Article

Effect of chitosan on variables of tomato growth, yield and nutritional content

Juan José Reyes-Pérez[1]
Emmanuel Alexander Enríquez-Acosta[2]
Miguel Ángel Ramírez-Arrebato[3]
Elizabeth Zúñiga Valenzuela[4]
Liliana Lara-Capistrán[5]
Luis Guillermo Hernández-Montiel[6§]

[1]Quevedo State Technical University. Av. Walter Andradem, route to Santo Domingo km 1.5, Quevedo, Los Ríos, Ecuador. (jreyes@uteq.edu.ec). [2]Technical University of Cotopaxi-La Maná Extension. Los Almendros y Pujilí Avenue, University Building, La Maná, Ecuador. (emmanuel250196@hotmail.com). [3]UCTB Los Palacios-National Institute of Agricultural Sciences (INCA). Highway La Francia km 1 s/n, Los Palacios, Pinar del Río, Cuba. (miguelar@inca.edu.ec). [4]Faculty of Agriculture and Animal Husbandry-Juárez University of the State of Durango. Gómez Palacio, Durango, Mexico. (elizabeth.zunigaval@yahoo.com.mx). [5]Veracruzana University-Xalapa *Campus*. Gonzalo Aguirre Beltrán University Circuit s/n, university area, Xalapa, Veracruz, Mexico. (llara_capistran@hotmail.com). [6]Northwest SC Biological Research Center-National Polytechnic Institute. No. 195, Colonia Playa Palo de Santa Rita Sur, La Paz, Baja California Sur, Mexico.

[§]Corresponding author: lhernandez@cibnor.mx.

Abstract

Chitosan is a compound of natural origin with properties that promote nutrition, growth and yield of crops, which is why it has been considered as a biostimulant. Its particular mechanisms of action allow it to act as a growth regulator, accelerator of seed germination, plant vigor and agricultural performance. The present work was developed under semi-controlled conditions on a completely randomized design, with the aim of evaluating the effect of different concentrations of chitosan (150, 200, 250 and 300 mg L^{-1}) on growth, yield, fruit quality and content of nutrients in tomato plants variety Floradade. The results show that the bioproduct exerts a stimulating effect on the variables: height of the plant, clusters with fruits, fruits per plant, equatorial and polar diameter of the fruit, diameter of the pericarp and fruit mass. The concentration of 300 mg L^{-1} significantly increased the values in all the variables evaluated with respect to the control treatment. However, in the indicators of fruit quality, there was a slight tendency to improve the acidity variable with the application of the biostimulant and the rest of the evaluated organoleptic and nutritional variables did not undergo notable alterations even when the highest doses of chitosan were used.

Keywords: bioproduct, biostimulant, quality, vegetable.

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Introduction

The tomato (*Solanum lycopersicum* L.), is the most cultivated and consumed vegetable nationally and internationally (FAOSTAT, 2017). In Ecuador, this crop is of utmost importance, for the basic family basket, with a consumption of 5 kg per capita, which has an increasing trend conditioned by new forms and styles of feeding (SINAGAP, 2013). However, the average yield of the crop, being below its potential, does not meet the demands of the industry or those of fresh consumption (SINAGAP, 2013; FAOSTAT, 2018).

Currently, biological products such as biostimulants are applied to minimize the use of chemicals that cause toxicity to human health and the agroecosystem in general, and in turn improve crop yields, as they contain active ingredients that act on the physiology of plants (Rodríguez *et al*., 2013).

Among these active ingredients is chitosan, reported by various authors with superior economic and biological effects than other traditional products, since it is easy to obtain, does not produce contaminants and is biocompatible with plant and animal tissues (Rodríguez-Pedroso *et al*., 2015; Berumen-Varela *et al*., 2015; González *et al*., 2017).

With the use of chitosan, relevant results have been obtained in grain crops such as rice and beans, in tubers such as potatoes and vegetables such as tomato and cucumber, among the most important, which have registered improvements in various physiological variables related to growth and development accelerating the phenological cycle, advancing flowering and fruiting, as well as exerting a marked influence on the increase in yield from improvement.

In patterns of adaptability to different forms of abiotic and biotic stress, such as increased tolerance to saline and water stress, as well as the activation of defense mechanisms against pathogens and the diseases they can cause (Van-Toan and Thi-Hanh, 2013; Morales-Guevara *et al*., 2015, 2016).

On the other hand, the influence of chitosan on the conservation and improvement of the properties of fruits and vegetables in the harvest and post-harvest period has been highlighted (Escudero *et al*., 2017; Jiang *et al*., 2018; Romanazzi *et al*., 2018; Rendina *et al*., 2019). Being in this way, chitosan can be a product with a positive influence on tomato cultivation.

