International Journal of Economic Plants

https://ojs.pphouse.org/index.php/IJEP

Crossref

IJEP August 2024, 11(3): 347-352

Article IJEP5493b

Full Research

Doi: HTTPS://DOI.ORG/10.23910/2/2024.5493b

Effects of Bio Stimulants on Growth, Yield and Quality of Tomato

Sourav Mollick[1], Chandan Karak[2*], Biplab Roy[2], Biswajit Chakraborty[2], Puspita Das[2] and Pradeep Bhutia[2]

[1]Dept. of Vegetable and Spices Crops, Faculty of Horticulture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal (736 165), India

[2]Dept. of Vegetable Science, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, PO-Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal (741 252), India

Corresponding Author

Chandan Karak

e-mail: todrck@gmail.com

Article History

Received on 29th May, 2024

Received in revised form on 10th August, 2024

Accepted in final form on 20th August, 2024

Abstract

The field experiment was carried out at Central Research Farm, Gayeshpur, BCKV, Nadia, West Bengal, India during the Rabi season (October, 2021 to March, 2022) with the aim to study the effects of different biostimulants for growth, yield and quality of tomato. The treatments were T_1 (Control or untreated), T_2 (Bayfolan Algae @ 1.5 ml l^{-1}), T_3 (Bayfolan Algae @ 2 ml l^{-1}), T_4 (Bayfolan Algae @ 2.5 ml l^{-1}), T_5 (Isabion @2 ml l^{-1}), T_6 (Bayfolan Algae @ 5 ml l^{-1}) and T_7 (Isabion @ 1.5 ml l^{-1}). Analysis of variance clearly revealed the significant effects of biostimulants with different treatments in respect to growth, yield and quality parameters of tomato. The treatment T_4 (Bayfolan Algae @ 2.5 ml l^{-1}) recorded significantly maximum plant height (82.47 cm), number of branches plant^{-1} (7.04) at 60 DAT, fruit weight (74.63 g), maximum average yield plant^{-1} (3.26 kg, yield plot^{-1} (130.18 kg) and yield ha^{-1} (872.32 q). The same treatment T_4 of Bayfolan Algae @ 2.5 ml l^{-1} also recorded maximum equatorial diameter (6.92 cm), maximum polar diameter (5.80 cm) and highest values of TSS (5.08 °brix), highest lycopene (5.05 mg 10^{-1}) and ascorbic acid (26.74 mg g^{-1}) content even which is economically viable and emerged as best treatment for getting better growth, yield and quality of Tomato.

Keywords: Biostimulants, bayfolan algae, growth, isabion, quality, tomato, yield

1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most popular and widely grown vegetable for its richness of vitamins, minerals, organic acids and micronutrients. It contains different types of antioxidants like lycopene, β-carotene, anthocyanin etc., ascorbic acid (Vitamin C), phenolic compounds, Vitamin E and small amounts of the vitamin B complex, like thiamin, riboflavin, and niacin (Sainju and Dris, 2006). The red pigment of tomato fruit due to lycopene is now being considered as most powerful antioxidant which reduces the risk of different types of cancer like prostate cancer (Miller et al., 2002), heart diseases (Rissanen et al., 2003) and cardiovascular diseases (Rissanen et al., 2003; Bai and Lindhot, 2007).

Maximum efforts have been made to increase the production by developing large number of high yielding varieties, hybrids, disease resistant varieties grown under protection condition by using different technologies. The excessive and over use of inorganic sources of plant nutrients cause health hazards due to its residual effects in all the plants parts. Ever increasing demand of quality produces from organic sources of biofertilizers, biopesticides and botanical pesticides, growth regulators; biostimulants etc. which do not have any residual effect appears to be most important new tool in increasing the crop yield. Though the tomato has high yield potential and also to address the production gap, different types of biostimulants are now gaining popular for increasing yield and quality of crops by reducing the production cost to generate extra income. Biostimulants are the commercial products obtained from *Ascophyllum modosum*, a seaweed algae, known to be rich in cytokinin and auxin precursors, enzyme, hydrolyzed protein and some kind of micro elements. Foliar sprays of biostimulants enhanced photosynthetic rate, canopy growth, photosynthesis, no. of fruits plant^{-1} and fruit yield. The Biozyme spray with normal fertilizer made the plant photosynthetically more efficient and thus increased yield (Kumar and Dube, 1999).

