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Reduced application of a plant growth regulator may increase yield and added net return of processing tomato in mediterranean climate conditions

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Abstract: Among the most valuable horticultural produce, tomato is cultivated for both fresh consumption and processing purposes. Therefore, good agricultural practices secure better production and income for farmers such as the adoption of biostimulant application throughout the growing cycle. The presence of different biostimulants in the market urge its testing to depict wider aftermath on a variety of crops. A field experiment was conducted on processing tomato where a plant growth regulator (PGR; Atonik) composed of phenolic compounds, was applied following a different schedule of field applications to improve growth and fruit setting and quality. Two interventions of this PGR increased tomato marketable yield by 32.1% including fruit number per square meters (+30.8%), while four applications increased few qualitative parameters such as total soluble solids (+15.4%), firmness (+15.3%), total flavonoids (+142.6%) and total polyphenols (+33.5%). However, the added net return was higher when only two applications were done. This finding underlines the utility of testing biostimulants on different crops and depicts the best agricultural practices in term of application number in order to maintain the best net return. However, qualitative aspects should not be underestimated when pricing horticultural commodities, since quality is equally an important target to be reached in food industry.

Keywords: CIE-Lab parameters; fruit setting; nitrophenolate; partial budget analysis; qualitative attributes; sustainability.

1. Introduction

Tomato (*Solanum lycopersicum* L.) represents one of the most valuable horticultural products owing to its pleasant taste and nutritional value which are globally appreciated (Covașă et al., 2023). Fruit flavor and quality may vary under different cultivation techniques (Li et al., 2023), although in general, tomato fruits represent a rich source of various nutrients, such as vitamins, minerals, carotenoids, polyphenols, and other bioactive components with positive effects on human health (Liu et al., 2023; Huang et al., 2023; Pinedo-Guerrero et al., 2020). Among these valuable compounds, carotenoids such as lycopene and carotene are important antioxidants as precursors of vitamin A and they are also responsible for the color of the fruit (Bashir et al., 2023).

Nowadays, tomato is grown throughout the world either in field conditions or protected (in greenhouses) conditions (Di Mola et al., 2023). Greenhouse tomatoes are intended for fresh consumption while processing tomatoes are grown under field conditions and are used for canning and tomato-based food products such as puree, ketchup, sauce, juice etc. (Cammarano et al., 2020). Tomato production is among the largest industries in the world and FAOSTAT reported that in 2021 the production of tomatoes was 123 million tons harvested from 4.5 million hectares (Ali et al., 2024). Processing tomato is an intensive crop that requires a significant amount of agronomic inputs (Cammarano et al., 2020; Cozzolino et al., 2021). However, despite the significant profits that farmers may have from this crop, it is important to adopt sustainable and environmentally-friendly systems to meet the nutritional demands of the population which is continuously increasing while preserving natural resources (Szparaga et al., 2018). Therefore, more sustainable strategies should be incorporated in farming systems aiming to improve the sustainability of processing tomato production (Ronga et al., 2019).

For instance, biostimulants can be an innovative practice for sustainable horticultural production since their application is eco-friendly and can beneficially affect the yield and quality parameters of processing tomato (Di Mola et al., 2023; Rouphael et al., 2017; Liava et al., 2023). Biostimulants can enhance plant growth and thus they can reduce fertilizer requirements through various mechanism of actions related with root enlargement and the availability of nutrients (Rakkammal et al., 2023). Synthetic biostimulants are composed of plant growth regulators or phenolic compounds, in addition to other important compounds (Przybysz et al., 2014; Szparaga et al., 2019). Plant growth regulators are natural or synthetic compounds that affect the growth or the metabolic processes of plants, reducing the susceptibility to stress, increasing the yield, and modifying the plant primary and secondary metabolism (Rademacher et al., 2015).