However, in order to achieve an optimal effect on its growth, development and performance, it is essential to determine the most appropriate dose for the conditions where the experiment was carried out. The objective of this work was to evaluate the effect of increasing doses of chitosan (150, 200, 250 and 300 mg L^{-1}), on the tomato crop.

Materials and methods

General conditions for the development of the experiment

The research was carried out under greenhouse conditions at the Faculty of Livestock Sciences of the Quevedo State Technical University. It is located between 01º 06’ south latitude and 79º 29’ west longitude, at a height of 73 m above sea level. The ecological zone where the experiment was established is classified as Tropical Humid Forest with a humid tropical climate, in which the maximum temperatures are 29.3 °C, the relative humidity is 86%, with rainfall of 1 587.5 mm year^{-1} and a heliophany of 994.4 hours light year^{-1}.

Certified seed of the tomato grower of certain growth Floradade was used. The seedlings for transplantation were obtained from seeds sown in plastic trays with 200 cavities containing soil and organic fertilizer. The management of nutrition, phytotechnics and the phytosanitary measures used were carried out following the methodology described by Ojodeagua-Arredondo *et al*. (2008).

The plants were transplanted 21 days after germination, in 1 kg bags with a mixture of sterile sand and substrate (1:1), at which time the plants presented an average height of between 10 and 15 cm. Two plants were placed in each bag to guarantee the success of the transplant process and once established, one of them was eliminated. After transplanting, the plants were watered daily with 150 mL of water.

Treatments used and experimental design

Five treatments were used that consisted of a control with sterile distilled water and the foliar application of chitosan (formulation composed of chitosan dissolved at 4 g L^{-1}, 0.5% acetic acid and 0.07% potassium) (Morales-Guevara *et al*. 2015), to the plants using concentrations of 150, 200, 250 and 300 mg L^{-1} at 10 days after transplanting and then at the beginning of flowering (25 days after transplanting). The treatments were distributed in a completely randomized experimental design with 4 replications, using 40 pots per treatment, and a total of 200 pots in the investigation.

Evaluations carried out

At 45 days after transplantation, the height of the plants (cm) was evaluated and then to carry out the fruit quality analysis, three plants were used at random from each treatment and total soluble solids (SST) were determined (Rangana, 1977). Acidity, vitamin C, expressed as contraction of ascorbic acid and protein percentage, were determined by the standardized methods of AOAC (1995).

The pH was determined using a pH meter. Nitrogen content was determined by the microKjedhal method, while phosphorus was determined by spectrophotometry. In the case of calcium and magnesium, complexometric volumetry was used and potassium was determined by flame photometry according to established analytical techniques (Paneque *et al*., 2010).

At the time of harvest, the polar and equatorial diameter of the fruits (cm), number of clusters per plant, number of fruits per cluster, diameter of the pericarp, fruit mass, and agricultural yield were estimated (Casierra-Posada *et al*., 2007).

Statistical analysis

The data obtained was processed with the Statistica package for Windows, version 10 (StatSoft, 2011). To determine if they complied with variance homogeneity, the Cochran, Hartley-Bartlet test was performed and to check if they were distributed normally, the Kolmogorov-Smirnov test was performed. A simple classification analysis of variance was performed and for the multiple comparison of means, Tukey's multiple range test with an error of 5% was used.

Results and discussion

The application of chitosan in the tomato plant positively influenced height, increasing its values regardless of the dose used, because the four concentrations (150, 200, 250 and 300 mg L^{-1}) significantly exceeded ($p \leq 0.05$) at control treatment (Figure 1). Thus, the higher concentrations (250 and 300 mg L^{-1}) stimulated the growth of the plants, increasing the height with respect to where the lowest dose was applied (150 mg L^{-1}).

