Tikrit Journal for Agricultural Sciences

ISSN:1813-1646 (Print); 2664-0597 (Online)

Journal Homepage: http://www.tjas.org

E-mail: tjas@tu.edu.iq

TJAS

Tikrit Journal for Agricultural Sciences

DOI: https://doi.org/10.25130/tjas.25.2.10

Promotion of Growth and Fruits Quality characteristics of Tomato Plant by Bio-Fertilizers (*Trichoderma Harzianum* and EM1) and IAA

Mais Ahmad Naoof , and Roula M. Bayerli

Damascus University, Faculty of Agriculture Engineering Department of Horticulture Science, Syria

Corresponding author: E-mail: **mais3462@gmail.com**

KEY WORDS:
Tomato, Lycopersicon esculentum, Biofertilizer, Trichoderma Harzianum, IAA

Received: 09/12/2024
Revision: **01**/**03**/2025
Proofreading: 05/04/2025
Accepted: **22**/**04**/202**5**
Available online: 30/06/2025

ABSTRACT

The present study was carried out in Hamah province, Syria, during the period from (2021-2022), to study the effect of treatment with *Trichoderma harzianum* bio-fertilizer (at a concentrations of 10^5, 10^6, 10^7 spores/ml) and EM1 bio-fertilizer (at a concentrations of 5, 10, 15 ml/l) and the indole acetic acid (IAA) (at concentrations of 50 and 100 ppm) and their interactions on growth, photosynthetic pigment concentration and Fruit quality of tomato plants (Mersini variety). The chemical analysis was carried out in the laboratories of Faculty of Agriculture Engineering - Damascus University - Syria. The study contains 21 treatments and the data (Average of the two seasons) was calculated using a randomized complete block design. The results showed that treatments with IAA 50 ppm ,*Trichoderma harzianum* 10^5 spores/ml, EM1 at all concentrations and their combination treatments with IAA 50 ppm improved all studied indicators compared to control, except TA parameter which increased with treatment IAA at 100 ppm and its combination with bio-fertilizers at all concentrations. The combination treatment of *Trichoderma harzianum* 10^5 spores/ml and IAA 50 ppm resulted in the best morphological characteristics (34.17 Days for Days to first flower, 39.17 Days for Days to first flowerset, 56.22 Days for Days to 50 % flowering), photosynthetic pigment concentration (4.69 mg/g Chlorophyll A, 2.17 mg/g Chlorophyll B, 2.05 mg/g Carotene), and TSS (4.82 Brix°). While the treatment *trichoderma harzianum* 10^5 spores/ml alone resulted in the best TSS/TA (20.53) and The combination treatment of *trichoderma harzianum* 10^7 and IAA 100 ppm resulted in the best TA (0.47 %).

تعزيز معايير النمو وجودة الثمار في نبات البندورة باستخدام الأسمدة الحيوية (*Trichoderma Harzianum* وEM1) وIAA

ميس احمد و رولا بايرلي
جامعة دمشق ، كلية الهندسة الزراعية ، قسم علوم البستنة ، سوريا

الخلاصة:

أجريت الدراسة الحالية في محافظة حماة، سورية، خلال الفترة (2021-2022)، لدراسة تأثير المعاملة بالسماد الحيوي *Trichoderma harzianum* (بالتراكيز 10^5، 10^6، 10^7 بوغة/مل), السماد الحيوي EM1 (بالتراكيز 5، 10، 15 مل/ل) وحمض الإندول الأسيتيك (IAA) (بتركيزات 50 و100 ppm) وتفاعلاتها, في مؤشرات النمو وتركيز أصبغة البناء الضوئي وجودة الثمار لنبات البندورة (صنف مرسيني). وأجري التحليل الكيميائي في مخابر كلية الهندسة الزراعية - جامعة دمشق - سورية. تضمنت الدراسة 21 معاملة وتم تحليل البيانات (متوسط قراءات الموسمين) باستخدام تصميم القطاعات الكاملة العشوائية. أظهرت النتائج أن المعاملات *Trichoderma harzianum* 10^5 بوغة/مل, EM1 بجميع التراكيز وتفاعلاتهما مع IAA 50 ppm إضافة للمعاملة المنفردة IAA 50 ppm حسنت جميع المؤشرات المدروسة مقارنة بالشاهد باستثناء قيمة المعاملة TA الذي زاد مع المعاملة IAA 100 ppm ومعاملته التفاعل مع الأسمدة الحيوية بجميع التركيزات. أدت معاملة التفاعل بـ *Trichoderma harzianum*10^5 بوغة/مل و IAA 50 ppm لأفضل قيم للمعايير المورفولوجية (34.17 يوم للأيام حتى الإزهار الأول، 39.17 يوم للأيام حتى لعقد أول زهرة، 56.22 يوم لتحقيق 50% من الإزهار)، تركيز أصبغة البناء الضوئي (4.69 ملغ/غ كلوروفيل A، 2.17 ملغ/غ كلوروفيل B، 2.05 ملغ/غ كاروتين) ومجموع المواد الصلبة الذائبة (4.82 بريكس°). في حين أن معاملة *Trichoderma harzianum* 10^5 بوغة/مل وحدها أعطت أفضل قيمة لـ TSS/TA (20.53) وأدت معاملة التفاعل *Trichoderma harzianum* 10^7 مع IAA 100 ppm لأفضل قيمة لـ TA (0.47%)..

الكلمات المفتاحية : البندورة, *Lycopersicon esculentum*, المخصب الحيوي, *Trichoderma Harzianum*, IAA.