Atonik in particular, is a biostimulatory product composed of three phenolic compounds, e.g. sodium para-nitrophenolate (0.3%), sodium orthonitrophenolate (0.2%), and sodium 5-nitroguaiacolate (0.1%) dissolved in water, with several applications in various crops (Haroun et al., 2011; Majeed et al., 2019). The mode of action of nitrophenolates has not been fully explained so far (Kocira et al., 2017); although they show significant potential as protective agents, growth regulators, and biostimulants (Szparaga et al., 2019). Several studies have shown that fully developed Atonik-treated plants are more advanced in terms of growth and development (Przybysz et al., 2014), where Atonik application may stimulate the flowering process and mitigate the negative effects of salt stress on tomato plants (Covașă et al., 2023). The aim of this study was to verify the effect of a reduced number of applications (two) of a plant growth regulator (PGR) compared to the ordinary number of applications (four) on yield and quality of processing tomato.

2. Materials and Methods

2.1. Experimental setting, tomato cultivar, and agricultural practices

An open-field trial was carried out in the private farm "D'Amore Francesco" located in the Caserta Plain (Southern-Italy; N41°02′; E14°17′; 70 m a.s.l.), an agricultural area particularly suitable for tomato cultivation. The chosen processing tomato cultivar (*Solanum lycopersicum* L.) was 'Jersey F_1' (ISI 28302 -ISI Sementi srl S.p.a., Fidenza, Italy), a medium-early maturing hybrid, highly productive, with blocky fruits of excellent consistency, color and quality.

The transplant was carried out on 18 April 2022 at a density of 33,000 plants ha^{-1} in paired rows with an intra-row spacing of 60 cm and an inter-raw spacing of 120 cm. The experimental soil was loamy (48% sand, 29% silt, and 23% clay) characterized by 0.10% of total nitrogen (Kjeldahl method), 1.34% organic matter, pH 7.2, 37.9 mg kg^{-1} of phosphorus (Olsen method) and 1219.1 mg kg^{-1} of assimilable potassium. The fertilization was managed according to the regular soil fertility management of the farm, including a base dressing before the transplant with an organo-mineral fertilizer (N-P: 10-24), and urea (46% N), providing a total of 100 kg ha^{-1} of nitrogen; as well as during the crop growth cycle where only nitrogen was applied seven times through fertigation with calcium nitrate (15.5%) providing a total of 150 kg ha^{-1}. Drip irrigation was used for the full replacement of water losses, determined by the Hargreaves method (Hargreaves et al., 1985). No weeds and pathogens control were needed throughout the growth cycle. The harvest occurred on 28 July 2022 on a sampling area of 3.64 m^2, corresponding to 12 plants per replicate.

2.2. Experimental design and characteristics of plant growth regulation

Two different application strategies of plant growth regulator were compared to an untreated control (CTR); the strategies were: a reduced number of applications (two) and an ordinary number of applications (four), hereafter named as BIO2 and BIO4, respectively. The treatments were replicated three times for a total of 9 plots, arranged in a randomized block design. Each plot was 32 m^2 (3.2 × 10.0 m).

The tested plant growth regulator was "Atonik" (Diachem Italia S.p.a., Bergamo, Italy). Atonik is a water-soluble concentrate, containing 5-nitroguaiacolate of 0.1% sodium, 0.2% sodium O-nitrophenolate, and 0.3% sodium P-nitrophenolate; it has a stimulating action on crop growth, fruit setting, rooting, yield and fruit quality. For both treatments, the plant growth regulator (PGR) was applied as foliar spray starting from flowering (1 June 2022) at a dose of 1 L ha^{-1}, according to the manufacturer's indications. Then in the case of BIO4, the other three applications were made on 13 and 22 June, and 5 July, while for BIO2 the second application was made on 22 June. Simultaneously to the PGR applications, the control plants were sprayed with tap water, as well as the BIO2 plants at the second and fourth applications of the BIO4 plants.

2.3. Yield, colorimetry, firmness and total soluble solids of tomato fruits

At tharvest (28 July 2022), the tomato fruits were separated into marketable, unmarketable (rotten or damaged), and green fruits. Then they were counted and weighed in order to determine the yield, the number of fruit m^{-2} and the average fruit weight. In addition, ten fruits per replicate were randomly selected to determine the maximum and minimum diameter via a caliper and then, a sub-sample was oven-dried at 70 °C until reaching constant weight, in order to assess the dry matter percentage.

