BIOSTIMULANT APPLICATION IMPROVES TOMATO (*SOLANUM LYCOPERSICUM* L.) FRUIT YIELD AND QUALITY DURING THE AUTUMN-WINTER SEASON

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Abstract. *The wide range of components, including amino acids, small peptides, and osmoactive substances (proline, glycine betaine), makes protein hydrolysate a promising biostimulant type, encouraging plant productivity both under smooth or adverse environmental conditions. Plant-based biostimulants can boost growth, yield, quality, and bioactive compounds in a variety of crops. The present study examined the effects of an enzymatic protein hydrolysate formulation (Activeg) applied different times (3, 6, or 9), compared to an untreated control, on production and quality of tomato (Solanum lycopersicum* L.*) 'miniplum' fruits grown in a greenhouse during the autumn-winter season. This study was carried out at the University of Federico II, Department of Agriculture (40°49' N, 14°20' E). A randomized complete block design was used to distribute the experimental treatments in the field; the obtained data were analyzed using ANOVA. The biostimulant applied 3 or 6 times led to the highest yields, whereas 6 or 9 sprayings enhanced fruit firmness, dry residue, soluble solids and antioxidants. The biostimulant treatment repeated 6 times resulted in the best overall tomato performances in terms of fruit yield, quality and antioxidant content, in the autumn-winter season, which suggests the chance to reduce the chemical fertilizer input, thus contributing to the vegetable crop system sustainability.*

Keywords*: protein hydrolysate, dry residue, soluble solids, firmness, colour, lycopene, vitamin C.*

INTRODUCTION

Tomato plants with indeterminate growth habit can be grown to satisfy market demands all the year round and, in this respect, the 'miniplum' type produces round-oval 25-30 g fruits, oriented to fresh market. Production and nutritional properties of fruits can be affected by environmental conditions such as temperature and humidity, as well as crop management practices. Because of lower temperature and higher atmospheric humidity in the autumn-winter season, the biosynthesis of nutritional components in tomato fruits is not so efficient as in spring-summer (ANZA et al., 2006). Biostimulants have been used in horticulture to help plants better cope with biotic and abiotic stresses, producing high-quality products in different year seasons (ROUPHAEL et al, 2017). Farmers can increase the use efficiency of organic and mineral fertilisers by using several types of biostimulants, via foliar or root application. The use of biostimulants resulted in an increase of overall tomato yield, according to COLLA et al. (2017). From research conducted by TALLARITA et al. (2020) on tomato, it arose that biostimulant application enhanced fruit production and nutraceuticals in the spring-summer season, proving as an effective tool for reducing chemical inputs. In the present research, the effects of three different treatment durations with an enzymatic protein hydrolysate biostimulant (Activeg) on tomato yield, quality and antioxidant performances were assessed in the autumn-winter season.

MATERIALS AND METHODS

Research was carried out at the Department of Agriculture of the University of Naples Federico II (40°49' N, 14°20' E, 63 m a.s.l.) in Portici (Naples), in 2020-2021, on tomato "miniplum" (*Solanum lycopersicum* L., cultivar Proxy F_1), in greenhouse. The plants were transplanted on 27 May, 2020, in 24 cm diameter polyethene pots filled with sandy-loam soil and placed on a 10 cm thick layer of polystyrene, at the density of four plants per m^2. A galvanized iron polytunnel covered with a thermal polyethene film was used for the present study, which consisted of three tunnels, each 5.0 m wide, 2.0 m and 3.5 m high at wall and roof respectively. The experimental protocol was based on the comparison between three biostimulant treatment durations (3, 6 or 9 applications at weekly intervals), plus an untreated control., using the enzymatic protein hydrolysate biostimulant Activeg. Drip irrigation and fertigations at 2 $L \cdot h^{-1}$ were practiced, the latter based on the addition of N, P, K, Ca, Mg, S, Fe, Mn, Zn, B, Cu and Mo to the available water, to reach 3 $mS \cdot cm^{-1}$ EC. The application of Hydro Fert Activeg, a biostimulant product based on enzymatic extracts from Fabaceae plants, began on 10 June. The autumn-winter tomato harvests started on 15 November, 2020, and ended on 26 January, 2021. The total weight, number, and average weight of marketable fruits (i.e., regular shaped and undamaged) were assessed at each harvest. In addition, random fruit samples per each treatment were analyzed in laboratory for measuring: soluble solids content (°Brix at 20°C) using a digital refractometer (Bellingham and Stanley, model RFM 81); dry residue (in an oven at 70°C until constant weight); firmness (digital penetrometer Fruti Tester, Effegi, Milan, Milan, Italy); colourimetric parameters (Minolta colourimeter, model Minolta, model CR-400, Tokyo, Japan); lycopene and ascorbic acid, using the methods described in previous research (CARUSO et al., 2019); antioxidant activity, using the method described by BRAND-WILLIAMS et al. (1995). The data obtained were statistically processed using the analysis of variance (ANOVA), and the mean separation was performed through Duncan's multiple range test at 0.05 probability level, using SPSS software (version 21). Finally, the data expressed in percentage were subjected to angular transformation before processing.

