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**Original article**

# Effect of a chitosan polymers mixture in tomato plants (*Solanum lycopersicom* L.)

## Efecto de una mezcla de polímeros de quitosano en plantas de tomate (*Solanum lycopersicom* L.)

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**ABSTRACT:** In order to evaluate the effect of a chitosan polymers mixture in tomato plants (*Solanum lycopersicum* L.), the present work was carried out in which different doses and moments biostimulant application were used. To do this, Amalia variety seeds sown in seed beds and later transplanted in the field at a distance of 0.25 m between plants and 1.20 m between rows were used. Polymers mixture of chitosan applications were made at two moments of the crop cycle, seven-eight days after transplantation and at the beginning off lowering, using the doses of 200, 400 and 600 mg ha$^{-1}$ in each of the moments mentioned above, there were also three treatments in which the previous doses were applied in equal parts in the two moments studied, and a control without bioestimulant made room for ten treatments. The length and diameter stem, dry mass of the aerial part, leaf surface, average number of fruits and fruit mass, and the yield per plant were evaluated. From the results obtained, it was possible to conclude that the polymers mixture of chitosan application in the start period of the flowering, increased the accumulation of dry matter, the leaf surface, the formation of a bigger fruits number and yield of tomato plants.

**Key words:** biostimulant, growth, yield, leaf surface.

**RESUMEN:** Con el objetivo de evaluar el efecto de una mezcla de polímeros de quitosano en plantas de tomate (*Solanum lycopersicom* L.), se realizó el presente trabajo en el que se utilizaron diferentes dosis y momentos de aplicación del bioestimulante. Se emplearon semillas del cultivar Amalia sembradas en semilleros y, posteriormente, trasplantadas en el campo a una distancia de 0,25 m entre plantas y a 1,20 m entre hileras. Las aplicaciones de quitosano se realizaron en tres momentos del ciclo del cultivo, a los siete-ocho días posteriores al trasplante, al inicio de la floración y la combinación de ambos momentos, con la mitad de las dosis totales en cada momento. Las dosis utilizadas fueron 200, 400 y 600 mg ha$^{-1}$ y un control sin bioestimulante, lo que dio lugar a diez tratamientos. Se evaluaron: la longitud y el diámetro de los tallos; la masa seca de la parte aérea; la superficie foliar; el número de frutos por planta; la masa fresca de los frutos y el rendimiento por planta. La aplicación de una mezcla de polímeros de quitosano en el período de inicio de la floración incrementó la acumulación de materia seca, la superficie foliar, la formación de mayor número de frutos y el rendimiento de las plantas.

**Palabras clave:** bioestimulantes, crecimiento, rendimiento, superficie foliar.

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## INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an annual herbaceous plant grown both in open field and protected conditions (1). It is one of the most important and popular vegetables worldwide, due to its high yield potential and adequate adaptability to the environment, being China, India, Turkey and the United States the main producers (2).

In Cuba, it represents 50 % of the total area dedicated to vegetables and the production oscillates around 750 000 t; however, yields registered in several productive areas of the country are low, due, among some causes, to the unfavorable edaphoclimatic conditions that prevail, the lack of inputs and the scarcity of alternatives to guarantee crop demands (3).

The search for new alternatives that allow a more rational use of resources, reduce production costs without affecting crop quality and yields, has led to the use of growth biostimulants for agricultural use (4).

The use of natural biostimulants for agriculture has been considered as a safe alternative due to its significant results, especially facing the rising cost of agricultural production and sustainability challenges, guaranteeing high yields without affecting quality (5).

Chitosan is a natural biostimulant that has been extensively studied in many plant species, including cereals, ornamentals, fruit and medicinal crops. The responses have been very diverse, depending on the structure and concentration of the molecules used, the spices and the plant development stage (6).