The color space parameters (L*: brightness, ranging between 0-black (no reflection) and 100 -white; a* parameter ranging between -60 (green) and +60 (red); b* parameter ranging between -60 (blue) and +60 (yellow)) were determined by a Minolta CR-300 Chroma Meter (Minolta Camera Co. Ltd., Osaka, Japan) on two sides of ten marketable fruits of each replicate. A digital penetrometer (T.R. Turoni srl, Forlì, Italy) equipped with an 8 mm diameter probe was used to measure fruit flesh firmness performing the measurements on two opposite sides of five fruits per replicate. The results were expressed in kg cm^{-2}. Finally, the total soluble solid (TSS) content was measured on fresh fruit juice using a digital refractometer (Sinergica Soluzioni, DBR35, Pescara, Italy), and the data were expressed as °Brix.

2.4. Chemical and qualitative traits of tomato fruits

At harvest, a pool of five fruits per replicate was used to determine, pH, titratable acidity, total polyphenols, total flavonoids, total anthocyanins, and antioxidant activity. The flesh juice pH was measured with a digital pH-meter (Jenway, 3540-Staffordshire -UK). As for the qualitative analyses, they were assayed on samples extracted with methanol solution (80% v/v) as reported in detail by Petriccione et al. (2015). The supernatants were filtered and then were used for the various assays. The Folin-Ciocalteu method was used to determine the total polyphenols content using 100 µL of methanolic extract (Singleton et al. 1965); the results were expressed as mg gallic acid equivalent (GAE) 100 g^{-1} fresh weight (FW). The total flavonoid content was determined using the aluminum complex formation according to Petriccione et al. (2015) and the results were expressed as catechin equivalent (CAE) 100 g^{-1}

FW. Titratable acidity (TA) was determined by titrating 10 mL of tomato juice with 0.1 N NaOH and the results were expressed as g citric acid L^{-1} of juice.

Total anthocyanins were measured by the pH differential method as described by Giusti and Wrolstad (2003) and the results were expressed as cyanidin-3-glucoside equivalent (C3G) 100 g^{-1} FW. The total antioxidant activity (AA) was measured by 1.1-diphenyl-2-picryl-hydrazil (DPPH) and ferric reducing antioxidant power (FRAP) according to the method of Brand-Williams et al. (1995) and Zhou et al. (2023), respectively. Results were expressed as μmol Trolox equivalents (TE) g^{-1} FW according to a dose-response curve built using Trolox as standard.

2.5. Partial budget analysis

Partial budget analysis was performed to evaluate the economic advantage that may industrial tomato growers achieve by applying commercial plant biostimulant, in particular plant growth regulators. The economic procedure used in the present work has been described in detail by Cardarelli et al. (2020). Briefly, for each biostimulant treatment modality the variable costs (added costs) and benefits (added gross return) were calculated in relation to the untreated control. The added net return (expressed in euro ha^{-1}) incurred by each treatment was also calculated as the difference between benefits and variable costs.

2.6. Statistical processing

All data were subjected to analysis of variance (one-way ANOVA) using the SPSS 21 software package, version 22 (IBM, Chicago, IL, USA). The means were separated using Tukey's HSD (Honestly Significant Difference) test at $p \leq 0.05$.

3. Results and Discussion

3.1. Yield parameters

As presented in Figure 1, the application of the plant growth regulator (PGR) induced a significant increase in marketable yield as compared to the Control. Two applications of the PGR (BIO2) increased

