WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

EFFECT OF FOLIAR SPRAYS OF BIOSTIMULANT ON GROWTH AND ECONOMICS BY TOMATO UNDER FERTIGATION

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ABSTRACT :

A Field experiment entitled, "Effect of foliar sprays of biostimulant on growth, yield, nutrient uptake and nutrient availability by tomato under fertigation" was conducted during the year 2023-24. The experiment was carried out in Randomized Block Design with ten treatments replicated three times. The experiment comprised of T_1 – RDF (Control), T_2 - RDF + Foliar application of Biostimulant @ 2 ml L^{-1}, T_3 - RDF + Foliar application of Biostimulant @ 3 ml L^{-1}, T_4 - RDF + Foliar application of Biostimulant @ 4 ml L^{-1}, T_5 - RDF + Foliar application of Biostimulant @ 5 ml L^{-1}, T_6 - RDF + Foliar application of Biostimulant @ 6 ml L^{-1}, T_7 - RDF + Foliar application of Biostimulant @ 7 ml L^{-1}, T_8 - RDF + Foliar application of Biostimulant @ 8 ml L^{-1}, T_9 - RDF + Foliar application of Biostimulant @ 9 ml L^{-1} and T_{10} - RDF + Foliar application of Biostimulant @ 10 ml L^{-1} where, RDF- Recommended dose of fertilizer and foliar sprays were applied at 30 and 50 Days after transplanting. Tomato crop was transplanted on 13th July, 2023 at 1.20 x 0.45 m spacing. The results indicated that the RDF + Foliar application of Biostimulant @ 7 ml L^{-1} through fertigation as per growth stages significantly enhanced the yield and yield contributing characters viz., Diameter of fruit (cm), Length of fruit (cm), Number of fruits $plant^{-1}$, Weight of tomato fruit (kg) and Yield (t ha^{-1}). Fertigation was found to be more beneficial than application of fertilizer through conventional method in respect of increasing yield and water saving. The treatment T_7 produced significantly higher yield (77.03 t ha^{-1}) over all other treatments. However, it was at par with T_6 (74.73 t ha^{-1}), T_5 (73.23 t ha^{-1}), T_8 (72.52 t ha^{-1}) and T_9 (71.72 t ha^{-1}). The treatment T_7 produced significantly higher yield (77.03 t ha^{-1}) over all other treatments. However, it was at par with T_6 (74.73 t ha^{-1}), T_5 (73.23 t ha^{-1}), T_8 (72.52 t ha^{-1}) and T_9 (71.72 t ha^{-1}). The treatment T_7 recorded significantly maximum yield over T_1 and it indicated that fertigation using water soluble fertilizer dose along with foliar sprays of biostimulant @ 7 ml L^{-1} increased 18.50 % in yield over T_1. In terms of economics, the treatment T_7 was profitable with higher net seasonal income of ₹. 561566 ha^{-1} with B:C ratio of 3. 69 followed by T_6. On the basis of the results obtained, it can be concluded that RDF (300:150:150 N:P_2O_5:K_2O kg ha^{-1})+ Foliar application of Biostimulant @ 7 ml L^{-1} as per growth stages is the best treatment for higher yield and monetary returns from tomato crop (var. Aryaman) as it showed at par result with treatment T_6, cultivated in medium deep soil of Maharashtra.

Key words: Biostimulant, RDF, Foliar application, fertigation, tomato

Introduction :

The tomato (*Solanum lycopersicum* L., 2X=24) is the third-largest vegetable crop in the world, behind potatoes and onions. It is a member of the tribe Solanaceae, sub-family Solanoideae,genus Lycopersicon and family Solanaceae (often referred to as the Nightshade family). Originally, the genus was split into two main sub-genera based on the colour of the fruits: Eriopersicon for species with green fruits and Eulycopersicon for species with coloured fruits. Its origin is Peru in the continent of South America. Not only is it one of the most well-liked vegetables in India, but it is also a highly valuable crop globally.

Tomatoes are a crucial crop cultivated in both open fields and protected environments withfertigation yielding superior results. Studies have shown that fertigated tomatoes out perform conventionally irrigated and fertilized crops in terms of yield, dry matter content and quality aspects like size, firmness and sugar content (Alcantar *et al.* 1999). Fertigation has been found to increase tomato yields by as much as 63 per cent compared to traditional irrigation and fertilizationmethods (Pan *et al.* 1999). The precise delivery of nutrients through fertigation is a key factor in this yield boost. Additionally, drip irrigation can significantly enhance tomato yields whileconserving water and fertilizer (Singandhupe *et al*. 2005). In fact, adopting efficient irrigation techniques like drip irrigation can reduce water usage by up to 50 per cent, allowing for the irrigation of approximately double the area.