RESULTS AND DISCUSSIONS

The application of the biostimulant Activeg repeated 3 or 6 times resulted in increased tomato yield, compared both to the untreated control and 9 applications, due to the greatest number of fruits per plant or their weight, respectively (Figure 1). The crop production increase elicited by the biostimulant treatment is in agreement with the finding of previous research (CARUSO et al., 2019). Our results suggest that the protein hydrolisate application was beneficial in the autumn-winter cycle, when the low temperatures may inhibit root growth, nitrogen uptake, and, consequently, plant biomass (XIAOYU et al., 2018; GERALDINE et al., 2020; SUN et al., 2012). Biostimulant formulations, either from animals or plant derivates, can mitigate the deleterious effect of some abiotic stresses on the root architecture of tomato plants by acting on specific gene regulation sites (CAMPOBENEDETTO et al., 2021). Indeed, they hinder the decrease in the number of root capillaries and average length, thus preventing the uptake depression of nutrients needed for plant development and fruit formation.

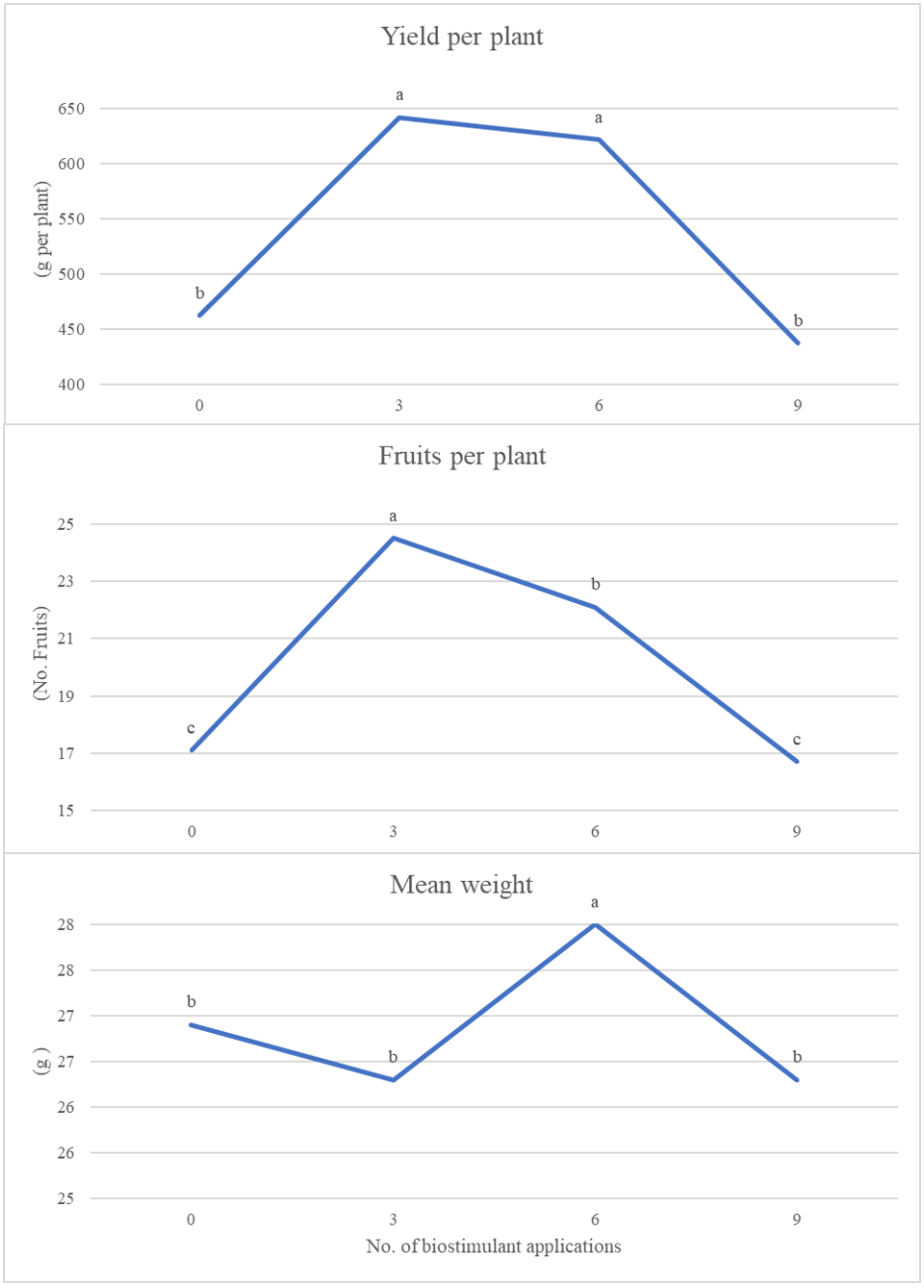

Fig. 1

Effects of biostimulant treatment duration on yield parameters per plant of tomato 'miniplum' Proxy F_1. The values associated with different letters are significantly different from each other, according to Duncan's multiple range test $p < 0.05$.