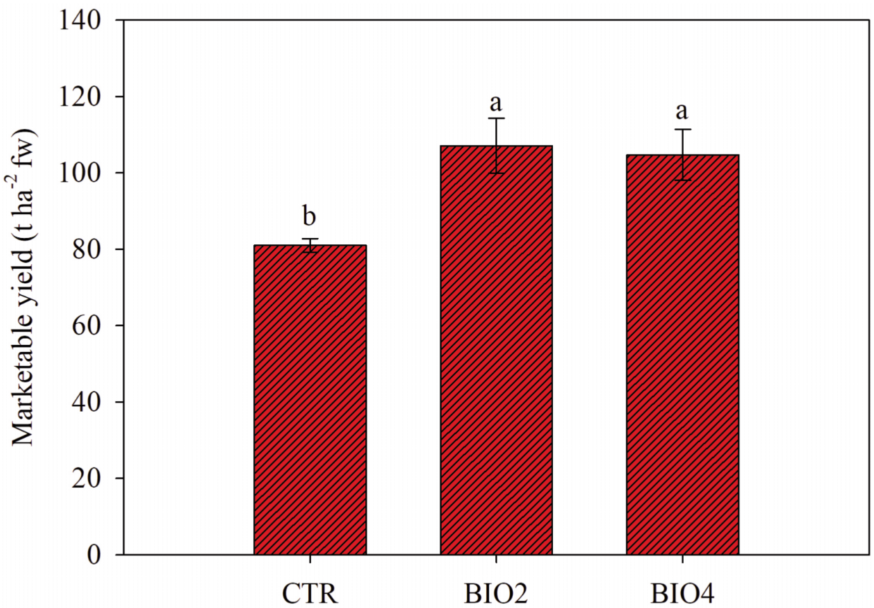

Figure 1. Tomato marketable yield as affected by the number of PGR applications (BIO2: two applications of PGR; BIO4: four applications of PGR; CTR: untreated control). Different letters indicate statistical differences according to Tukey's HSD test at p = 0.05. All data are expressed as mean ± standard error, n = 3. Vertical bars indicate ± SE of means (Significance ≤ 0.001).

the marketable yield by 32.1%, while four applications (BIO4) increased it by 28.4%. But no significant difference between these two treatments was found.

The number of marketable fruits per square meter was equally influenced by the application of BIO2 and BIO4 (Table 1), registering a significant increase of this parameter by 30.8% and 21.7%, respectively. Therefore, the increase in marketable yield of biostimulant treated plants could be attributed to the number of fruits per plant and not to the increase of the fruit weight. Similar findings were recorded for green and unmarketable fruits where differences in yield among the tested treatments were associated to the different number of fruits instead to differences in fruit weight. However, a significant increase in green fruit number per square meter and yield was noted for BIO2 treated plants, whereas the unmarketable fruits parameters did not vary between the tested treatments. Previously, Przybysz et al. (2014) observed that Atonik increased the marketable yield of cucumber owing to the higher photosynthetic activity wich is similar to the results of Batool et al. (2023) and Al-Badiri et al. (2022) regarding the grain yield of maize and rice. Atonik also increased the yield of legumes such as beans and soybeans (Szparaga et al., 2018; Szparaga et al., 2019; Kociraet al 2017). This increase could be due to the use of biostimulants at the appropriate stages of plant growth (Szparaga et al., 2018) which could be attributed to the increase of endogenous concentration of auxins (Djanaguiraman et al., 2005). In previous studies on tomato crop, Atonik augmented the number of fruits per plant (Covașă et al., 2023), while the application of other biostimulants which contained *Trichoderma afroharzianum* and *Ascophyllum nodosum* seaweed extracts, a legume derived protein hydrolysate, fulvic acids, and silicon increased the marketable yield of tomato fruit (Pinedo-Guerrero et al., 2020; Di Mola et al., 2023; Cozzolino et al., 2021; Shu et al., 2014; Chakma et al., 2021; Ahmed et al., 2022; Dou et al., 2023).

Table 1. Yield parameters (marketable, green and unmarketable fruit) of processing tomato in relation to biostimulant application. (CTR: untreated control; BIO2: two applications of plant growth regulator (PGR) and BIO4: four applications of PGR).

Treatment	Marketable		Green			Unmarketable		
	Number of fruit m^{-2}	g $fruit^{-1}$	t ha^{-1}	Number of fruit m^{-2}	g $fruit^{-1}$	t ha^{-1}	Number of fruit m^{-2}	g $fruit^{-1}$
CTR	169.3 ± 15.1 b	48.6 ± 6.2	22.0 ± 2.3 b	58.5 ± 5.2 b	37.9 ± 3.9	3.26 ± 0.87	7.22 ± 1.95	45.2 ± 1.04
BIO2	221.5 ± 2.9 a	48.3 ± 2.4	27.3 ± 1.5 a	81.7 ± 7.5 a	34.1 ± 4.3	2.11 ± 1.38	4.63 ± 2.98	45.3 ± 1.33
BIO4	206.1 ± 11.8 a	51.4 ± 2.5	22.3 ± 1.1 b	64.8 ± 4.2 ab	34.9 ± 4.0	4.07 ± 1.50	9.63 ± 3.21	40.6 ± 2.84
Significance	*	*NS*	*	*	*NS*	*NS*	*NS*	*NS*

NS and *: non-significant or significant at $p \leq 0.05$, respectively. Different letters indicate statistical differences according to Tukey's HSD test at $p = 0.05$. All data are expressed as mean ± standard error, n = 3.