Foliar application involves applying fertilizer directly to a plant's leaves, allowing for nutrient absorption through the foliage. While most field crops absorb nutrients primarily throughroot absorption from the soil, foliar application provides an additional pathway for nutrient uptake.Fertilizer is a crucial input that significantly impacts crop growth and yield, particularly for vegetable crops like tomatoes. Phosphorus plays a vital role in root development, water and nutrient utilization and flowering. When combined with nitrogen and potassium, phosphorus enhances peel color, taste, hardiness, vitamin C content and accelerates maturity. As one of the most essential macronutrients, phosphorus is second only to nitrogen in importance for plant growth and development.

Biostimulants are organic substances or microorganisms applied to soil to enhance plant growth, increase nutrient uptake and improve tolerance to environmental stresses and diseases. They also boost product quality (Turan *et al.* 2021). According to Jardin's definition, biostimulantsare substances or microorganisms that, regardless of their nutrient content, enhance nutrient efficiency, abiotic stress tolerance and quality traits in plants (Silvana Francesca

et al. 2020). Research has explored using biostimulants to improve heat tolerance, although their impact on tomato plant physiology under high temperatures is still unclear. In organic agriculture, biostimulants like panchagavya and jeevamrut - fermented products made from readily available materials - are used to promote plant growth. Studies have investigated the effects of these biostimulants, used separately or in combination, on tomato yield and quality (Maach *et al*. 2021).

Materials and Methods :

The experiment was conducted at Research Farm of Inter Faculty Department of IrrigationWater Management, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra). Geographically the central campus of Mahatma Phule Krishi Vidyapeeth, Rahuri (MS) is situated in between 19^0 47' and 19^0 57' North latitudes and between 74^0 32' and 74^0 19' East longitudes. The altitude varies from 495 to 569 meters above the mean sea level. This tract lying on the eastern side of western ghats and falls under rain shadow areas.

Climatically the central campus is located in semi-arid zone with the annual rainfall ranging from 307 to 619 mm, with an average of 520 mm. However, the rainfall is unpredictable and unevenly distributed, with 45 or more rainy days typically occurring during the monsoon months of June to September. The South West Monsoon is responsible for the majority of the rainfall. The soil of the experimental site was uniform and leveled. The soil was well drained clayey in texture with 60 cm depth with available nitrogen (162.60 kg ha^{-1}), moderate in available phosphorus (18.20 kg ha^{-1}) and high in available potassium (468.20 kg ha^{-1}). The soil was slightly alkaline in reaction with pH as 7.95 and EC values of 0.21 dSm^{-1}. The values of fieldcapacity, permanent wilting point, bulk density, infiltration rate and available soil moisture content were 40.2 per cent, 17.1 per cent, 1.22 Mg m^{-3}, 4.5 cm hr^{-1} and 23.00 per cent, respectively.

The experiment was carried out in Randomized Block Design with ten treatments replicated three times. The experiment comprised of T_1 - RDF (Control), T_2 - RDF + Foliar application of Biostimulant @ 2 ml L^{-1}, T_3 - RDF + Foliar application of Biostimulant @ 3 ml L^{-1}, T_4 - RDF + Foliar application of Biostimulant @ 4 ml L^{-1}, T_5 - RDF + Foliar application of Biostimulant @ 5 ml L^{-1}, T_6 - RDF + Foliar application of Biostimulant @ 6 ml L^{-1}, T_7 - RDF + Foliar application of Biostimulant @ 7 ml L^{-1}, T_8 - RDF + Foliar application of Biostimulant @ 8 ml L^{-1}, T_9 - RDF + Foliar application of Biostimulant @ 9 ml L^{-1} and T_{10} - RDF + Foliar application of Biostimulant @ 10 ml L^{-1} where, RDF- Recommended dose of fertilizer and foliar sprays were applied at 30 and 50 Days after transplanting.

Transplanting of tomato was done on July 13, 2023 at 1.2 x 0.45 m spacing. The drip irrigation is applied at every alternate day. Plant protection measures and the cultural operations were carried out timely. Initial and treatment wise soil samples at 30, 60, 90 DAT and at harvest of plant from 0-15 cm soil depth were collected from experimental field. Soil samples collected were dried in shade, powdered with mortar and pestle and passed through 2 mm sieve and analyzed for organic carbon content (%), pH (1:2.5), EC (dSm^{-1}), available nitrogen, phosphorus and potassium content of the soil. The standard methods were used for determination of nutrient content of the soil. The observational tomato plants and fruits were at harvest for chemical analysis. These plant samples were dried under shade followed by oven drying at 65^0 C till constant weight. The samples are then chopped, mixed thoroughly and composite sample was used for estimation of nutrient concentration.