Several studies have been carried out using chitosan for different purposes, and some examples with very favorable results can be mentioned, such as those related to food preservation (7). The preservation of fruits stored in cold storage, in which no modifications have been found in their biochemical composition and antioxidant activity (8); in the coating of fruits for their preservation [9] ; in the induction of plant defense mechanisms against diseases (10); in the treatment of seeds to obtain seedlings (11) and in foliar applications to reduce the incidence of physio-pathologies in fruits, which also caused an increase in their antioxidant activity (12), among others.

The need to use technologies that allow increasing agricultural productions, through the use of techniques and products that do not harm the environment and do not affect people's health, the present work was carried out with the objective of evaluating the effect of a mixture of chitosan polymers in tomato plants (*Solanum lycopersicom* L.).

## MATERIALS AND METHODS

The study was carried out at the experimental farm of the National Institute of Agricultural Sciences (INCA), in a compacted Ferrallitic red eutrophic soil (13). Seeds of Amalia variety were planted at a distance of 0.25 m between plants and 1.20 m between rows.

Three doses of a mixture of chitosan polymers (Quitomax®) were applied at three different times during crop development. Treatments evaluated were:

- Control with no product application
- 200 mg $ha^{-1}$ at 7-8 days after transplanting
- 400 mg $ha^{-1}$ at 7-8 days after transplanting
- 600 mg $ha^{-1}$ at 7-8 days after transplanting
- 200 mg $ha^{-1}$ at the beginning of flowering
- 400 mg $ha^{-1}$ at the beginning of flowering
- 600 mg $ha^{-1}$ at the beginning of flowering
- 100 mg $ha^{-1}$ at 7-8 days and 100 mg $ha^{-1}$ at the onset of flowering
- 200 mg $ha^{-1}$ at 7-8 days and 200 mg $ha^{-1}$ at the start of flowering
- 300 mg $ha^{-1}$ at 7-8 days and 300 mg $ha^{-1}$ at the beginning of flowering

The different treatments were distributed in the field according to a randomized block design with four replications. The plots consisted of ten 10 m long furrows. For the evaluations, 10 plants per plot were randomly selected, which resulted in a sample of 40 plants per treatment.

The data presented correspond to two-year averages.

At 20 days after the last application, length and stem thickness variables were evaluated; the dry mass of the aerial part and leaf area per plant and at harvest time, the number of fruits per plant; the fresh mass of the fruits and the yield was estimated on the basis of the fresh mass.

Cultural and phytosanitary work was carried out according to the technical guidelines for tomato cultivation.

The efficiency of the biostimulant on the number of fruits, fruit fresh mass, leaf area and yield per plant was estimated as the increase in percent of the values reached by the variable in each treatment with respect to the value shown by the control (14).

The SPSS 19.0 statistical program for Windows was used to process the data, the means were compared using Tukey's multiple range test and the SIGMA PLOT 11.0 program was used to plot the results.

## RESULTS AND DISCUSSION

The statistical analysis of the different indicators evaluated showed no interaction between the factors under study.

Table 1 shows the analysis of the different growth variables evaluated.

When analyzing the response of treated plants at different times of their biological cycle, it was found that the product slightly favored growth in stem length, with differences between the treated plants and the control, while stem diameter showed no differences between the plants treated with the product and those not treated.

The response shown by plants in terms of stem length and diameter behavior seems to be characteristic of the plants, at least when using low doses such as those used in this work, results of the product at the beginning of flowering, with respect to the application after transplanting and the control.