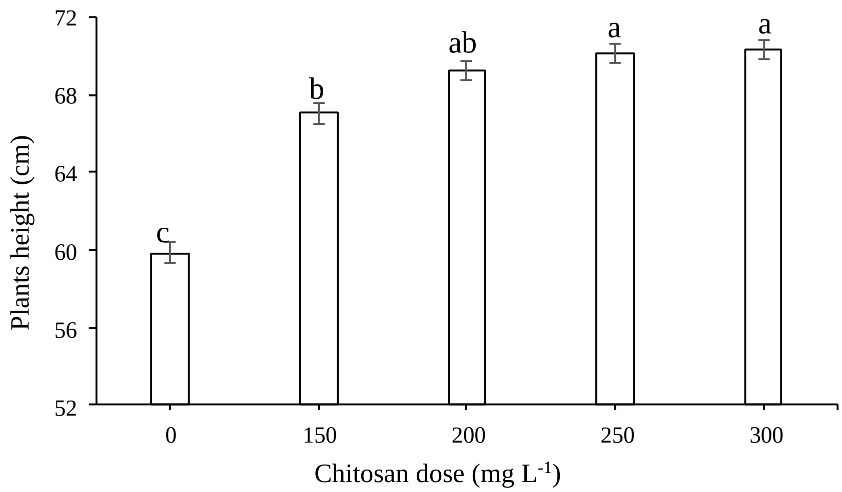

Figure 1. Effect of chitosan on the height of the cultivated tomato cultivar Floradade. Means with different letters on the bars indicate significant differences, according to the Tukey test ($p \leq 0.05$).

The results obtained are similar to those found by Terry-Alfonso *et al*. (2017), who observed that by applying chitosan at the concentration of 1 g L^{-1}, tomato seedlings managed to reach a higher height among all the concentrations applied. However, this same product at the same concentration in the rice crop did not show significant differences with respect to the control (Rodríguez-Pedroso *et al*., 2017), which suggests that the activity of chitosan may vary depending on the characteristics of the species under study.

The doses of chitosan applied also caused significant differences in the components of tomato yield (Table 1). The highest concentrations (200 to 300 mg L^{-1}), in all cases stimulated the evaluated performance components, when compared to the control treatment, even the lowest concentration of chitosan (150 mg L^{-1}) managed to improve significantly ($p \leq 0.05$) the results of the variables, bunches per fruit, polar and equatorial diameter of the fruit, as well as fruit mass, in relation to where chitosan was not applied.

Table 1. Effect of chitosan on the yield components of the cultivated tomato cultivar Floradade.

Chitosan dose (mg L^{-1})	RF	FP	DEF	DPF	DP	MF (g)
			(cm)			
0	8.5 d	35.2 c	4.68 d	3.2 c	0.29 b	90.17 e
150	9.75 c	44.5 c	6.05 c	4.2 b	0.33 b	120.83 d
200	12.9 b	84.8 a	7.02 b	5.06 a	0.46 a	140.9 c
250	14.45 a	69.05 b	7.23 ab	5.07 a	0.49 a	155.1 b
300	15 a	83.6 a	7.38 a	5.18 a	0.5 a	188.48 a
Esx	0.29	2.29	0.11	0.08	0.01	3.63

Different letters in the same column indicate significant differences, according to the Tukey test ($p\leq 0.05$). Esx= standard error of the mean; RF= bunches with fruits; FP= fruits per plant; DEF= equatorial diameter of the fruit; DPF= fruit polar diameter; DP= pericarp diameter; MF= fruit mass.

In the variable fruit mass, the treatment based on 300 mg L^{-1}, was superior with significant differences ($p\leq 0.05$) to the rest of the doses used and the control. Regarding the number of fruits per plant, the treatments of 200 and 300 mg L^{-1} reached the highest values ($p\leq 0.05$), while the control without application and the dose of 150 mg L^{-1} did not differ from each other.

In this sense, Jiménez-Arteaga *et al.* (2015) verified that similar concentrations achieved the highest values of equatorial diameter in tomato cultivation, but in cultivar H-3108 and in conditions of protected cultivation houses, however, they reported an opposite effect for the polar diameter of the fruit, since the lowest concentration achieved the largest diameter in cultivar H-3108.

Some authors have found stimulation of growth and yield with the application of chitosan in different crops such as tobacco, beans and corn (Martínez-González *et al*., 2017; Torres-Rodríguez *et al*., 2018). This response has been attributed to the fact that chitosan stimulates chlorophyll production and photosynthesis in plants (Iriti *et al*., 2009).

This could explain the increase in height and the yield components of the tomato cultivar used in our study. Likewise, Ordookhani and Zare (2011); Kerch (2015) also state that the application of chitosan or its formulations, can improve both external and internal quality of the fruits.

These results were equally evident in our experiment, because the different applied concentrations of chitosan showed different results in the quality parameters of tomato fruits, such as the content of total soluble solids, dry matter, vitamin C, pH and acidity (Table 2).

In the protein content, the tomatoes treated with the dose of 300 mg L^{-1} presented the lowest value with respect to the rest of the treatments and the control, between which there were no significant differences ($p\leq 0.05$). The total soluble solids showed similar results to the protein content, with a higher content when the bioproduct was not applied.

Table 2. Effect of chitosan on the biochemical indicators of the quality of the tomato fruit cultivar Floradade.