INTROUCTION

Tomato (*Lycopersicon esculentum*) is one of the most consumed vegetables worldwide belonging to the Solanaceae family, Solanum genus, Solanum lycopersicum species (Knapp, 2002), andit is one of the largest and most important vegetables, ranks first as the most produced vegetable with 186 million tons in 2022 (FAO, 2023). Tomatoes are an important vegetable since they can be used in so many different ways, used in salads, sauces, soups (Raghuwanshi *et al*., 2023). For the highest production, an adequate supply of nutrients in an appropriate ratio is crucial, and Since almost all farmers rely on commercial fertilizers to produce lucrative yields, our soil does not accumulate enugh organic matter, and when applied continuously over time, mineral fertilizers change the soil's physical characteristics and may make it more difficult to increase yields (Zia *et al*., 2000), where The overuse of chemical fertilizers can lead to soil acidification and soil crust thereby reducing organic matter content, humus content, beneficial organisms, stunting plant growth, change the soil pH, increase pests, and even contribute to the release of greenhouse gases (Cooper *et al.*, 2018). So The bio fertilizers, either alone or in conjunction with inorganic fertilizers, enhance the vegetative growth, productivity, and fruit quality of the tomato (Raghuwanshi *et al*., 2023).

Soil microorganisms including rhizobacteria and fungi play a key role in soil health, biodiversity and productivity of natural and managed ecosystems (Fasusi *et al*., 2023). Beneficial soil microorganisms could replace chemicals and pesticides by enabling the use of sustainable agricultural practices and supporting organic farming (Nagrale *et al.*,2023). The benefits of using microbial biofertilizers as plant growth-promoting microorganisms (PGPMs) in crop production are well proven; however, their application in agricultural management is still limited (Muñoz-Carvajal *et al*., 2023).

Trichoderma a filamentous fungus is opportunistic, avirulent symbionts that are used as biopesticide. In recent years, they have become popular as a plant growth promoter (Cai *et al.* 2015). Trichoderma strains able to colonize root surfaces and cause substantial changes in plant metabolism (Harman *et al*., 2004). Furthermore, Trichoderma may produce organic acids that decrease soil pH and permit the solubilization of phosphates, micronutrients and mineral cations like iron, manganese, and magnesium that are useful for plant metabolism (Benı´tez *et al*., 2004). Phytohormones realesed from trichoderma are compounds that are responsible for the growth and development of the plant, Some are responsible for plant elongation, shoot and root developments, others are involved in plant pests and disease control (Ren *et al*., 2018). Trichoderma has been reported to produce some of the plant growth hormones such as indole-3-acetic acid (IAA), gibberellic acid (Singh *et al*., 2017). Scientists and farmers exploit these properties by developing biofertilizers, in this case using Trichoderma as the organism that can produce multiple phytohormones (Akladious & Abbas, 2014). Trichoderma improve root architecture and other plant organs (Machado-Rosa *et al.* 2023). It assist in meeting nutritional needs of plants by solubilizing minerals from chemical fertilizers or the soil itself (Paul and Rakshit 2021). And during Trichoderma-plant interaction, numerous photosynthesis-related proteins were shown to be up-regulated in plants which may increase photosynthetic capacity of the plants leading to yield and quality of crops (Harman 2000). Previous studies have also shown that Trichoderma can accelerate seed germination and enhance the early responses and establishment of seedlings in greenhouse and field conditions, It promote plant growth and enhance the productivity and yields in several crops, such as tomato (Khan *et al.*, 2017), cucumber (Altintas and Bal 2005), sugarcane (Srivastava *et al*. 2006) and mustard (Haque *et al.* 2010).

Effective microorganism (EM) is environmentally friendly technology, absolutely natural blended cultures of useful normally fermented microorganisms which may be used for expansion the fundamental microbial assorted variety in soil (Sajid *et al.*, 2023). It is a mixture including photosynthetic bacteria (Rhodopseudomonas palustris, Rhodobacter sphaeroides), lactic acid bacteria (Lactobacillus plantarum, L. casei, Streptococcus lactis), yeasts (Saccharomyces cerevisiae, Candida utilis), actinomycetes (Streptomyces albus, S. griseus), and fermenting fungi (Aspergillus oryzae, Penicillium spp., Mucor hiemalis) (Higa and Parr 2019). EM suppresses plant pathogens and agents of disease, solubilizes minerals, conserves energy, maintains the microbial balance of the soil, increases photosynthetic efficiency, and fixes biological nitrogen (Ezeagu *et al*., 2023). also, EM increases the yield of tomatoes. EM inoculation to both cpmpost and chicken manure increased photosynthesis, improving morphological parameters (plant height, number of leaves, and area), physiological parameters (total soluble solids, vitamin C, and measurable acidity) and productivity parameters (number of flowers and fruits/plant and plant yield) (Alomar *et al.*, 2023). Tommonaro *et al* (2021) indicated that EM increase plant productivity as well as increased antioxidant activity in EM-treated cultivars, Polyphenol and carotenoid contents, increased nitrogen and phosphorus concentrations in soil compared to control (Ncube *et al*., 2020), increased stem diameter, root length, fresh and dry weight of leaves and roots (González et al., 2021). The application of EM promote early fruiting in tomato (Ncube and Calistus, 2012). Olle (2021) found that The nutrient content of tomato leaves was very good and The contents of nitrates, N, P, K, Ca and Mg were higher in EM treatment compared to control treatment. Siqueira *et al* (2012) found that EM increased seed germination and vigour in carrot, cucumber, pea, beet, and tomato, increased leaf areas, improved photosynthesis and yields in cabbage. Auxin is one of the well-known plant hormone used extensively in Agriculture and Horticulture to manipulate various vegetative and reproductive growth (Zaidi and Yadav, 2023). Indole Acetic acid (IAA) is the only naturally occurring Auxin, whereas 1 naphthalene acetic acid (NAA), indole 3-butyric acid (IBA) and 2,4 dichlorophenoxyacetic acid (2,4-D) are common synthetic analog of natural Auxin