The cost of cultivation (₹. ha^{-1}) for each treatment was worked out by taking intoconsideration the cost of all the operations carried out from preparatory tillage up to the harvesting and the cost of all inputs involved. The gross monetary returns (₹. ha^{-1}) was worked out on the basis of total yield of tomato fruits for each treatment by multiplying with prevailed market price of tomato (₹. t^{-1}). The treatment wise net monetary returns were worked out by subtracting treatment wise cost of cultivation from the treatment wise gross monetary returns. Benefit: cost ratio was calculated for each treatment by dividing the gross monetary returnswith the cost of cultivation of each treatment.

Results and Discussion :

Growth Characters

Data regarding to growth characters of tomato as influenced by different treatments are presented in following Tables *viz*., plant height, number of branches $plant^{-1}$ and dry matter content.

Plant height

The data regarding periodical plant height of tomato crop was significantly influencedat all stages of crop growth was presented in Table 1 and graphically depicted in Figure 1.

At 30 DAT, the significantly maximum plant height i.e. 83.21 cm was observed in the treatment of RDF + Foliar application of Biostimulant @ 7 ml L^{-1} (T_7). However, treatments T_6 and T_5 were at par with T_7. The plant height increased with the age of crop and was more vigorous during 60 and 90 days after planting. The treatment of RDF + Foliar application of Biostimulant @ 7 ml L^{-1} (T_7) recorded significantly maximum plant height i.e., 123.46 cm, 132.44 cm and 131.1 cm at 60 DAT, 90 DAT and at harvest, respectively. However, treatment T_6, T_5, T_8 and T_4 were at par with T_7. Control i.e. RDF (T_1) recorded minimum plant height i.e., 66.91,116.06, 124.31 and 123.1 cm at 30, 60, 90 DAT and at harvest respectively at all stages.

The significantly maximum plant height might be due to sufficient availability of moisture and nutrients in the root zone of the crop at various growth stages. The application of recommended dose of fertilizer with biostimulant as foliar sprays at pre-flowering, flowering and fruit setting stages, enhanced the growth parameters like plant height, no. of branches and number of leaves/plant. Similar results were reported by Chakravarthy (2023) and Zodape *et al*. (2011).

Table 1 Periodical plant height of tomato as influenced by different treatments.

Tr.no	Treatments	Plant height (cm)			
		30 DAT	60 DAT	90 DAT	At harvest
T1	RDF without Biostimulant application (Control)	66.91	116.06	124.31	123.1
T2	RDF + Foliar application of Biostimulant @2 ml L^{-1}	69.19	119.33	126.43	125.7
T3	RDF + Foliar application of Biostimulant @ 3 ml L^{-1}	70.19	120.42	127.30	126.2
T4	RDF + Foliar application of Biostimulant @4 ml L^{-1}	76.81	121.57	128.92	127.6
T5	RDF + Foliar application of Biostimulant @5 ml L^{-1}	78.80	122.12	130.88	129.9
T6	RDF + Foliar application of Biostimulant @ 6 ml L^{-1}	81.45	122.92	131.78	130.6
T7	RDF + Foliar application of Biostimulant @7 ml L^{-1}	83.21	123.46	132.44	131.1
T8	RDF + Foliar application of Biostimulant @ 8 ml L^{-1}	78.15	122.02	130.47	129.1
T9	RDF + Foliar application of Biostimulant @9 ml L^{-1}	74.74	121.11	128.70	127.6
T10	RDF + Foliar application of Biostimulant @ 10 ml L^{-1}	75.75	120.09	128.04	127.1
	S.E m ±	1.47	1.14	1.28	1.17
	CD at 5%	4.41	3.41	3.84	3.50
	GM	76.52	120.99	128.93	128.46

