

3.11 Abundance of fungi and bacteria in rhizosphere

The fungi and bacteria in rhizosphere soil was quantified at 60 DAT as shown in Table 8. Fungal populations were significantly ($P \leq 0.05$) increased in T3 treatment, followed by the treatments T4 and T5. In fact, the treatments T3 and T4 were found equally potential for the growth of microbial populations in soils. Likewise, the treatments T3, T4 and T5 all resulted in abundance of the bacterial populations. However, fungal and bacterial populations in the T2 treatment were significantly lower compared to the treatments T3, T4 and T5. Thus, BioF/compost seemed to be more efficient at increasing the population of soil microflora.

Table 8. Abundance of microbial populations in rhizospheric soils influenced by *Trichoderma*-enriched biofertilizer (BioF/compost) alone or in combination with reduced rates of N

Treatments	Fungi (×105 g–1)	Bacteria (×109 g–1)
T1	11.00±0.54 b	9.37±20.84 c
T2	12.29±0.82 b	19.63±67.66 b
T3	17.67±0.57 a	26.73±82.32 a
T4	17.33±0.83 a	25.24±68.06 a
T5	15.67±0.96 ab	25.09±98.26 ab
T6	13.33±0.68 ab	19.65±80.21 b
CV (%)	17.75	12.66

Source: Yeakub *et al*. (2017)

CHAPTER 4

CONCLUSION

The results of this study imply that the chemical fertilizer could not be avoided without compromising the yield by employing only *Trichoderma*-enriched biofertilizer (BioF/Compost). This premise is supported by the results that-

1. Growth, yield attributes and yield with BioF/compost were significantly higher than the recommended dose of chemical fertilizer.
2. Nutritional quality and bioactive compounds were also significantly higher in tomato received BioF/compost than recommended dose of chemical fertilizer.
3. BioF/compost at least increased soil P and microbial populations such as fungi and bacteria in the rhizosphere soils.

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