(Khan and Nabi. 2023). Plant growth regulators (PGRs) are used extensively in horticulture to enhance plant growth and improve yield by increasing fruit number, fruit set and size (Batlang, 2008). Also the use of growth regulators improve the production of tomato and other vegetable in respect of better growth and quality. (Pramanik and Mohapatra, 2017). But at higher concentrations hastened maturity of fruits, induce malformations in tomato vegetative growth (Serrani *et al*., (2007), and higher concentration doses reduce growth parameters (Zaidi and Yadav, 2023). IAA increases the plant height, number of branches, fruit size, TSS content (Patel *et al*., 2012), number of leaves (Khaled *et al*., 2015), promote fruit set (Verma et al., 2014), fruit growth and development and delays fruit senescence in tomato and protectes the flower and premature fruit drop (Bayerli, 2023), chlorophyll content, acidity and highest sugar content (Rai *et al*., 2002). It inhances fruiting with larger size with attractive ripe fruit color and highest dry matter (Gupta *et al*., 2003).

Tomato is considered as one of the most important economic crops in the world. It is soil stress plant and Chemical fertilizers are required to achieve the best growth and the highest productivity. Biofertilizers (Trichoderma harzianum and EM1) are good alternatives to chemical fertilizers and one of the applications of organic agriculture, compatible with climate-smart agriculture to achieving food security, raising the level of food safety and producing crop free of the residual effects of chemicals used in traditional agriculture. For that, this search aimed to use the biofertilizers as an alternative to chemical fertilizers and study the effect of biofertilizer (Trichoderma harzianum and EM1) and IAA on the growth and productivity of tomato plants.

MATERIALS AND METHODS

A field experiment was conducted during summer season of (2021-2022) on sandy, loamy soil of farm (open field) at Hama province, Syria, to study the effect of Biofertilizers (*Trichoderma harzianum* and Em1) and on growth, photosynthetic pigment and Fruit quality of tomato plants Mersini variety (Middle early variety, high yield, virus resistant, disease and pest tolerant, good fruit firmness, middle size fruits). Chemical analysis was performed at the Laboratory of plant physiology, Faculty of Agriculture, Damascus University. The soil was plowed up to a 35 cm depth, then planted in terraces form with 90×45 cm distance between lines and plants. During the experiment period, plants were irrigated and fertilized. Organic fertilizer was added (30 m3/hectare) and compost (5000 liter/ hectare) before planting, The soil samples were taken and analyzed to be described physically and chemically as shown in table (1).

Table (1): The physical and chemical characters of the soil for before experiment implementation

mechanical analysis of soil (%)			pH suspendec	EC Extract (1:5)	Organi matter	N tota	P2O5 availabl	K2O available
sand	**silt**	**Cla**	**(1:2.5)**	**ds.m -1**	**%**	mg/kg (ppm)		
27.5	**15.2**	**57.3**	**7.8**	**0.52**	**2.**6	**21.**	**17.56**	390.9

The treatments:

Bio-fertilizer *Trichoderma harizianum:* A spore suspension of *Trichoderma harizianum* fungus, produced in the biological control department in Hama. It was applied in three concentrations (10^5, 10^6, 10^7 spore/ml) according to the recommendations of the production center.

Bio-fertilizer (Em1): suspension of fermented microorganisms (from Al-ANAM Company, Made in Syria under license from Japanese company EMRO) with three concentrations (5, 10, 15 ml/l) with irrigation water. IAA was foliar sprayed at tow concentrations (50, 100 ppm).

These treatments were applied three times during growth: (After planting, After 4 weeks from the first treatment and in the beginning of flowering). In addition to Spraying with distilled water as a control treatment, the average readings for the two seasons were calculated.

- The experiment treatments were as follows:

T0: Un-Treated control plants.
T1: Treatment with IAA at a concentration of 50 ppm.
T2: Treatment with IAA at a concentration of 100 ppm.
T3: Treatment with EM1 at a concentration of 5 ml/l.
T4: Treatment with EM1 at a concentration of 10 ml/l.
T5: Treatment with EM1 at a concentration of 15 ml/l.
T6: Treatment with Trichderma at a concentration of 10^5 spore/ml.
T7: Treatment with Trichderma at a concentration of 10^6 spore/ml.
T8: Treatment with Trichderma at a concentration of 10^7 spore/ml.
T9: Treatment with IAA at a concentration of 50 ppm + EM1 at a concentration of 5 ml/l.
T10: Treatment with IAA at a concentration of 50 ppm + EM1 at a concentration of 10 ml/l.
T11: Treatment with IAA at a concentration of 50 ppm + EM1 at a concentration of 15 ml/l.
T12: Treatment with IAA at a concentration of 50 ppm + Trichderma at a concentration of 10^5 spore/ml.
T13: Treatment with IAA at a concentration of 50 ppm + Trichderma at a concentration of 10^6 spore/ml.
T14: Treatment with IAA at a concentration of 50 ppm + Trichderma at a concentration of 10^7 spore/ml.
T15: Treatment with IAA at a concentration of 100 ppm + EM1 at a concentration of 5 ml/l.
T16: Treatment with IAA at a concentration of 100 ppm + EM1 at a concentration of 10 ml/l.
T17: Treatment with IAA at a concentration of 100 ppm + EM1 at a concentration of 15 ml/l.
T18: Treatment with IAA at a concentration of 100 ppm + Trichderma at a concentration of 10^5 spore/ml.
T19: Treatment with IAA at a concentration of 100 ppm + Trichderma at a concentration of 10^6 spore/ml.
T20: Treatment with IAA at a concentration of 100 ppm + Trichderma at a concentration of 10^7 spore/ml.