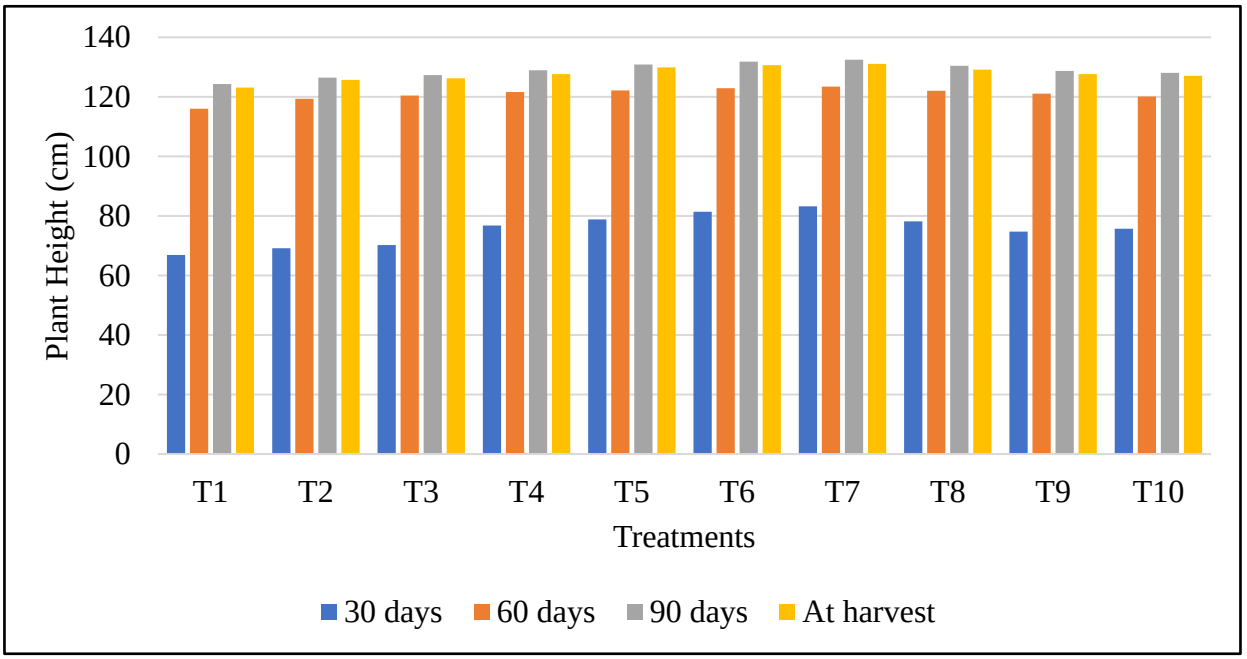

Fig. 1 Periodical plant height of tomato as influenced by different treatments

1.2 Number of branches plant^{-1}

The data regarding number of branches plant^{-1} was found to be influenced significantly bydifferent treatments was presented in Table 2 and graphically depicted in Figure 2.

At 30 DAT, the significantly maximum number of branches (22.22) was observed in the treatment of RDF + Foliar application of Biostimulant @ 7 ml L^{-1} (T_7), However treatment of RDF + Foliar application of Biostimulant @ 6 ml L^{-1} (T_6) was at par with T_7.

The treatment of RDF + Foliar application of Biostimulant @ 7 ml L^{-1} (T_7) recordedsignificantly higher number of branches i.e. 22.43, 22.96 and 18.7 at 60, 90 DAT and at harvest. However, treatment T_6 and T_5 at 60 DAT, T_6, T_5 and T_8 at 90 DAT and T_6, T_5, T_8 and T_9 at harvest were at par with T_7. This might be due to higher uptake of nutrients during growth period,which increases the protein and protoplasm synthesis for higher rate of mitosis and ultimately increasing growth parameters.

Table 2 Periodical number of branches plant^{-1} as influenced by different treatment.

Tr.no	Treatments	Number of branches plant^{-1}			
		30 DAT	60 DAT	90 DAT	At harvest
T_1	RDF without Biostimulant application (Control)	15.33	15.73	15.89	13.7
T_2	RDF + Foliar application of Biostimulant@ 2 ml L^{-1}	15.66	15.93	16.22	14.1
T_3	RDF + Foliar application of Biostimulant@ 3 ml L^{-1}	15.78	17.29	18.77	14.8
T_4	RDF + Foliar application of Biostimulant @ 4 ml L^{-1}	17.22	18.57	20.44	15.5
T_5	RDF + Foliar application of Biostimulant@ 5 ml L^{-1}	17.67	19.24	20.77	17.2
T_6	RDF + Foliar application of Biostimulant @ 6 ml L^{-1}	20.89	21.57	21.00	17.5
T_7	RDF + Foliar application of Biostimulant@ 7 ml L^{-1}	22.22	22.43	22.96	18.7
T_8	RDF + Foliar application of Biostimulant@ 8 ml L^{-1}	17.00	18.44	20.77	16.7
T_9	RDF + Foliar application of Biostimulant@ 9 ml L^{-1}	16.52	18.72	19.33	16.2
T_{10}	RDF + Foliar application of Biostimulant@ 10 ml L^{-1}	17.00	18.59	19.78	15.9
	S.E m ±	0.97	1.12	0.71	0.83
	CD at 5%	2.89	3.33	2.11	2.50
	GM	17.60	18.65	19.52	16.03

More number of branches in T_7 among all treatments might be due to effect of foliar sprays as well as availability of sufficient moisture at proper growth stages and use of the recommended dose of water soluble fertilizers resulted in availability of nutrients at proper growth stage. The minimum number of branches plant^{-1} i.e., 15.33, 15.73, 15.89 and 13.7 was observed in control i.e. RDF (T_1) at 30, 60, 90 DAT and at harvest respectively.