3.2. Fruit quality parameters

Among the CIE-Lab parameters, the brightness coordinate L* and the coordinate b* were reduced upon the application of PGR (Table 2). L* decreased significantly by 14.0% after the application of BIO4, while b* decreased significantly by 31.8% on average in response to the application of BIO2 and BIO4. On the contrary, the parameter a*, that indicates the redness of tomato fruits, slightly increased in response to the biostimulant treatment, although no significant differences were recorded compared to the control treatment. According to the literature, biostimulant application may affect the color parameters of tomato fruit. In particular, Cozzolino et al. (2021) reported that biostimulants containing seaweed extracts, legume-derived protein hydrolysates, or tropical plant extract led to an increased a*/b* ratio. Moreover, the application of *Trichoderma afroharzianum*, alone or in combination with *Ascophyllum nodosum*, enhanced the brightness of tomato fruit, although it negatively affected a* and b*parameters (Di Mola et al., 2023). Finally, the application of *Ascophyllum nodosum* seaweed extract increased the color index of tomato fruit (Ahmed et al., 2022).

Table 2. Color parameters of processing tomato fruit in relation to biostimulant application. (CTR: untreated control; BIO2: two applications of plant growth regulator (PGR) and BIO4: four applications of PGR).

Treatment	*L**	*a**	*b**
CTR	44.0 ± 1.42 a	30.0 ± 0.67	38.1 ± 1.6 a
BIO2	39.8 ± 0.76 ab	31.5 ± 1.18	29.3 ± 1.3 b
BIO4	38.6 ± 0.68 b	31.5 ± 0.44	28.5 ± 0.5 b
Significance	*	*NS*	*

NS and *: non-significant or significant at $p \leq 0.05$, respectively. Different letters indicate statistical differences according to Tukey's HSD test at $p = 0.05$. All data are expressed as mean ± standard error, n = 3.

The fruit quality parameters such as total soluble solids (TSS) and firmness were both increased by the application of PGR, but only BIO4 induced a significant increase for both parameters by 15.4 and 15.3%, respectively, compared to the control treatment (Table 3). On the other hand, the dry matter percentage and fruit dimensions were not significantly affected by the tested treatments (Table 3). Similarly, the application of fulvic acids had no significant effect on the percent dry matter of tomato fruit, while there was an increase trend in fruit firmness with the increasing concentration of the applied fulvic acid biostimulant (Shu et al., 2014). Moreover, biostimulants based on seaweed extracts, microorganisms, or silicon improved the firmness (Di Mola et al., 2023; Jalali et al., 2022) and the TSS of tomato fruit (Ahmed et al., 2022; Jalali et al., 2022; Mzibra et al., 2021; Subramaniyan et al., 2023).

Total soluble solids (TSS) content is an important qualitative parameter in processing tomato production (Ronga et al., 2019) which is associated mostly with soluble sugars and organic acids content (Mzibra et al., 2021). The main sugars usually detected in tomato fruit are fructose, glucose, and sucrose and their content was significantly affected by biostimulant products containing protein and amino acids with carboxylic acids, protein and amino acids with seaweed extracts, or humic and fulvic acids with seaweed extracts and SiO_2 (Liava et al., 2023).

Table 3. Fruit quality parameters of processing tomato fruit in relation to biostimulant application. (CTR: untreated control; BIO2: two applications of plant growth regulator (PGR) and BIO4: four applications of PGR).