-The study included 21 treatments, each treatment was repeated for three times, where each experimental unit contains 9 plants. A Randomized complete Block Design (R.C.B.D) was used. Results were analyzed using the statistical analysis program (Statistix 8.1.). The difference between various treatments means are tested the 5% probability level.

- The Studied parameters:

Morphological parameters:

Days to first flower.
Days to first flower set.
Days to 50% flowering.

1) photosynthetic pigment concentration:

Chlorophyll A, Chlorophyll B and Carotene (mg / gm leaf-tissues).
They were estimated according to Arnon (1949) and Villanueva *et al.* (1985)).

Fruit quality parameters:

Total Soluble Solids (TSS %) Content in fruits was determined using digital refractometer.
Titrated Acidity (%) Content in fruits was estimated in according to Gunness *et al*., (2009).

TSS / TA: flavor index (by dividing the TSS value by the TA value).

RESULTS AND DISCUSSION:

Table (2) indicates that The highest days to first flower (34.17 days), days to first flower set (39.17 days) and days to 50% flowering (56.22 days) were observed in the interaction treatment of Trichderma 10^5 spore/ml and IAA 50 ppm without any significant differences with bio-fertilizer Trichderma (10^5 spore/ml) alone. While the lowest values (26.61, 31.61 and 39.28 days) for studied characteristics days to first flower, days to first flower set and days to 50% flowering respectively were with the interaction Trichderma 10^7 spore/ml and IAA 100 ppm.

Table 2: Effect of bio-fertilizers and IAA in morphological characteristics:

Treatment	Days to first flower	Days to first flower set	Days to 50 % flowering
T0	30 cd	34.16 fg	48.78 f
T1	30.17 c	36.5 e	49.17 f
T2	26.83 gh	32 jk	40.44 l
T3	32.17 b	34.44 f	51.44 e
T4	33.11 ab	37.55 bcd	53.39 c
T5	32.61 b	36.94 cde	53.11 cd
T6	33.17 ab	38.16 ab	55.22 ab
T7	29.33 cde	33.61 fgh	46.5 g
T8	28.67 ef	33.16 ghi	44.5 hi
T9	32.17 b	36.61 de	51.78 de
T10	33.17 ab	37.66 bc	54.22 bc
T11	32.83 b	37.22 bcde	53.89 bc
T12	34.17 a	39.17 a	56.22 a
T13	28.89 def	32.89 hij	45.44 gh
T14	28.61 ef	32.83 hij	43.72 ijk
T15	26.94 gh	32.11 jk	40.61 l
T16	28.61 ef	32.44 ijk	44 hij
T17	27 gh	32.67 hij	42.28 k
T18	28 fg	32.22 ijk	42.89 jk
T19	26.78 h	31.89 jk	39.89 l
T20	26.61 h	31.61 k	39.28 l
LSD $_{0.05}$	1.21	1.02	1.5

Different letters within column indicating of significant differences ($p<0.05$)

The interpretation of these results due to root colonization by Trichoderma spp. Which leads to increases growth and development of roots and improve nutrient absorption resulting in greater vegetative growth and plant biomass (Awad-Allah and Elsokkary, 2020), so The extended number of flowering days by extended vegetative growth of plants attribute to provide plant growth promoting hormones, advanced plant growth, and finally an extended vegetative period (Mutetwa *et al*., 2022). In addition to the role of auxin in stimulating the formation and growth of buds, stimulating cell division, expansion and elongation. Also auxin stimulate the formation of organic acids and proteins in plant cells, which leads to longer period of vegetative growth, and thus delayed flowering (Hopkins and Huner,2004). While the higher concentrations used of IAA and biofertilizers reduced the values of the studied indicators which due to the increase in the growth hormone IAA content in the root environment and plant cells which inhibits growth and vital processes at high concentrations, especially in the interaction treatment with IAA at a concentration of 100 mg/L (Khalid *et al*., 2015).

It is noted from Table (3) that there are significant differences in the effect of bio-fertilizers and IAA on photosynthetic pigment concentration, as the highest Chlorophyll A (4.69 mg /g), Chlorophyll B (2.17 mg/g) and Carotene (2.05 mg /g) were with the interaction treatment of Trichderma 10^5 spore/ml and IAA 50 ppm. And the lowest values (2.07, 1.2 and 1.17 mg /g) of characteristics Chlorophyll A, Chlorophyll B and Carotene respectively were with the interaction treatment Trichderma 10^7 spore/ml and IAA 100 ppm.

Table 3: Effect of bio-fertilizers and IAA on photosynthetic pigment concentrations

Treatment	**Chlorophyll A mg /g**	**Chlorophyll B mg /g**	**Carotene mg /g**
T0	3.18 e	1.7 bcd	1.61 bcde
T1	3.27 e	1.82 abc	1.63 bcde
T2	2.61 gh	1.4 defg	1.22 fg
T3	3.27 e	1.7 bcd	1.67 bcd
T4	3.99 d	1.89 ab	1.8 abc
T5	3.95 d	1.83 ab	1.72 abcd
T6	4.48 ab	2.11 a	1.94 ab
T7	2.79 g	1.65 bcde	1.43 cdefg
T8	3.13 ef	1.63 bcdef	1.39 defg
T9	3.31 e	1.83 ab	1.68 abcd
T10	4.34 bc	1.99 ab	1.94 ab
T11	4.04 cd	1.94 ab	1.78 abc
T12	4.69 a	2.17 a	2.05 a
T13	2.84 fg	1.34 defg	1.28 efg
T14	2.42 hi	1.28 fg	1.22 fg
T15	2.45 hi	1.31 efg	1.22 fg
T16	2.85 fg	1.37 defg	1.59 bcdef
T17	2.42 hi	1.46 cdefg	1.28 efg
T18	3.13 ef	1.63 bcdef	1.44 cdefg
T19	2.19 ij	1.22 g	1.19 g
T20	2.07 j	1.2 g	1.17 g
LSD 0.01	0.31	0.36	0.38