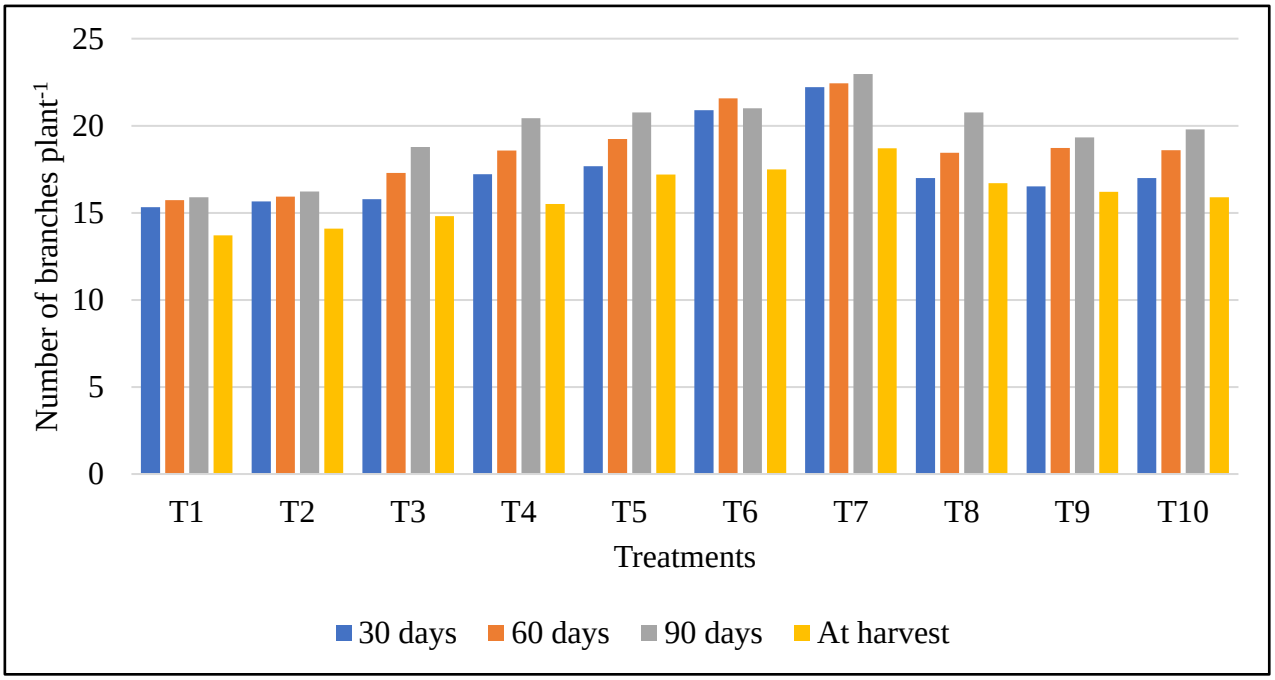

Fig. 2 Periodical number of branches plant^{-1} as influenced by different treatments

1.3 Dry matter content

The data regarding dry matter content per plant was found to be influenced significantly by different treatments was presented in Table 3 and graphically depicted in Figure 3.

At harvest, the significantly maximum dry matter content in plant (221.07 g plant^{-1}) and in fruit (111.17 g plant^{-1}) was observed in the treatment of RDF + Foliar application of Biostimulant @ 7 ml L^{-1} (T_7), However treatment of RDF + Foliar application of Biostimulant @ 6 ml L^{-1} (T_6) was at par with T_7. The dry matter content was increased with increase in age of the crop and higher dry matter was recorded at harvest.

The minimum dry matter content was recorded in control i.e. RDF (T_1) i.e. in plant 181.97 g plant^{-1} and in fruit 97.79 g plant^{-1} at harvest respectively.

Similar results were reported by Suh *et al.* (2014) that the application of recommended dose of fertilizer with foliar application of fulvic acid as biostimulant with on the leaves of tomato plants, led to a significant increase in plant height and fresh and dry weight, which subsequently resulted in an increase of marketable yield.

Table 3 Periodical dry matter content of tomato plant as influenced by different treatments.

Tr. No.	Treatment	Dry matter content (g plant^{-1})		
		Plant	Fruit	Total
T_1	RDF (Control)	181.97	97.79	279.77
T_2	RDF + Foliar application of Biostimulant@ 2 ml L^{-1}	185.20	102.26	287.47
T_3	RDF + Foliar application of Biostimulant@ 3 ml L^{-1}	191.97	103.25	295.23
T_4	RDF + Foliar application of Biostimulant@ 4 ml L^{-1}	197.21	104.68	301.90
T_5	RDF + Foliar application of Biostimulant @ 5 ml L^{-1}	214.97	108.64	323.62
T_6	RDF + Foliar application of Biostimulant@ 6 ml L^{-1}	217.97	109.99	327.96
T_7	RDF + Foliar application of Biostimulant@ 7 ml L^{-1}	221.07	111.17	332.24
T_8	RDF + Foliar application of Biostimulant @ 8 ml L^{-1}	210.31	107.78	318.09
T_9	RDF + Foliar application of Biostimulant@ 9 ml L^{-1}	205.09	106.74	311.84
T_{10}	RDF + Foliar application of Biostimulant @ 10 ml L^{-1}	200.65	106.01	306.67
	S.E m ±	1.03	0.70	1.40
	CD at 5%	3.09	2.10	4.21
	GM	202.64	105.83	308.47