Biostimulants are environment-friendly promising natural products have potential to increase the use efficiency of natural resources even in biotic and abiotic stress conditions and also to reduce the input of agrochemicals. It can also increase the sustainability of agricultural and horticultural production systems as well as improve the quality and quantity of food for the ever-growing world's population (Shahrajabian et al., 2021).

Bayfolan Algae is a sea weed extract derived from *Ascophyllum species* and it contains different nutrients like Potassium (1.14% w/v), Boron (0.91%), Zinc (1.36%), Chlorine (1.48% w/v) and bio-stimulating elements like Auxins, Cytokinins, Gibberellins and Betaines for growth and development of fruits and vegetables along with natural stress busters like Alginates, Mannitol, marine polysaccharides like Laminarin and Polyphenol. Foliar application is recommended during flowering and different stages of fruiting to enhance quality of produce. It has beneficial effects for enhancing stress resilience in crops and increases quality of fruits, vegetables, flowers, etc. It comes in an exclusive gel formulation which has enhanced spreading and penetration properties for excellent nutrient availability (www.agro.bayer.pe)

Isabion, a natural biostimulant derived from pure natural animal collagen, which contains different types of amino acids with a specific role for increasing yield and stress resistance. Isabion is recommended as an organic biostimulant for fruits and vegetables like tomato, chilli, brinjal, potato, cole crops, cucurbits, onion and leafy greens. Foliar application during the active growth phases of the production cycle is recommended however at transplantation, flowering, fruiting, ripening are the most important (www.syngenta.co.in).

Different studies revealed that the foliar application of biostimulants on tomato plants promotes the vegetative growth, yield and quality. Considering above, the present experiment was framed to study the effects of different biostimulants especially Bayfolan Alage and Isabion on growth, yield and quality of tomato.

2. Materials and Methods

The field experiment of the present investigation was conducted during the Rabi season (October, 2021 to March, 2022 at Central Research Farm, Gayeshpur, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India following Randomized Block Design with three replications along with seven treatments viz. T_1 (Control or untreated), T_2 (Bayfolan Algae @ 1.5 ml l^{-1}), T_3 (Bayfolan Algae @ 2 ml l^{-1}), T_4 (Bayfolan Algae @ 2.5 ml l^{-1}), T_5 (Isabion @ 2 ml l^{-1}), T_6 (Bayfolan Algae @ 5 ml l^{-1}), and T_7 (Isabion @ 1.5 ml l^{-1}) on a plot size of 6×2.4 m^2 with the spacing of 60×60 cm^2 to study the effects of different biostimulants for growth yield and quality of tomato. One month old seedlings of PAN-3682 variety of tomato were transplanted in the field. Four sprays of two different biostimulants were applied at 20 DAT (First spray), second spray at flower initiation stage, third spray at fruit initiation stage and fourth spray at 10 days after 3rd spray. The standard packages of practices were followed for management of the crops. Ten plants were randomly selected from each plot to record the observations in respect of growth characters at 20, 30, 45 and 60 days after transplanting (DAT). Ten matured ripe fruits from each treatment from all three replications were picked at random to analyse the quality parameters of tomato. The important quality parameters of tomato i.e. TSS were estimated by ERMA hand refractometer, Lycopene content of ripe fruits of tomato was estimated by 'acetone-ether extraction method' as suggested by Ranganna (2000). The ascorbic acid content in the fruit was determined by 2, 6-dichlorophenol-indophenol visual titration method as described by Ranganna (1986) and the leaf chlorophyll content plot^{-1} at 10 days after each application for each treatment was estimated as per Sadasivam and Manickam (1996). The data were then analysed statistically.

3. Results and Discussion

The analyses of variance revealed the significant differences of the treatments for all the characters under the study whcih amply justified the influences of biostimulants with various treatments in tomato. The effects of various treatments on the important parameters of tomato are presented in the Table 1 discussed hereunder.