Different letters within column indicating of significant differences ($p<0.05$)

The increase in chlorophyll A, B by inoculating plants with Trichoderma due to Trichoderma-plant interaction that lead to numerous photosynthesis-related proteins are up regulated in plants which may increase photosynthetic capacity of the plants so increase chlorophyll content (Harman, 2000). In addition to promoting the greater root growth, which provides more enhanced water and nutrient absorption from the soil (N, P, and K), magnesium and iron, which are essential elements for chlorophyll synthesis (Zhang *et al*., 2020). In addition to the role of bio-fertilizers in producing growth hormones which stimulate chlorophyll synthesis and delay chlorophyll destruction and aging (Harman *et al.*, 2021). On the other hand Coppola *et al.* (2019) indicates that trichoderma drives sugar accumulations which produced by the plant for the production of carotenoids. Where The carotenoids indirectly affect flavor as precursors of aromatic compounds, while chlorophylls contribute to sugar production through the process of photosynthesis (Aono *et al.*, 2021). Our results agree with (Rêgo Meneses *et al*. 2022) which demonstrated that Trichoderma can Improve photosynthetic capabilities due to the increase of photosynthetic of pigments or increase gene expressions regulating chlorophyll biosynthesis and finally that is reflected in the synthesis of sugars and carotenoids. Also, high concentrations of IAA and bio-fertilizers led to the lowest values, this is due to the fact that higher concentration doses of IAA and hormones from the bio-fertilizers cause abnormalities in vegetative growth, reduce growth parameters, and play a inhibitory role to biosynthetic processes that negatively affect cellular components (Zaini *et al*., 2017).

It is also noted from table (4) that The highest TSS value (4.87 brix°) was observed in the interaction treatment of Trichderma 10^5 spore/ml and IAA 50 ppm without any significant differences with bio-fertilizer Trichderma at 10^5 spore/ml alone, and The highest TSS/TA value was observed in treatment Trichderma 10^5 spore/ml. While the lowest TSS value (3.42 brix°) and TSS/TA value (7.79) were with the interaction treatment Trichderma 10^7 spore/ml and IAA 100 ppm. On the other hand, the interaction treatment Trichderma 10^7 spore/ml and IAA 100 ppm led to the highest TA value (0.47), while the treatment Trichderma 10^5 spore/ml led to the lowest value (0.25)**.**

Table 4: Effect of bio-fertilizers and IAA on Fruit quality characteristics:

Treatment	TSS Brix°	TA %	TSS / TA
T0	4.23 efg	0.33 efghij	14.31 def
T1	4.32 def	0.33 efghij	14.85 cdef
T2	3.72 jk	0.42 abcd	9.42 ghi
T3	4.39 cde	0.31 fghij	16.03 bcde
T4	4.7 ab	0.26 ij	20.05 a
T5	4.48 cd	0.27 ghij	18.74 ab
T6	4.72 ab	0.25 j	20.53 a
T7	4.16 fgh	0.34 cdefgh	13.32 def
T8	3.54 kl	0.34 defghi	11.57 fgh
T9	4.42 cde	0.31 fghij	16.14 bcd
T10	4.82 a	0.27 ghij	20.14 a
T11	4.58 bc	0.28 fghij	18.39 abc
T12	4.87 a	0.26 hij	20.5 a
T13	4.1 gh	0.36 cdef	12.34 efgh
T14	3.54 kl	0.41 abcde	9.19 hi
T15	3.56 kl	0.33 efghij	11.96 fgh
T16	4.01 hi	0.37 bcdef	11.66 fgh
T17	3.84 ij	0.43 abc	9.37 hi
T18	4.09 gh	0.35 cdefg	13.13 defg
T19	3.68 jk	0.44 ab	8.69 hi
T20	3.42 l	0.47 a	7.79 i
LSD 0.01	0.21	0.08	3.73

Different letters within column indicating of significant differences ($p<0.05$)

The interpretation of these results is due to releasing nutrients from organic fertilizer and soil by enzymes secreted by microorganisms, which lead to increasing its content of nitrogen and other mineral elements above the initial levels so improving the vegetative growth of the plant (Abdelmoatya *et al*., 2022), so increasing the rates of photosynthesis and the accumulation of nutritional products of sugars, organic acids and nutritional compounds and transferring them to the fruits that leads to improving their quality and sugar content (Ennab, 2016). Also, high concentrations of growth-promoting enzymes and hormones produced by microorganisms play an important role in biosynthesis and transport of carbohydrates to the fruits, thus increasing the percentage of total soluble solids (Thejaswini *et al*., 2022). In addition to increasing the level of endogenous auxins in the treated plants with IAA, these high levels of auxins in the fruits enhance the continuous supply of nutrients to the fruits during their growth and ripening (Lobo *et al*., 2022). In contrast, the increase in the TSS percentage leads to decrease in the acidity of the fruits (Thejaswini *et al*., 2022). The increase in TSS and decrease in TA led to the increase in percentage of TSS/TA, Where fruits with a higher TSS/ TA ratio have a better flavor. But this increase in the ratio of sugars to acidity in fruits depends on the genetic constitution of the cultivar (Tigist *et al*., 2013), So the use of Trichoderma in the management of tomato crops could help to improve the flavor of tomato fruits. Rao *et al*. (2022) explained that high concentrations of bio-fertilizer lead to an increase in the concentration of hormones produced from it, which negatively affects growth and production indicators. Therefore, the value of the previous indicators decreased at higher concentrations of biofertilizers as well as with the highest concentration of IAA (100 ppm), because auxin enhances growth and biosynthesis processes at a low concentration dose, while inhibiting them at a higher concentration (Khan and Nabi, 2023).