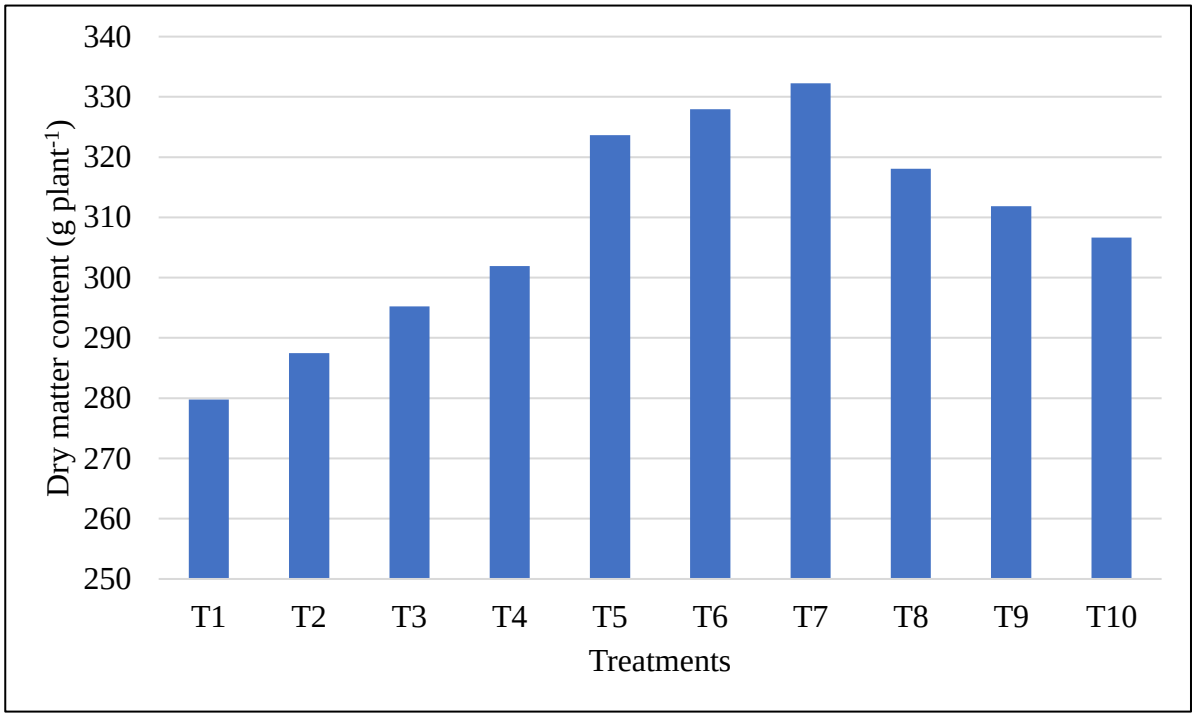

Fig. 3 Dry matter content g plant^{-1} as influenced by different treatments

2. Yield (t ha^{-1})

The data regarding the yield of tomato in tones ha^{-1} was found to be influenced significantlyby different treatments presented in Table 4.
The weight of tomato itself is the function of photosynthesis by plant and their translocationefficiency. The photosynthetic rate was affected by all the growth parameters such as plant height,number of branches, leaf area and yield contributing characters such as, diameter of fruit, length of fruit, no. of fruits and yield parameters such as average weight of tomato fruits, weight of fruits plant^{-1}. From the data, it was observed that treatment of RDF + Foliar application of Biostimulant @ 7 ml L^{-1} (T7) recorded significantly higher yield (77.03 t ha^{-1}) over all other treatments.

Table 4 Yield (t ha^{-1}) of tomato as influenced by different treatments.

Tr.no	Treatments	Yield (t ha^{-1})	Increasein yieldover T1 %
T1	RDF without Biostimulant application (Control)	65.00	-
T2	RDF + Foliar application of Biostimulant@ 2 ml L^{-1}	66.35	2.07
T3	RDF + Foliar application of Biostimulant@ 3 ml L^{-1}	67.55	3.92
T4	RDF + Foliar application of Biostimulant@ 4 ml L^{-1}	68.76	5.78
T5	RDF + Foliar application of Biostimulant @ 5 ml L^{-1}	73.23	12.66
T6	RDF + Foliar application of Biostimulant @ 6 ml L^{-1}	74.73	14.96
T7	RDF + Foliar application of Biostimulant@ 7 ml L^{-1}	77.03	18.50
T8	RDF + Foliar application of Biostimulant @ 8 ml L^{-1}	72.52	11.56
T9	RDF + Foliar application of Biostimulant@ 9 ml L^{-1}	71.72	10.32
T10	RDF + Foliar application of Biostimulant@ 10 ml L^{-1}	69.71	7.24
	S.E m ±	1.78	--
	CD at 5%	5.35	--
	GM	70.66	--