3.1. Vegetative growth characters

3.1.1. Plant height

The maximum plant height (23.18 cm) was recorded in T_5 at 20 days after transplanting as pre-treatment or before spraying of the biostimulants. Almost all the treatments showed similar results and had no or a negligible difference among the treatments as it is expected as pre-treatment effect. Whereas, the maximum plant height was recorded in the treatment T_4 (Bayfolan algae @ 2.5 ml l^{-1}) 27.84 cm, 76.05 cm and 82.47 cm after 30, 45 and 60 days after transplanting respectively as post treatment effects.

It was observed that the treatment T_4 (Bayfolan algae @ 2.5 ml l^{-1}) and T_2 (Bayfolan algae @ 1.5 ml l^{-1}) significantly influenced on plant height at 30 days after transplanting and it was quite expected from the above studied that the treatment T_6 of Bayfolan algae @ 5 ml l^{-1} and T_1 of untreated control plot recorded minimum plant height because of high doses of Bayfolan algae @ 5 ml l^{-1} caused stunted growth might be due to the phytotoxicity effect and even in lower than the T_1 (control). Similar findings were also reported by Charles O. Olaiya (2010) and Soltys et al. (2012). It is clearly indicated from above fact that biostimulants with various treatments have significant positive role on growth characters specially on plant height due to the presence of different growth promoting substances like hormones, nutrient supplements and other organic acids which promotes stem elongation by enhancing the cell elongation rate and meristematic activity of growing tip of the plants. All the growth characters have

Table 1: Effect of biostimulants on plant height (cm), number of primary branches, flowering and fruit setting in tomato

Treatment	20 DAT	30 DAT	45 DAT	60 DAT	20 DAT	30 DAT	45 DAT	60 DAT	Days taken to 50% flowering	No. of trusses plant^{-1}	No. of fruits truss^{-1}
T_1: Untreated control	20.95	26.11	64.31	70.05	No primary branches	1.61	4.62	5.16	41.99	8.21	3.96
T_2: Bayfolan algae (1.5 ml l^{-1})	22.80	27.76	68.85	74.10		1.61	4.65	4.99	41.33	9.47	3.94
T_3: Bayfolan algae (2 ml l^{-1})	22.55	26.76	69.23	76.40		1.97	5.17	5.55	40.00	9.63	3.99
T_4: Bayfolan algae (2.5 ml l^{-1})	23.08	27.84	76.05	82.47		2.28	6.45	7.04	38.33	9.21	4.71
T_5: Isabion (2 ml l^{-1})	23.18	27.28	73.99	80.57		1.97	6.39	6.64	39.33	8.44	4.75
T_6: Bayfolan algae (5 ml l^{-1})	21.42	25.82	73.68	79.93		1.96	6.43	6.84	39.66	8.52	4.92
T_7: Isabion (1.5 ml l^{-1})	21.82	26.55	68.34	76.58		1.62	4.85	5.18	40.66	8.79	4.22
SEm±	0.402	0.279	0.397	0.528		0.122	0.196	0.305	0.471	0.264	0.126
CD (p=0.05)	1.252	0.870	1.238	1.646		0.379	0.611	0.951	1.469	0.824	0.393

strong positive correlations with flowers and fruits production in plants with the increases of source.

3.1.2. Number of primary branches plant^{-1}

All the treatments were recorded no primary branches at 20 days after transplanting before spraying of any biostimulants. The spraying of biostimulants revealed the significant effects at 30, 45, and 60 days after transplanting and maximum number of primary branches (2.28, 6.45 and 7.04 respectively) were recorded in the treatment T_4 when Bayfolan algae applied with the dose of 2.5 ml l^{-1} of water.

The biostimulants have positive effects when applied with higher doses might be due to the stimulating effects of substances present in it which influence the faster rate of cell division during the different growth stages of plants. More number of primary branches has also positive effects on flowering and fruiting which further lead to higher yield as the photosynthates increases. Similar findings on stimulating effects of different biostimulants on plant growth were also reported by Tomar and Ramgiry (1997), Adediran et al. (2006), Farouk et al. (2012), Ruban et al. (2019), Sharma and Chauhan (2019).