Chitosan doses (mg L^{-1})	TSS	P	C	A	DMA	DMAa	pH
	(°Brix)	(g 100 g^{-1} DM)		(%)			
0	5.25 a	16.75 a	8.85 b	0.64 a	85.5 a	6.4 a	4.3 a
150	4.66 b	16.52 a	8.86 b	0.49 b	86 a	6 a	4.3 a
200	4.61 b	16.65 a	8.95 b	0.52 b	86 a	6 a	4.3 a
250	4.68 b	16.45 a	9.54 a	0.42 c	86 a	6.2 a	4.3 a
300	3.35 c	12.25 b	7.85 c	0.55 b	85.5 a	6 a	4.1 a
Esx	0.26	0.31	0.18	0.08	ns	ns	ns

Different letters in the same column indicate significant differences, according to the Tukey test ($p\leq 0.05$). NS= not significant; DM= dry matter; °Brix= degrees Brix; P= protein; TSS= total soluble solids; C= vitamin C; A= acidity; DMA= absolute dry matter; DMAa= air dry matter.

The doses of 150, 200 and 250 mg L^{-1}, presented similar results between them and in turn were higher ($p\leq 0.05$) than the highest dose applied. Tomatoes treated with the 250 mg L^{-1} dose had the highest content of Vitamin C content in the fruits; however, increasing the dose to 300 mg L^{-1} resulted in the lowest content of this variable in relation to the control.

The variables of absolute dry matter, dry matter in air and pH were not influenced by the application of chitosan in any of the doses used because the results obtained in them were similar to the control. It should be noted that in most of the variables evaluated where the highest chitosan concentration was applied, the lowest values were obtained, except for the percentage of acidity.

Furthermore, in this last variable, the control treatment was more acidic than the rest of the treatments, while with the application of 250 mg L^{-1} of chitosan, there was a decrease in the percentage of acidity. The results obtained can be attributed to the fact that chitosan, in addition to having a biostimulant action on the growth of plants and fruits, also has an eliciting activity, which increases the synthesis of enzymes and defensive metabolites, at the expense of the energy reserves of the plants (Malerba and Cerana, 2016).

This fact could lead to a decrease in the contents of total soluble solids and vitamin C; starting from a certain concentration of chitosan that according to the results found in this investigation would be 300 mg L^{-1}. However, Reyes-Pérez *et al*. (2018) obtained different results in tomato cultivation, demonstrating that the foliar application of chitosan at concentrations of 300 and 400 mg L^{-1} produced the highest amounts of total soluble solids.

Regarding the mineral content in plants, the application of the biostimulant did not exert a marked influence on any of the evaluated elements, only a slight tendency to decrease was observed when the highest dose (300 mg L^{-1}) was used without significant differences in relation to the rest of the treatments, including the control (Table 3).

Table 3. Effect of chitosan on the mineral content in the fruit of the cultivar Floradade tomato.

Chitosan doses (mg L^{-1})	N (%)	P	K^+	Ca^{2+}	Mg^{2+}
		(mg 100 mg^{-1} DM)			
0	2.73 a	0.35 a	3.45 a	0.38 a	0.22 a
150	2.58 a	0.34 a	3.52 a	0.43 a	0.23 a
200	2.57a	0.27 a	3.43 a	0.37 a	0.25 a
250	2.76 a	0.31 a	3.36 a	0.45 a	0.26 a
300	2.35 a	0.24 a	3.1 a	0.25 a	0.17 a
Esx	ns	ns	ns	ns	ns

Different letters in the same column indicate significant differences, according to the Tukey test ($p \leq 0.05$). ns= not significant; N= nitrogen; P= phosphorus; K^+= potassium; Ca^{2+}= calcium; Mg^{2+}= magnesium.

This expression could be linked to what was previously explained in relation to the fact that the stimulation of biochemical, molecular and physiological processes, which are closely related to the growth, development, defense of plants and even crop performance, act to the detriment of those who They are related to the biochemistry of the fruit and the concentration of nutrients, therefore, there are no significant changes with the application of chitosan (Malerba and Cerana, 2016).

However, these results do not coincide with those obtained by Salachna and Zawadzińska, (2014), who found in the varieties used that the applied chitosan concentration influences the increase in nutrient uptake by plant roots and stimulates the biosynthesis of nutrients and defense mechanisms from the biostimulant effect on plants.

Conclusions

The best results in the variables plant height and yield components were obtained when applying the concentration of 300 mg/L of chitosan. The biochemical indicators of tomato fruit quality and its mineral content did not show differences with the application of chitosan.

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