Conclusions

We conclude from this study that bio-fertilizer *Trichoderma harzianum* at a concentration of 10^5 spores/ml can increase the vegetative growth of tomato with or without using the growth hormone auxin IAA (at low concentration 50 ppm), as the results of the study indicated noticeable increases in vegetative growth so increases days to first flower, first flower set and 50% flowering, improves photosynthetic pigment concentrations and Fruit quality characteristics (TSS, TA and TSS/TA) compared to other bio-fertilizers and IAA treatments. This study recommends Application of *Trichoderma Harzianum* bio-fertilizer in open field tomato cultures as a safe alternative to chemical fertilizers.

REFRANCES:

Abdelmoatya, S., Khandakera, M. M., Mahmudb, K., Majrashid, c. A., Alenazie, M. M., & Badaluddina, N. A., (2022). Influence of *Trichoderma harzianum* and *Bacillus thuringiensis* with reducing rates of NPK on growth, physiology, and fruit quality of Citrus aurantifolia. Brazilian Journal of Biology, 2022, vol. 82, e261032.

Akladious, S. A., & Abbas SM., (2014). Application of Trichoderma Harzianum T22 As a biofertilizer potential in maize growth. Journal of Plant Nutrition. 2014;37(1):30-49. DOI: 10.1080/ 01904167.2013.829100.

Alomar, M., Bayerli, R., & Sharaby, H. (2023). Effect of biofertilizer (EM1) and seaweed extract (Alga 600) on growth and productivity of strawberry Fragaria × ananassa plant. Iraqi Journal of Science, 2023, Vol. 64, No. 10, pp: 5042- 5050.

Altintas, S., & Bal, U., (2005). Application of Trichoderma harzianum increases yield in cucumber (Cucumis sativus) grown in an unheated glasshouse. Journal of Applied Horticulture, 7, 25–28.

Aono, Y., Asikin, Y., Wang, N., Tieman, D., Klee, H., & Kusano, M., (2021). High-throughput chlorophyll and carotenoid profiling reveals positive associations with sugar and apocarotenoid volatile content in fruits of tomato varieties in modern and wild accessions. Metabolites 11(6):398. doi:10.3390/metabo11060398.

Asahira T., Takeda Y., Nishio T., Hirabayashi M. & Tsukamoto, Y., (1967).Studies on fruit development in tomato. I. Ovule development and content of diffusible auxin- and gibberellin-induced parthenocarpic tomato fruits in relation to their development. Memoirs of the Research Institute for Food Science, Kyoto University 28: pp. 47–74.

Awad-Allah, E. F., & Elsokkary, I. H., (2020). Influence of potassium nutrition and exogenous organic acids on iron uptake by monocot and dicot plants. *Open J. Soil Sci.* **2020**, *10*, 486–500.

Batlang, U., (2008). Benzyladenine plus gibberellins (GA4+7) increase fruit size and yield in greenhouse-grown hot pepper (Capsicum annuum L.). Journal of Biological Science 8(3): 659-662.

Bayerli, R. (2023). Effect of foliar application with zinc and auxin on growth and productivity of potato plant cv. Sponta. Accepted in Damascus University J. for Agricultural Sciences.

Benı´tez, T., Rinco´n, AM., Limo´n, MC., Codo´n, AC., (2004). Biocontrol mechanisms of Trichoderma strains. Intl Microbiol 7:249–260.

Cai, F., Chen, W., Wei, Z., Pang, G., Li, R., Ran, W., & Shen, Q., (2015). Colonization of Trichoderma harzianum strain SQR-T037 on tomato roots and its relationship to growth, nutrient availability and soil microflora. Plant and Soil, 388, 337–350.

Cooper, J., Reed, E. Y., Ho¨rtenhuber, S., Lindenthal, T., Løes, A. K, Ma¨der, P., Magid, J., Oberson, A., Kolbe, H., & Mo¨ller, K., (2018). Phosphorus availability on many organically managed farms in Europe. Nutr Cycl Agroecosyst 110:227–239.

Coppola, M., et al., (2019). Transcriptome and metabolome reprogramming in tomato plants by trichoderma harzianum strain T22 primes and enhances defense responses against aphids. Front. Physiol. 10, 745. https://doi.org/10.3389/fphys.2019.00745.

Ennab, H., (2016). Effect of Organic Manures, Biofertilizers and NPK on Vegetative Growth, Yield, Fruit Quality and Soil Fertility of Eureka Lemon Trees (Citrus limon L. Burm). Journal of Soil Sciences and Agricultural Engineering 7(10):767- 774.

Ezeagu, G.G., Omotosho, A. O., & Suleiman K. O., (2023). Effective Microorganisms, Their Products and Uses. Nile Journal of Engineering and Applied Science, DOI: https://doi.org/10.5455/NJEAS.147954.

FAO, 2023. https://www.fao.org/faostat/en/#data/QCL.

Fasusi, O. A., Babalola, O. O., & Adejumo, T. O., (2023). Harnessing of plant growth-promoting rhizobacteria and arbuscular mycorrhizal fungi in agroecosystem sustainability. *CABI Agric Biosci* **4**: 26 (2023).

Gupta, P. K., Gupta, A. K., & Reddy, S., (2003). Response of plant growth regulators and micronutrient mixtures on fruit size, color and yield of tomato (Lycopersicon esculentum Mill.). Ann. Agric. Res., 24 (1): pp. 100-103.

Haque, M. M., Haque, M. A., Ilias, G. N. M., & Molla, A. H., (2010). Trichoderma-enriched biofertilizer: A prospective substitute of inorganic fertilizer for mustard (Brassica campestris) production. The Agriculturists, 8, 66–73.