3.1.3. Earliness

The earliness in terms of flowering and fruiting is desirable for consumers' point of view and to fetch early market price. Significantly earliest (38.33 days) flowering in terms of production of 50% flowers was recorded in the treatment T_4 (Bayfolan algae @ 2.5 ml l^{-1}) compared to all other treatments though the treatments T_5 (Isabion @ 2 ml l^{-1}), and T_6 (Bayfolan Algae @ 5 ml l^{-1}) 39.33 days, 39.66 days also showed statistically similar results with T_4 (Bayfolan algae @ 2.5 ml l^{-1}).

Stimulating effects of biostimulants enhanced the flowering due to the early completion of vegetative growth of the plants also reported by Ziosi et al. (2012) concluded that biostimulant namely FOLICIST enhanced plant metabolism leading to improved flowering and fruit set of tomato, melon, and cherry. Maach et al. (2020) observed the improving effects of flowering and fruit quality by foliar application of two biostimulants formulation namely Tecamin Flower (TF) and Tecamin Brix (TB). Ruban et al. (2019) reported the positive effect of biostimulants to days taken for 50% flowering.

3.1.4. Number of trusses plant^{-1}

The maximum number of trusses (9.63) was recorded in the treatment T_3 (Bayfolan Algae @ 2 ml l^{-1} followed by T_2 (Bayfolan Algae @ 1.5 ml l^{-1}) (9.47) which surpassed the treatment T_4 (Bayfolan Algae @ 2.5 ml l^{-1}) (9.21) and which are statistically at par whereas the lowest number was recorded in the untreated control plot.

3.1.5. No. of fruits truss^{-1}

The settings of fruits truss^{-1} have significant positive effect on total yield of plants. The treatment T_6 (Bayfolan Algae @ 5 ml l^{-1}) recorded highest number of fruits truss^{-1} (4.92) followed by T_5 (Isabion @ 2 ml l^{-1}) (4.75) and T_4 (Bayfolan Algae @ 2.5 ml l^{-1}) (4.71) and they are at per statistically. The lowest fruits truss^{-1} (3.94) were recorded in T_2 (Bayfolan Algae @ 1.5 ml l^{-1}), T_1 (Untreated control) (3.96) and T_3 (Bayfolan Algae @ 2 ml l^{-1}) (3.99) and which are statistically at par.

The low doses or no doses as in the cases of experiment significantly different than the higher doses of treatments which support the proposition that the biostimulants play significant role for production of fruits which has even direct effect on fruit yield. Earlier Sharma and Chauhan (2019) observed even higher number of fruits cluster^{-1} (5.67) with the application of triacontanol @ 1.5 ml l^{-1} in tomato and Francesca et al. (2020) also observed number of fruits increased up to 105.3% with biostimulants application.

3.2. Yield parameters

The different yield related parameters are discussed below and data were presented in the Table 2.

Table 2: Effect of biostimulants on different yield parameters of tomato

Treatment	No. of fruits plant^{-1}	Fruit weight (g)	Equatorial diameter (cm)	Polar diameter (cm)	Yield plant^{-1} (kg)	Total yield (t)
T_1: Untreated control	32.25	61.03	5.62	4.66	1.97	51.83
T_2: Bayfolan algae (1.5 ml l^{-1})	37.28	62.70	5.71	4.68	2.34	62.14
T_3: Bayfolan algae (2 ml l^{-1})	38.54	70.74	6.16	5.15	2.73	72.34
T_4: Bayfolan algae (2.5 ml l^{-1})	43.60	74.63	6.92	5.80	3.26	87.23
T_5: Isabion (2 ml l^{-1})	40.09	71.62	6.81	5.64	2.87	75.88
T_6: Bayfolan algae (5 ml l^{-1})	41.96	70.69	6.31	5.16	2.97	80.08
T_7: Isabion (1.5 ml l^{-1})	37.05	65.48	5.93	4.84	2.42	64.38
SEm±	1.003	0.974	0.131	0.111	0.097	18.306
CD (p=0.05)	3.124	3.035	0.407	0.346	0.303	57.030

3.2.1. No. of fruits plant^{-1}

The highest number of fruits were recorded in T_4 (43.60) after the application of Bayfolan Algae @ 2.5 ml l^{-1} followed by the treatment T_6 of Bayfolan algae @ 5 ml l^{-1} though which are statistically at par each other.