However, treatment of RDF + Foliar application of Biostimulant @ 6 ml L^{-1} (T6) (74.73 t ha^{-1}), RDF + Foliar application of Biostimulant @ 5 ml L^{-1} (T5) (73.23 t ha^{-1}), RDF + Foliar application of Biostimulant @ 8 ml L^{-1} (T8) (72.52 t ha^{-1}) and RDF + Foliar application of Biostimulant @ 9 ml L^{-1} (T9) (71.72 t ha^{-1}) at par with T7. The minimum yield of 65.00 t ha^{-1} wasobserved in control i.e. RDF (T1). The percent increase in Tomato yield was maximum in T_7 (18.50 %) followed by T_6 (14.96 %) as influenced by application of Biostimulant.

3. Economics

The economic evaluation of tomato crop was assessed in terms of cost of cultivation, grossmonetary returns, net monetary returns and benefit: cost ratio documented in table 5.

3.1 Cost of Cultivation

The cost of cultivation of tomato crop was influenced by application of biostimulant of different treatment. The highest cost of cultivation was observed in treatment of RDF + Foliar application of Biostimulant @ 7 ml L^{-1} (T7) i.e. ₹. 208733 ha^{-1} followed by RDF + Foliar application of Biostimulant @ 6 ml L^{-1} (T6) i.e. ₹. 204820 ha^{-1}. The lowest cost of cultivation was found for control i.e. RDF (T1) i.e. ₹.192314 ha^{-1}.

3.2 Gross Monetary Returns

The data regarding gross monetary returns was given in Table 5. The highest gross monetary returns of ₹. 770300 ha^{-1} was obtained in treatment of RDF + Foliar application of Biostimulant @ 7 ml L^{-1} (T7) followed by RDF + Foliar application of Biostimulant @ 6 ml L^{-1} (T6) i.e. ₹.747300. Lowest gross monetary returns of ₹. 650000 ha^{-1} wasobserved in control i.e. RDF (T1). The highest gross monetary returns were documented in T_7 because of higher fruit yield due to foliar application of biostimulant to tomato crop.

3.3 Net Monetary Returns

The data regarding net monetary returns was given in Table 5 and graphically depicted in Figure 4. The maximum net monetary returns of ₹. 561566 ha^{-1} was obtained in treatment of RDF + Foliar application of Biostimulant @ 7 ml L^{-1} (T7) followed by RDF + Foliar application of Biostimulant @ 6 ml L^{-1} (T6) i.e. ₹. 542479 ha^{-1}. Minimum net monetary returns of ₹. 457685 ha^{-1} was observed in control i.e. RDF (T1). Simiar results for net monetary returns were reported by Chaurasia *et al.* (2005) in tomato due to foliar sprays of water soluble fertilizer gives average net monetary returns.

3.4 B: C ratio

The data regarding B: C ratio was given in Table 5. The B:C ratio is related with gross monetary returns and cost of cultivation, which is graphically depicted Figure 5. The tomato crop with treatment of RDF + Foliar application of Biostimulant @ 7 ml L^{-1} (T_7) documented maximum B: C ratio of 3.69 followed by RDF + Foliar application of Biostimulant @ 6 ml L^{-1} (T6) i.e. 3.64.