Harman, G. E., (2000). Myths and dogmas of biocontrol: Changes inperceptions derived from research on *Trichoderma harzianum* T-22. Plant Disease, 84, 377–393.

Harman, G. E., Howell, C. R., Viterbo, A., Chet, I., & Lorito, M., (2004). Trichoderma species—opportunistic, avirulent plant symbionts. Nat Rev Microbiol 2:43–56.

Harman, G. E., Doni, F., Khadka, R.B., & Uphoff, N., (2021). Endophytic strains of Trichoderma increase plants' photosynthetic capability. J. Appl. 2021, 130, 529–546.

Higa, T., & Parr, J. F., (2019). Beneficial and Effective Micro-organisms for a Sustainable Agriculture and Environment. Available online: http://www.em-la.com/archivos-de-usuario/base_datos/ (accessed on 10 May 2019).

Hopkins, W. G. and Huner, N. P. A. (2004). Introduction to Plant Physiology, 3rd Edition. John Wiley and sons. Inc. 111 River street, Hoboken, NJ, 07030. USA.

Khan, M. N., & Nabi, G. (2023). Role of Auxin in vegetative growth, flowering, yield and fruit quality of Horticultural crops. . Pure and Applied Biology. Vol. 12, Issue 2, pp1234-1241.

Knapp, S., (2002). A phylogenetic perspective on fruit diversity in the Solanaceae. Journal of Experimental Botany 53(377):2001-22.

Khaled, A. M., Sikder, S., Islam, M. R., Hasan, M. A. & Bahadur, M. M., (2015). Growth Yield and Yield Attributes of Tomato (Lycopersiconesculentum Mill.) as Influenced by Indole Acetic Acid.J. Environ. Sci. & Natural Resources.8 (1): pp.139-145.

Khan, M. Y., Haque, Md. M., Molla, A. H., Rahman, Md. M., & Alam, M. Z., (2017). Antioxidant compounds and minerals in tomatoes by Trichodermaenriched biofertilizer and their relationship with the soil environments. Journal of Integrative Agriculture, 16(3): 691–703. Available online at www.sciencedirect.com.

Khan, M. N., & Nabi. G., (2023). Role of Auxin in vegetative growth, flowering, yield and fruit quality of Horticultural crops - A review. Pure and Applied Biology. Vol. 12, Issue 2, pp1234-1241. http://dx.doi.org/10.19045/bspab.2023.120126.

Lobo, L. L. B., Silva, M. S. R. d. A. d., Castellane, T. C. L., Carvalho, R. F., & Rigobelo, E. C., (2022). Effect of Indole-3-Acetic Acid on Tomato Plant Growth. Microorganisms , 10 (11), 2212. https://doi.org/10.3390/microorganisms10112212.

Machado-Rosa, T. A., Barbosa, E. T., Cortes, M. V. B. C., & Logo, J. M., (2023) Microtiter method for quantitative assay of IAA from fungal isolates, demonstrated with Trichoderma. Rhizosphere 25:100666. https://doi.org/10.1016/j.rhisph.2023.100666.

Mukherji, S. K, & Roy, B. K., (1966). Reducing fruit drop in West Bengal. World Crops 18(3): 34.

Muñoz-Carvajal, E., Araya-Angel, J. P., Garrido-Sáez, N., González, M., & Stoll, A., (2023). Challenges for plant growth promoting microorganism transfer from science to industry: a case study from Chile. *Microorganisms* **11**: 1061 (2023).

Mutetwa, M., Chagonda, I., Gwaziwa, T., Mangezi, P., Midzi, T., Sithole, L., Mtaita, T., Masaka, J., & Muziri, T., (2022). Effect of Trichoderma-Based Biofertilizers on the Flower and Fruit Pattern of Horned Melon (Cucumis metuliferus E. Mey. ex Naudin). International Journal of Agronomy Volume, Article ID 6866853, 5 pages https://doi.org/10.1155/2022/6866853.

Nagrale, D.T., Chaurasia, A., Kumar, S., Gawande, S. P., Hiremani, N.,S., & Shankar, R., (2023). PGPR: the treasure of multifarious beneficial microorganisms for nutrient mobilization, pest biocontrol and plant growth promotion in field crops. *World J Microbiol Biotechnol* **39**: 100 (2023).

Ncube, L., & Calistus, B., (2012). Effects of the integrated use of effective microorganisms, compost and mineral fertilizer on greenhouse-grown tomato. Afr. J. Plant Sci. 2012, 6, 120–124.

Ncube, L., & Calistus, B. (2012). Effects of the integrated use of effective microorganisms, compost and mineral fertilizer on greenhouse grown tomato. Afr. J. Plant Sci., 6, 120–124.

Olle, M., (2021). The Influence of Effective Microorganisms on the Growth and Nutrient Content of Tomato Transplants. Biol. Life Sci. Forum, 1, x. https://doi.org/10.3390/xxxxx.

Patel, J. S., Sitapara, H. H. & Patel, K. A., (2012).Influence of plant growth regulators on growth, yield and quality of tomato and brinjal, Internat. J. Forestry & Crop Improv., 3 (2) : 116- 118.

Paul, S., & Rakshit, A., (2021). Effect of Seed Bio-priming with Trichoderma viride Strain BHU-2953 for Enhancing Soil Phosphorus Solubilization and Uptake in Soybean (Glycine max). J Soil Sci Plant Nutr 21:1041–1052. https://doi.org/10.1007/s42729-021-00420-4.

Pramanik, K., & Mohapatra, P. P., (2017). Role of Auxin on Growth, Yield and Quality of Tomato. Int.J.Curr.Microbiol.App.Sci 6(11): 1624-1636. Journal homepage: http://www.ijcmas.com.