The results revealed the positive influences of biostimulants in respect to number of fruits plant^{-1} which has direct effect from the growth characters. Previously Sharma and Chauhan (2019) reported the higher number of fruits plant^{-1} (52.50) in tomato with the application of triacontanol @ 1.5 ml l^{-1} and Francesca et al. (2020) found number of fruits increased up to 105.3% with the application of biostimulants in tomato. Csizinszky et al. (2009) reported that the application of Seaweed-based 'SOAR' biostimulants, on fresh market tomato cultivars 'Florida 47' increases the marketable yield of fruit by producing the higher number of fruits rather than heavier weight fruit^{-1}. Hernandez et al. (2016) reported the effect of chitosan (CH) and 2, 4-epibrasinolide (BRs) in tomato increase the number of fruits which has relation to increase the yield.

3.2.2. Fruit weight (g)

The average fruit weight was recorded significantly higher in the case of treatment T_4 (74.63 g) of Bayfolan Algae @ 2.5 ml l^{-1} followed by T_5 of Isabion @ 2 ml l^{-1} (71.62 g) and both are statistically similar whereas lowest fruit weight (61.03 g) recorded in the untreated control.

As the higher fruit weight has direct contribution to the total yield, it indicated that the biostimulants influences the fruit weight might be due to higher accumulation of photosynthates in fruits. An agreement with other findings reported by Rajasekar et al. (2021), Caruso et al. (2019) and Katsenios et al. (2021) in different biostimulants other than investigated two.

3.2.3. Equatorial diameter of fruit (cm)

The maximum average equatorial diameter of fruits (6.92 cm) was recorded in T_4 of Bayfolan Algae @ 2.5 ml l^{-1} followed by T_5 of Isabion @ 2 ml l^{-1} (6.81 cm) and both are statistically at par and minimum equatorial diameter (5.62 cm) recorded in T_1 i.e untreated control plot. Earlier report by Kleiber and Markiewicz (2013) also supported the above findings.

3.2.4. Polar diameter of fruit (cm)

The average maximum polar diameter of fruit (5.80 cm) was recorded in T_4 (Bayfolan Algae @ 2.5 ml l^{-1}) followed by T_5 (5.64 cm) though they are statistically similar. The minimum polar diameter of fruit (4.66 cm) was also recorded in untreated control.

3.2.5. Yield plant^{-1} (kg)

The application of biostimulants played significant role in affecting the yield plant^{-1}. The highest average fruit yield plant^{-1} (3.26 kg) recorded in the treatment T_4 (Bayfolan Algae @ 2.5 ml l^{-1}) followed by the treatment T_6 (Bayfolan Algae @ 5 ml l^{-1}) both are statistically at par and the lowest yield plant^{-1} (1.97 kg) was recorded in T_1 or control plot.

Effect of biostimulants on yield plant^{-1} also reported by other researchers like Sharma and Chauhan (2019) observed that the application of triacontanol @ 1.5 ml l^{-1} in tomato recorded fruit yield plant^{-1} (3.79 kg) and Katsenios et al. (2021) also observed yield plant^{-1} was increased 51.94% with the use of *Bacillus licheniformis* compared to that of control.

3.2.6. Total yield ha^{-1} (q)

All the treatments have significant influenced on yield. In case of total yield hectare^{-1} the maximum yield ha^{-1} (87.23 t) was recorded in the treatment T_4 (Bayfolan algae @ 2.5 ml l^{-1}) followed by the treatment T_6 of Bayfolan Algae @ 5 ml l^{-1} (800.88 q ha^{-1}) and T_5 of Isabion @ 2 ml l^{-1} (758.84 q ha^{-1}). Previous report of Mandour et al. (2017) also supported the fact of positive effect of biostimulants which influenced the total yield of fruits.