**Table 1.** Effect of a chitosan polymer mixture on stem length and thickness (cm), aerial part dry mass (g), and leaf area ($cm^2$ ) of tomato plants

| Treatments | Stem length | Stem thickness | Aerial dry mass | Leaf area |
|---|---|---|---|---|
| **Timing** | | | | |
| Control without application | 53.06 b | 0.95 | 6.13 d | 1480.15 d |
| At 7-8 days post-transplanting | 55.63 a | 0.92 | 6.77 c | 1693.38 c |
| At the beginning of flowering | 56.19 a | 0.93 | 7.06 b | 1722.13 b |
| At 7-8 days after transplanting and at the beginning of flowering | 56.29 a | 0.94 | 7.68 a | 1978.95 a |
| Se: | 0.733* | 0.019 | 0.062** | 29.40** |
| **Dose** | | | | |
| Control without application | 53.06 b | 0.95 | 6.13 b | 1480.15 b |
| 200 mg $ha^{-1}$ | 55.83 a | 0.91 | 7.16 a | 1768.52 a |
| 400 mg $ha^{-1}$ | 56.08 a | 0.95 | 7.16 a | 1810.65 a |
| 600 mg $ha^{-1}$ | 56.19 a | 0.93 | 7.19 a | 1815.28 a |
| Se | 0.733* | 0.019 | 0.125* | 46.92* |

These results are in agreement with those reported in potato (*Solanum tuberosum* L.) and bean (*Phaseolus vulgaris* L.) crops (15,16).

On the other hand, the behavior analysis of dry matter accumulation in the aerial part and leaf area did show highly significant differences among all treatments, with the best results in those that received the product at the beginning of flowering, with respect to the application after transplanting and the control.

The behavior of the leaf surface may be associated with the emission of a greater number of leaves, an aspect that has been pointed out by other authors, since they found a similar response when they made several foliar applications of this product (17,18).

This similar behavior manifested by the dry mass of the aerial part and the foliar surface, can be explained by the greater photosynthetic capacity of plants with greater foliar surface, since it is in the leaves where the receptor centers capable of capturing the light that makes possible the photosynthetic process, which gives rise to the accumulation of dry matter in the different organs of plants.

In this regard, it has been suggested that the behavior of the leaf surface allows determining the plant nutritional status, its growth, the capacity to absorb carbon, the transpiration rate, and the efficient use of water and the conversion of photoassimilates (19).

The response shown by plants when the biostimulant was applied at the beginning of flowering confirms what was planted in relation to the fact that the response of plants is related, among other aspects, with the moment in which the application of chitosan is done (5).

Other authors have reported an increase in vegetative growth as a response to the foliar application of chitosan (20), as well as in the quality of tomato seedlings, with seed treatments before sowing (11).

Interestingly, plants responded in the same way with the different doses of the product applied, with no difference between them, although they showed a positive effect with respect to untreated plants.

This response suggests that only a small dose of these polymers is sufficient to transmit the signal that triggers the growth process and perhaps some others that have not been evaluated in this work.

Figure 1 shows the variables fruit number and mass as the main components that determine the yield of tomato plants.

It was found that the number of fruits was the variable that most influenced yield increase.

In both variables, the treatments that were sprayed with the biostimulant showed higher values than the control treatment (without biostimulant). It was also observed that fruit mass did not show differences between the treatments in which the biostimulant was applied, both between the times when it was applied and between the doses used.

In the case of the number of fruits, it was possible to distinguish a significant increase in them, according to the moment in which the biostimulant was applied, with the highest values when the applications coincided with the beginning of flowering; while, the doses used only showed superiority with respect to the plants that were not treated with the biostimulant.

The spraying of the biostimulant at the beginning of flowering seems to indicate that its addition at that moment triggers a series of physiological and biochemical events that contributed to the increase in the number of fruits, which indicates that this component is the one that had the greatest influence on the increase in plant yield.

A quite frequent characteristic when phytohormones are applied is that the perception of environmental signals by plants can be inductive; that is, they are produced even when the stimulus-signal has disappeared or has a systemic character.

This behavior leads to suggest that the response is mediated by some substances synthesized in small quantities, by the secondary metabolism of some cells/ tissues that can act in other parts of the plant (21).

In this regard, in studies carried out with other crops, it has been reported a greater growth of plants expressed by the greater number of leaves and a greater quantity of fruits per plant, which led to an increase in yields; besides, it was pointed out that this increase in yield did not imply alterations in the content of chlorophylls, nor in the quality of fruits (20).