Regarding the qualitative aspects (Table 1), the 9-time application of the biostimulant Activeg elicited the best effect on tomato fruit dry residue, though not statistically different from the 6-time supply; the two latter treatments were the most effective on soluble solids and firmness, but only significantly higher than the untreated control. The results of the present investigation are consistent with those recorded in previous research (ADAMS AND HO, 1989).

Table 1

Effects of biostimulant treatment duration on the quality parameters of tomato 'miniplum' Proxy F_1. The values associated with different letters are significantly different from each other, according to Duncan's multiple range test $p < 0.05$.

No. biostimulant application	Dry residue %	Soluble solids °Brix	Firmness $Kg \cdot cm^{-2}$
0	10.1 c	8.8 b	0.73 b
3	10.7 bc	9.3 ab	0.78 ab
6	11.1 ab	9.6 a	0.82 a
9	11.5 a	9.8 a	0.84 a

Regarding fruit colour (Table 2), the 9-time biostimulant application resulted in less intense yellow and red coloration of tomato fruits. In a previous work conducted by CARUSO et al. (2019) on cherry tomato Vesuvian Piennolo POD, the biostimulant application promoted the production of brighter fruits (higher value of the parameter L*), compared to the untreated control.

Table 2

Effects of biostimulant treatment duration on the fruit colour parameters of tomato 'miniplum' Proxy F_1. The values associated with different letters are significantly different from each other, according to Duncan's multiple range test for $p < 0.05$; 'n.s.', not significant.

No. biostimulant spplication	L*	A*	B*
0	40.00	34.5 a	20.2 a
3	39.80	32.6 a	21.0 a
6	39.20	31.7 ab	20.3 a
9	38.60	28.9 b	17.7 b
	n.s.		

As reported in Table 3, the biostimulant treatment led to the highest accumulation of lycopene in tomato fruits when repeated 6 times, and of vitamin C when applied 9 times. The opposite trend was recorded for lipophilic and hydrophilic antioxidant activities, with the highest content in the untreated control, with no differences compared to the 3-time treatment with regard to hydrophilic AOA. A previous investigation carried out by ALI et al. (2021) showed that the application of amino acid-based biostimulants under salt stress conditions increased the formation of polyphenols and carotenoids, particularly lycopene. Plant phytochemical accumulation (e.g. lycopene) is elicited by exogenous biostimulation which activates molecular and physiological nitrogen metabolism pathways (BULGARI et al., 2015; ERTANI et al., 2014). However, the opposite trends of lipophilic and hydrophilic antioxidant activities respect to those of lycopene and vitamin C contents, may relate to the occurrence of other antioxidant compounds which have not been analysed in our research.

Table 3

Effects of biostimulant treatment duration on the fruit antioxidants of tomato 'miniplum' Proxy F_1. The values associated with different letters are significantly different from each other, according to Duncan's multiple range test at $p < 0.05$; 'n.s.', non significant.

No. biostimulant applications	Lycopene mg $\cdot g^{-1}$ f.w.	Lipophilic AOA mmol trolox equivalent 100 $\cdot g^{-1}$ d.w.	Vitamin C mg $\cdot$ 100g^{-1} f.w.	Hydrophilic AOA mmol ascorbic acid eq $\cdot$ 100g^{-1} d.w.
0	11.05 b	26.90 a	35.42 c	12.01 a
3	12.12 b	23.15 b	44.28 b	12.14 a
6	14.13 a	8.03 c	49.66 ab	6.17 b
9	10.83 b	7.45 c	56.01 a	6.15 b

CONCLUSIONS

From the present research, it arose that the biostimulant treatment to tomato plants enhanced the overall performance in terms of fruit yield, quality and antioxidant content, compared to the untreated control. However, the biostimulant application repeated 6 times allowed to achieve the best compromise between the different goals. Considering the producer and consumer expectations of high yield and quality, the enzymatic protein hydrolysate biostimulant Activeg showed interesting characteristics with the perspective to reduce the chemical fertilizer input, thus contributing to the crop system sustainability.

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