3.3. Quality parameters

3.3.1. Total soluble solids (°Brix)

Significantly maximum TSS was recorded in T_4 of Bayfolan Algae @ 2.5 ml l^{-1} (5.08°Brix) followed by T_6 (4.80°Brix) of

Bayfolan Algae @ 5 ml l^{-1} and T_3 of Bayfolan Algae @ 2 ml l^{-1} (4.68°Brix) (Table 3).

Table 3: Effect of biostimulants on different quality parameters of tomato

Treatment	TSS (°Brix)	Lycopene (mg 100 g^{-1})	Ascorbic acid (mg g^{-1})	Chlorophyll (mg 100 g^{-1})
T_1: Untreated control	3.96	4.22	23.36	385.40
T_2: Bayfolan algae (1.5 ml l^{-1})	4.27	4.10	24.22	489.50
T_3: Bayfolan algae (2 ml l^{-1})	4.68	4.82	23.95	507.10
T_4: Bayfolan algae (2.5 ml l^{-1})	5.08	5.05	26.74	589.28
T_5: Isabion (2 ml l^{-1})	4.41	4.10	24.45	436.76
T_6: Bayfolan algae (5 ml l^{-1})	4.80	4.73	24.55	395.17
T_7: Isabion (1.5 ml l^{-1})	4.14	4.07	22.54	427.98
SEm±	0.031	0.232	0.334	16.119
CD (p=0.05)	0.098	0.721	1.039	50.21

3.3.2. *Lycopene content (mg 100 g^{-1})*

The significant highest lycopene content (5.05 mg 100 g^{-1}) was recorded in the treatment T_4 of Bayfolan algae @2.5 ml l^{-1} followed by T_3 of Bayfolan Algae @ 2 ml l^{-1} and T_6 of Bayfolan Algae @ 5 ml l^{-1}.

Earlier reports of Katsenios et al. (2021) and Rouphael et al. (2021) also supported the fact of positive effect of biostimulants which influenced lycopene content of fruits. However, Hernandez et al. (2016) observed no significant effects of biostimulants (BRs) on lycopene content of fruits.

3.3.3. *Ascorbic acid content (mg 100 g^{-1})*

Significantly highest ascorbic acid content (26.74 mg g^{-1}) was recorded in treatment T_4 of Bayfolan Algae @ 2.5 ml l^{-1} followed by T_6 of Bayfolan Algae @ 5 ml l^{-1} (24.55 mg g^{-1}) and T_5 of Isabion @ 2 ml l^{-1} (24.45 mg g^{-1}).

Previous reports of positive effect of biostimulants on tomato by Francesca et al. (2020) and Kavipriya and Boominathan (2018) in respect to ascorbic acid content in fruits.

3.3.4. *Total chlorophyll content (mg 100 g^{-1})*

The chlorophyll content of leaf (589.28 mg 100 g^{-1}) significantly highest was recorded in T_4 when it is sprayed with Bayfolan Algae @ 2.5 ml l^{-1} followed by the treatments T_3 of Bayfolan Algae @ 2 ml l^{-1} and T_2 of Bayfolan Algae @ 1.5 ml l^{-1}.

Positive effects of other biostimulants in tomato supported by earlier findings of different researchers like Farouk et al. (2012) found the foliar application of biostimulants, chitosan (Chit), humic acid (HA), seaweed extract (SE) and thiamine (Thi) proved to be effective in increasing the growth characters and chlorophyll. Petrozza et al. (2014) observed the treatment of Megafol® produced higher biomass and chlorophyll in tomato under drought stress condition. Chenxu Niu et al. (2022) observed Boosten and Megafol treatments boosted the synthesis of chlorophylls and photosynthetic rates in tomato. Chrysargyris et al. (2020) reported an eco-product (EP), once (EP-1x) increased chlorophyll content in tomato compared to the control (sprayed with water). Rajasekar et al. (2021) and Kavipriya and Boominathan (2018) reported positive effect of biostimulants on chlorophyll content in tomato.