Treatment	TSS (°Brix)	Fruit dry matter (%)	Flesh firmness (kg cm^{-2})	Maximum fruit diameter (cm)	Minimum fruit diameter (cm)
CTR	4.15 ± 0.06 b	5.26 ± 0.11	1.11 ± 0.01 b	5.89 ± 0.07	4.67 ± 0.16
BIO2	4.54 ± 0.10 ab	5.48 ± 0.25	1.22 ± 0.04 ab	5.80 ± 0.10	4.47 ± 0.13
BIO4	4.79 ± 0.13 a	5.44 ± 0.13	1.28 ± 0.02 a	5.87 ± 0.08	4.67 ± 0.13
Significance	**	*NS*	**	*NS*	*NS*

NS and **: non-significant or significant at $p \leq 0.01$, respectively. Different letters indicate statistical differences according to Tukey's HSD test at $p = 0.05$. All data are expressed as mean ± standard error, n = 3.

More qualitative aspects (e.g. pH of juice, titratable acidity (TA), total polyphenols, total flavonoids and total anthocyanins, antioxidant activity (DPPH, FRAP) of tomato fruits in relation to biostimulant application were assessed as listed in Table 4. In this case, only total polyphenols and total flavonoids were significantly affected by the application of PRG, and especially in response to BIO4 that significantly increased these parameters by 1.3 and 2.4-fold, respectively. According to the literature, the use of Atonik increased the total phenolic compounds and flavonoids content in soybean and bean seeds, while the highest value was recorded after the application of the higher dose (Szparaga et al., 2019; Szparaga et al., 2017).

Moreover, Kocira et al. (2017) observed that the impact of Atonik on total phenolic compounds and flavonoids content varied depending on the bean cultivar tested. Regarding tomato fruit, the application of a legume-derived protein hydrolysate had no significant effect on total phenolic compounds content (Rouphael et al., 2017), while the use of *Trichoderma afroharzianum* or *Ascophyllum nodosum* extract increased the levels of plant phenolics (Di Mola et al., 2023; Ali et al., 2022). According to Liava et al. (2023), four biostimulant products affected differently the total phenolic compounds and flavonoids content of tomato fruit depending on the composition of the biostimulant formulation.

As for the rest of the analyzed parameters, such as the pH of tomato pulp and its titratable acidity, no significant changes were recorded, while similar findings were recorded for total anthocyanins and the antioxidant activity measured with DPPH and FRAP assays (Table 4)**.** Similarly to our study, Suh et al. (2014) and Cozzolino et al. (2021) observed that biostimulants containing fulvic acids, seaweed extracts, legume-derived protein hydrolysates, and tropical plant extracts had no significant effect on fruit juice pH. In contrast, in previous studies the application of biostimulants significantly affected the pH (Ahmed et al., 2022) and titratable acidity (Pinedo-Guerrero et al., 2020; Jalali et al., 2022; Mzibra et al., 2021; Subramaniyan et al., 2023). Therefore, the contrasting reports in the literature suggest that the response of these parameters to biostimulant application is associated with the composition of the biostimulatory product. As mentioned by Liava et al. (2023) and Fernandes et al. (2022) the main organic acids of tomato fruits are citric, malic, and oxalic acid, while ascorbic acid may contribute to the overall antioxidant activity of tomato fruit. In previous reports, the application of biostimulants affected the antioxidant activity of tomato fruit evaluated with different assays such as DPPH, ABTS, TBARS, and OxHLIA. The reported results suggest that some biostimulants may enhance the antioxidant activity, whereas others may negatively affect this fruit quality trait (Pinedo-Guerrero et al., 2020; Liava et al., 2023; Fernandes et al., 2022). In contrast, Di Mola et al. (2023) observed that biostimulant application had no significant effect on the lipophilic antioxidant activity of tomato fruit. Similar to this study, the antioxidant activity of bean seeds evaluated with FRAP assay was not affected by Atonik application (Szparaga et al., 2019), whereas it increased antioxidant activity assayed with ABTS method (Kocira et al., 2017). The effect of Atonik on total anthocyanins content also varies as there are different reports obtained from different growing seasons which suggest the importance of weather conditions on the recorded parameters (Szparaga et al., 2019). Finally, Szparaga et al. (2018) mentioned that the mode of action of Atonik may be multi-oriented and its effect on plants is probably not due to the direct ability to regulate the metabolism.