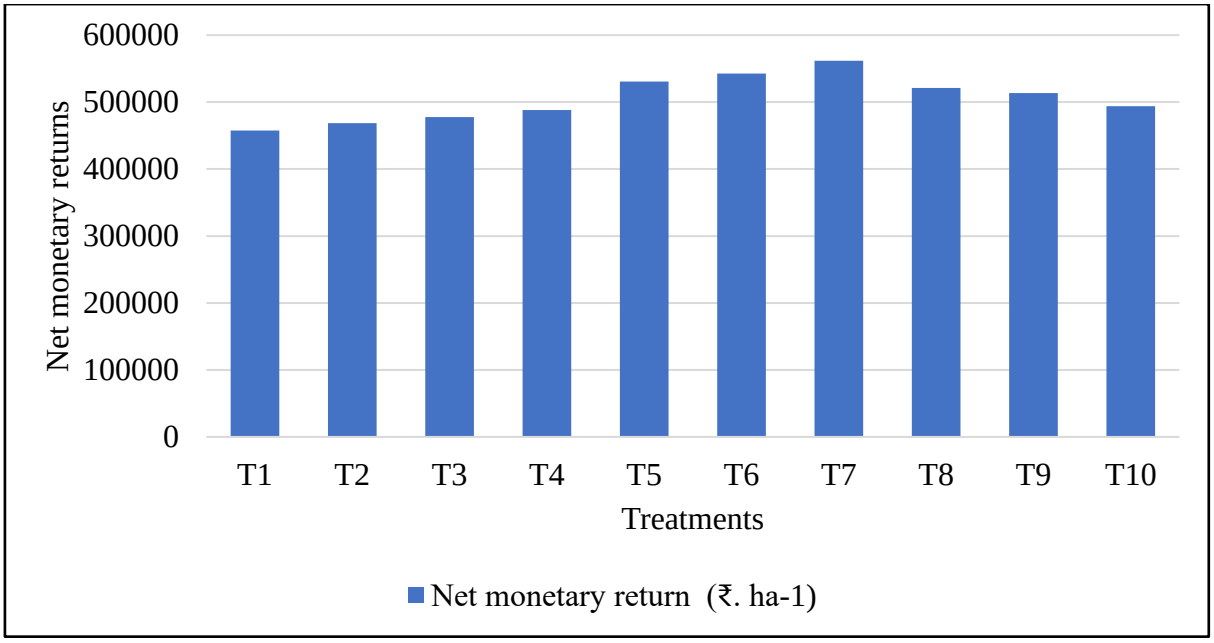

Fig. 4 Net monetary returns of tomato as influenced by different treatments

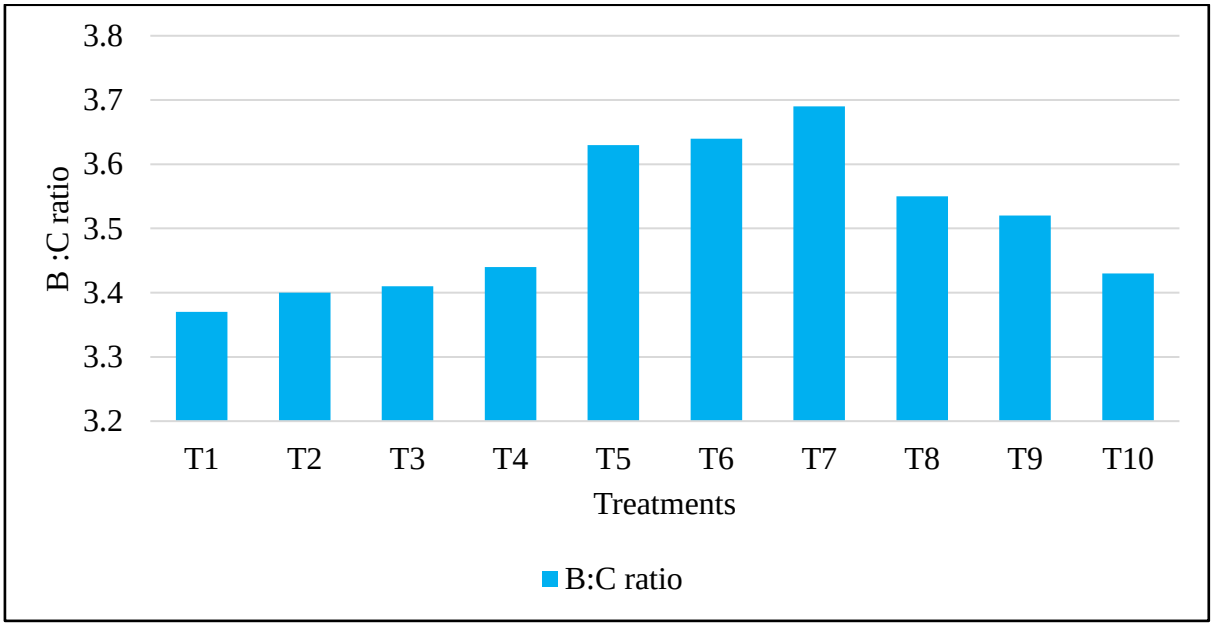

Fig. 5 B: C ratio of tomato as influenced by different treatments

Conclusion :

When we go through the experimental results "Effect of foliar sprays of biostimulant ongrowth, yield, nutrient uptake and nutrient availability by tomato under fertigation", the following conclusion could be drawn;

1. The growth contributing parameters *viz*, plant height, no. of branches, dry matter content and yield (t ha^{-1}) were recorded higher with application of RDF + Foliar application of Biostimulant @ 7 ml L^{-1} (T7).

2. The higher gross monetary returns, net monetary returns and B:C ratio was obtained the treatment of RDF + Foliar application of Biostimulant @ 7 ml L^{-1} (T7).

Thus, it is concluded that the treatment RDF (300:150:150; N:P_2O_5:K_2O Kg ha^{-1}) + Foliar application of Biostimulant @ 7 ml L^{-1} (T7) at 30 and 50 DAT is the best treatment for higher yield and monetary returns from tomato crop cultivated in medium deep soil of Maharashtra followed by treatment RDF + Foliar application of Biostimulant @ 6 ml L^{-1} (T6) at 30 and 50 DAT.

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