Rai, G.,K., Singh, J., Singh, S., & Gupta, A. K., (2002). Effect of plant growth regulators (IAA and NAA) and micronutrient mixtures (Humaur and Multiplex) on growth, yield and quality of tomato (Lycopersicon esculentum Mill.) Ann. Biol. (India), 18(1):13-17.

Raghuwanshi, O. S., Nagaich, N. K., Pandey, D. & Bele, M., (2023). Effect of fertilizer levels through inorganic fertilizers and bio-fertilizers on growth and yield of tomato (Solanum lycopersicum L.). The Pharma Innovation Journal; 12(10): 127-132.

Rao, Y., Zeng, L., Jiang, H., Mei, L., & Wang, Y., (2022). Trichoderma atroviride LZ42 releases volatile organic compounds promoting plant growth and suppressing Fusarium wilt disease in tomato seedlings. BMC Microbiology, № 1,

Rêgo Meneses, do. FJ., Oliveira Lopes, de. ÁL., Setubal, IS., Neto, VPC., & Bonifácio, A., (2022) Inoculation of Trichoderma asperelloides ameliorates aluminum stress-induced damages by improving growth, photosynthetic pigments and organic solutes in maize. 3 Biotech 12:246. https://doi.org/10.1007/s13205-022-03310-3.

Ren, K., Hayat, S., Qi, X., Liu, T., & Cheng, Z., (2018). The garlic allelochemical DADS influences cucumber root growth involved in regulating hormone levels and modulating cell cycling. Journal of Plant Physiology. 2018;230:51-60. DOI: 10.1016/j.jplph.2018.08.007.

Sajid, M., Butt, S. J., Haq, Z. U., I. Naseem, A. Iqbal, Khan, Q. A., & Ali H., (2023). Effects of organic substrates and effective microorganisms (EM) on growth and yield of tomato (Lycopersicon esculentum Mill.) in greenhouse condition. Pure and Applied Biology. Vol. 12, Issue 1, pp116-127. Pure Appl. Biol., 12(1):116-127, March.

Serrani, J. C., Fos, M., Atare´s, A., & Garcı´aMartı´nez, J. L., (2007). Effect of gibberellin and auxin on parthenocarpic fruit growth induction in the cv MicroTom of tomato. J. Plant Growth Regul. 26: 211-221.

Singh, B., Yadav, A. L., & Meena, A. K., (2017). A study on foliar feeding of GA3 and NAA on vegetative growth and yield of phalsa (Grewia Subinaequalis D.C.). Int J Curr Microbiol Appl Sci 6(6): xx-xx.

Siqueira, M. F. B., Sudré, C. P., Almeida, L. H., Pegorerl, A. P. R. & Akiba, F. (2012). Influence of Effective Microorganisms on Seed Germination and Plantlet Vigor of Selected Crops. http://futuretechtoday.com/em/EMSeedGermPlantVigor.pdf**.**

Srivastava, S. N., Singh, V., & Awasthi, S. K., (2006). Trichoderma induced improvement in growth, yield and quality of sugarcane. Sugar Tech, 8, 166–169.

Thejaswini, H. P., Shivakumar, B. S., Sarvajna, B. S., Ganapathi, M., & Yallesh, H. S., (2022). Studies on split application of NPK fertilizers and liquid bio-formulation (Jeevamrutha) on yield and quality of pomegranate (*Punica granatum L.)* in central dry zone of Karnataka. The Pharma Innovation Journal, vol. 11, no. 1, pp. 494-498.

Tigist, M., Workneh, T. S., & Woldetsadik, K., (2013). Effects of variety on the quality of tomato stored under ambient conditions. Journal of Food Science and Technology 50:477-486.

Tommonaro, G., Abbamondi, G. R., Nicolaus, B., Poli, A., D'Angelo, C., Iodice, C., & Prisco, R. D. (2021). Productivity and Nutritional Trait Improvements of Different Tomatoes Cultivated with Effective Microorganisms Technology. Microorganisms Technology. Agricultu, 11, 112.

Verma, P. S., Meena, M. L., & Meena, S. K., (2014). Influence of Plant Growth Regulators on Growth, Flowering and Quality of Tomato (Lycopersicon esculentum Mill), cv. H-86. Indian Journal of Hill Farming 27(2):19-22.

Zaidi, S.and Yadav R. K., 2023. "Effect of plant growth regulators on growth and yield of black gram (Vigna mungo L.)". Thesis Submitted In Partial Fulfilment of The Requirements for The Degree of Master of Science in Agriculture in Plant Physiology, University of Agriculture and Technology, Kanpur208002 (U.P.).

Zhang, F., Dou, K., Liu, C., Chen, F., Wu, W., Yang, T., Li, L., Liu, T., & Yu, L., (2020) The application potential of Trichoderma T-soybean containing 1-aminocyclopropane-1-carboxylate for maize production. Physiol Mol Plant Pathol 110:101475. https://doi.org/10.1016/j.pmpp.2020.101475.

Zia, M. S., Mann, R. A., Aslam, M., Khan, M. A., & Hussain, F., (2000). The role of green manuring in sustaining rice-wheat production. In: Proc. Symp. Integrated Plant Nutrition Management, NFDC, Islamabad; 2000. p. 130-149.

Zaini, M., Adnan., & Juanda, B.R. (2017). Pengaruh Konsentrasi Dan Lama Perendaman Dalam ZPT Auksin Terhadap Viabilitas Benih Semangka (Citurullus Lunatus) [Effect Of Concentration And Soaking Time In Auxin ZPT On The Viability Of Watermelon Seeds (Citurulus Lunatus)]. Penelitian 4(1), 45-55. In Indonesian Language.