Table 4. Quality parameters (pH, titratable acidity (TA), total polyphenols (POL), total flavonoids (FLA), total anthocyanins (ANT) content and antioxidant activity 1.1-diphenyl-2-picryl-hydrazil (DPPH) and ferric reducing antioxidant power (FRAP) of processing tomato fruit in relation to biostimulant application. (CTR: untreated control; BIO2: two applications of plant growth regulator (PGR) and BIO4: four applications of PGR).

Treatment	pH	TA g citric acid L^{-1}	POL mg GAE 100 g^{-1} FW	FLA mg CAE 100 g^{-1} FW	ANT mg C3G 100 g^{-1} FW	DPPH µmol TE g^{-1} FW	FRAP µmol TE g^{-1} FW
CTR	4.14 ± 0.09	3.41 ± 0.33	67.77 ± 3.07 b	9.40 ± 1.10 b	8.16 ± 0.66	5.72 ± 0.24	6.49 ± 0.24
BIO2	4.04 ± 0.02	3.51 ± 0.19	69.86 ± 3.32 b	15.05 ± 1.33 b	9.16 ± 0.40	5.95 ± 0.28	7.35 ± 0.23
BIO4	4.11 ± 0.07	2.66 ± 0.09	90.46 ± 7.48 a	22.80 ± 1.39 a	7.71 ± 0.69	6.11 ± 0.37	7.24 ± 0.40
Signific.	NS	NS	*	*	NS	NS	NS

NS and *: non-significant or significant at $p \leq 0.05$, respectively. Different letters indicate statistical differences according to Tukey's HSD test at $p = 0.05$. All data are expressed as mean ± standard error, n = 3. GAE: gallic acid equivalent. CAE: catechin equivalent. C3G: cyanidin-3-glucoside equivalent. TE: Trolox equivalent.

The partial budget analysis on industrial tomato treated with PGR biostimulant was also assessed (Table 5). The application of BIO2 and BIO4 induced an increase of 32.2% and 29.3% of the marketable yield (tons per hectare). However, the utility of adopting only two applications (BIO2) of the biostimulant instead of four (BIO4) demonstrated a relevant higher added net return of 3133.5 euro per hectare compared to 2430.4 euro per hectare, respectively. This finding was partially attributed to the slightly higher marketable yield of BIO2 but mainly to the lower added variable costs of BIO2 due to lower number of applications. A similar increase in added net return was registered in different studies that approached both processing tomato (Cardarelli et al., 2020) and greenhouse fresh tomato (Rouphael et al., 2021), where biostimulants applications proved to be a promising eco-sustainable technology that can boost productive attributes of tomato plants and thus increase the added return of such cultivations. Some qualitative attributes were improved in this current research under BIO4 treatment, such as total soluble solids, firmness, total polyphenols and total flavonoids, which can be an added value as well in the industry chain. Qualitative attributes such as total soluble solids can increase the price of processed tomato when taken into consideration by the food canning industry.

Table 5. Added gross and net return together with added variable costs as aftermath of plant growth regulator (PGR) application (BIO2: two applications of PGR and BIO4: four applications of PGR).

Treatment	Added gross return	Added variable costs (euro ha^{-1})				Added net return
	(euro ha^{-1})	Biostimulant	Foliar spraying	Fruit harvest	Total	(euro ha^{-1})
BIO2	3915.0	80.0	300.0	401.5	781.5	3133.5
BIO4	3555.0	160.0	600.0	364.6	1124.6	2430.4

4. Conclusions

Biostimulant application is a convenient and sustainable practice in horticulture. Other than being eco-friendly and sustaining natural plant processes, biostimulants assist crops in coping with abiotic stress, and more importantly in boosting yield parameters and some qualitative traits of horticultural crops. In this study, the application of biostimulants such as plant growth promotors (PGP) and in particular nitrophenolates on processing tomato demonstrated to enhance fruit number and marketable yield even with less applications being comparable with the maximum field applications. Some qualitative attributes of processing tomato such as total soluble solids and phenols were ameliorated with the maximum number of applications. As proved by the partial budget analysis, the added net return was highlighted by only two applications of the PGP, especially that the selling price is related to yield in the industry. This finding underlines the utility of testing biostimulants on different crops and depicts the best agricultural practices in term of application number in order to maintain the best net return. However, qualitative aspects should not be underestimated when pricing horticultural commodities, since quality is equally an important target to be reached in food industry.

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