4. Conclusion

The treatment T_4 of Bayfolan Algae @ 2.5 ml l^{-1} has significantly influenced most of the characters in tomato which recorded the maximum plant height, number of branches, maximum TSS content, lycopene content, ascorbic acid content in fruit etc. and maximum yield.

5. Acknowledgement

This research work is a part of the sponsored project of Bayer Crop Science Limited.

6. References

Adediran, J.A., Akande, M.O., Akanbi, W.B., 2005. Effect of organic root plus (biostimulant) on nutrient content, growth and yield of tomato. Nigerian Journal of Soil Science 15, 26–33.

Bai, Y., Lindhot, P., 2007. Domestication and breeding of tomatoes: what have we gained and what can we gain in the future. Annals of Botany 100, 1085–1094.

Caruso, G., De Pascale, S., Cozzolino, E., Cuciniello, A., Cenvinzo, V., Bonini, P., Rouphael, Y., 2019. Yield and nutritional quality of Vesuvian Piennolo tomato PDO as affected by farming system and biostimulant application. Agronomy 9(9), 505.

Chrysargyris, A., Charalambous, S., Xylia, P., Litskas, V., Stavrinides, M., Tzortzakis, N., 2020. Assessing the biostimulant effects of a novel plant-based formulation on tomato crop. Sustainability 12(20), 8432.

Csizinszky, A.A., 2009. Yield response of fresh market tomato cultivars to'soar'biostimulants in consecutive seasons. In proceedings of the 36th annual meeting of the Plant Growth Regulation Society of America, Asheville, North Carolina, USA, 2–6 August 2009, 75–83.

Farouk, S., Youssef, S.A., Ali, A.A., 2012. Exploitation of biostimulatants and vitamins as an alternative strategy to control early blight of tomato plants. Asian Journal of Plant Sciences 11(1), 36–43.

Francesca, S., Arena, C., Hay Mele, B., Schettini, C., Ambrosino, P., Barone, A., Rigano, M.M., 2020. The use of a plant-based biostimulant improves plant performances and fruit quality in tomato plants grown at elevated temperatures. Agronomy 10(3), 363.

Hernandez, V., Hellan, P., Fenoll, J., Cava, J., Garrido, I., Molina, M.V., Flores, P., 2016. The use of biostimulants can mitigate the effect of high temperature on productivity and quality of tomato. In VIII International Postharvest Symposium: Enhancing Supply Chain and Consumer Benefits-Ethical and Technological Issues 1194, 85–90.

Katsenios, N., Andreou, V., Sparangis, P., Djordjevic, N., Giannoglou, M., Chanioti, S., Efthimiadou, A., 2021. Evaluation of plant growth promoting bacteria strains on growth, yield and quality of industrial tomato. Microorganisms 9(10), 2099.

Kavipriya, R., Boominathan, P., 2018. Influence of biostimulants and plant growth regulators on physiological and biochemical traits in tomato (*Lycopersicon esculentum* Mill.). Madras Agricultural Journal 105(1–3), 1.

Kleiber, T., Markiewicz, B., 2013. Application of "Tytanit" in greenhouse tomato growing. Acta Scientiarum Polonorum Hortorum Cultus 12(3), 117–126.

Kumar, P., Dube, S.D., 1999. Photosynthetic and yield response of capsicum to foliar spray of biozyme. ICAR News 5(2), 13.

Maach, M., Boudouasar, K., Akodad, M., Skalli, A., Moumen, A., Baghour, M., 2021. Application of biostimulants improves yield and fruit quality in tomato. International Journal of Vegetable Science 27(3), 288–293.

Mandour, M.A., 2017. Effect of irrigation water quantity and some biostimulants on water relationship, water use efficiency and productivity of tomato grown in plastic house. Zagazig Journal of Agricultural Research 44(1), 145–157.

Miller, E.C., Hadley, C.W., Schwartz, S.J., Erdman, J.W., Boileau, T.M.W., Clinton, S.K., 2002. Lycopene, tomato products, and prostate cancer prevention. Have we established causality? Pure and Applied Chemistry 74(8), 1435–1441.

Niu, C., Wang, G., Sui, J., Liu, G., Ma, F., Bao, Z., 2022. Biostimulants alleviate temperature stress in tomato seedlings. Scientia Horticulturae 293, 110712.

Olaiya, C.O., 2010. Presowing bioregulator seed treatments increase the seedling growth and yield of tomato (*Solanum lycopersicon*). Journal of Plant Growth Regulation 29(3), 349–356.

Petrozza, A., Santaniello, A., Summerer, S., Di Tommaso, G., DiTommaso, D., Paparelli, E., Piaggesi, A., Perata, P., Cellini, F., 2014. Physiological responses to Megafol® treatments in tomatoplants under drought stress: A phenomic and molecular approach. Scientia Horticulturae, 174, 185–192. https://doi.org/10.1016/j.scienta.2014.05.023.

Rajasekar, R., Ravichandran, L., Babu Rajendra Prasad, V., Sakthivel, N., 2021. Response of organic biostimulants and silicon to growth, yield and quality of tomato under soil salinity conditions. International Journal of Plant & Soil Science 33(23), 41–54. DOI: 10.9734/ijpss/2021/v33i2330717.

Ranganna, S., 2000. Handbook of analysis and quality control for fruit and vegetable products (2nd Edition) TataMcGraw-Hill publishing company Ltd, New Delhi, India, 1112.

Ranganna, S., 1986. Manual of analysis of fruit and vegetable products. Tata McGraw Hill Publisher, New Delhi, 89–90.

Rissanen, T.H., Voutilainen, S., Nyyssonen, K., Salonen, R., Kaplan, G.A., Salonen, J.T., 2003. Serum lycopene concentration and carotid atherosclerosis: the Kuopio Ischemic heart disease risk factor study. The American Journal of Clinical Nutrition 77, 133–138.

Rouphael, Y., Formisano, L., Ciriello, M., Cardarelli, M., Luziatelli, F., Ruzzi, M., Colla, G., 2021. Natural biostimulants as upscale substitutes to synthetic hormones for boosting tomato yield and fruits quality. Italus Hortus 28, 88–99.

Ruban, S., Priya, M.R., Barathan, G., Suresh Kumar, S.M., 2019. Effect of foliar application of biostimulants on growth and yield of brinjal (*Solanum melongena* L.). Plant Archives 19(2), 2126–2128.

Sadasivam, S., Manickam, A., 1996. Biochemical methods (2nd edn.) New Age International Publisher, New Delhi, 187–188.

Sainju, U.M., Dris, R., 2006. Sustainable production of tomato. 190–216. In: R. Dris(ed.), Crops: Quality, growth, and biotechnology. WFL Publisher, Helsinki, Finland.

Shahrajabian, M.H., Chaski, C., Polyzos, N., Petropoulos, S.A., 2021. Biostimulants application: A low input cropping management tool for sustainable farming of vegetables. Biomolecules 11(5), 698.

Sharma, D., Chauhan, A., 2019. Effect of plant growth regulators on yield and quality of tomato (*Solanum lycopersicum* L.) under mid-hill conditions of Himachal Pradesh. International Journal of Bio-resource and Stress Management 10(3), 215–218.

Soltys, D., Rudzińska-Langwald, A., Gniazdowska, A., Wiśniewska, A., Bogatek, R., 2012. Inhibition of tomato (*Solanum lycopersicum* L.) root growth by cyanamide is due to altered cell division, phytohormone balance and expansin gene expression. Planta 236(5), 1629–1638.

Tomar, I.S., Ramgiry, S.R., 1997. Effect of growth regulators on yield and yield attributes in tomato (*Lycopersicon esculentum* Mill). Advances in Plant Sciences 10(2), 29–31.

Ziosi, V., Zandoli, R., Vitali, F., Di Nardo, A., 2012. Folicist®, a biostimulant based on acetyl-thioproline, folic acid and plant extracts, improves seed germination and radicle extension. In I World Congress on the Use of Biostimulants in Agriculture 1009, 79–82.