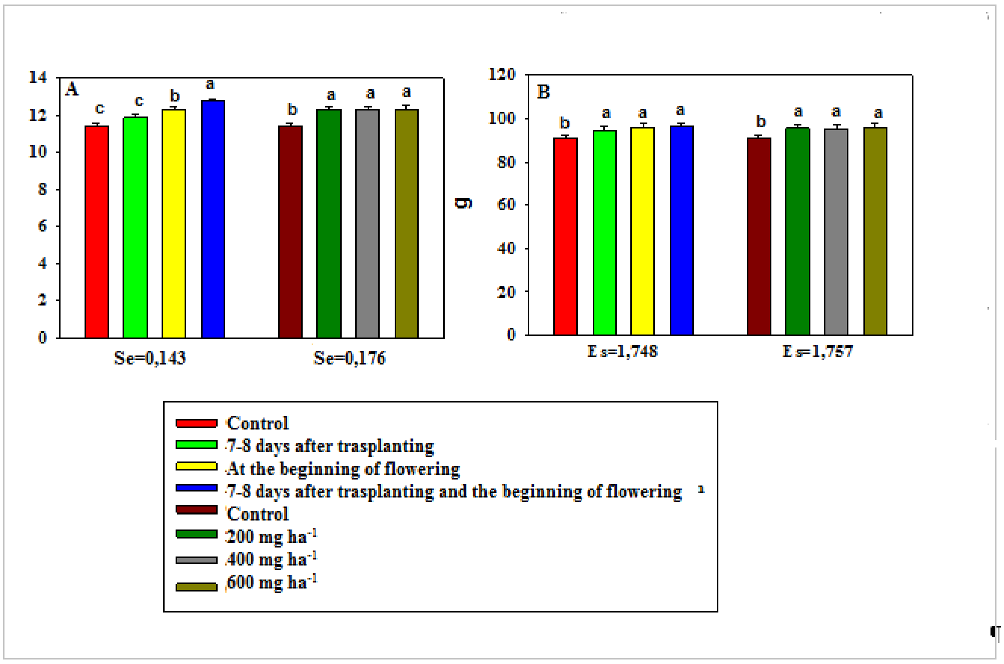


**Figure 1.** Effect of a mixture of chitosan polymers on the number (A) and mass of fruits (B) of tomato plants

Figure 2 shows the effect of a mixture of chitosan polymers on the average yield per plant. The behavior was concordant with that of the yield components analyzed.

It was detected that the plants of all treatments that received the application of the biostimulant showed higher and significant values, in relation to the untreated plants.

Plants that received the product significantly increased their yield compared to those that were not treated with the biostimulant.

It was also observed that there was no differentiated response among the plants treated with the different doses used, which indicated that large doses of these polymers are not required to transmit the necessary impulse to trigger the physiological and biochemical processes that give rise to the different manifestations of plants.

The behavior analysis of plants when sprayed with the mixture of these polymers, at different moments of their biological cycle, showed a highly significant increase among them, with a more outstanding response when applications were made at the beginning of flowering, which indicated that the addition of the biostimulant at this moment of the development of plants acts on the genetic-physiological characteristics that determine the response of this variable.

When evaluating the response of this variable, it was possible to demonstrate that its behavior is determined by the greater number of fruits per plant, results that agree with those obtained in other crops (5,22) and that have also been found when comparing the response of the tomato crop to the addition of the biostimulant, through foliar sprays in different moments of plant development (23).

The analysis of the efficiency of the product (Table 2) in the variables number of fruits, fresh fruit mass, leaf area and plant yield (14) showed the highest efficiency in yield and leaf area, mainly when the product was applied at different times of the biological cycle of plants, with increases that varied between 10 and 25 % of leaf area and 14-34 % of yield.

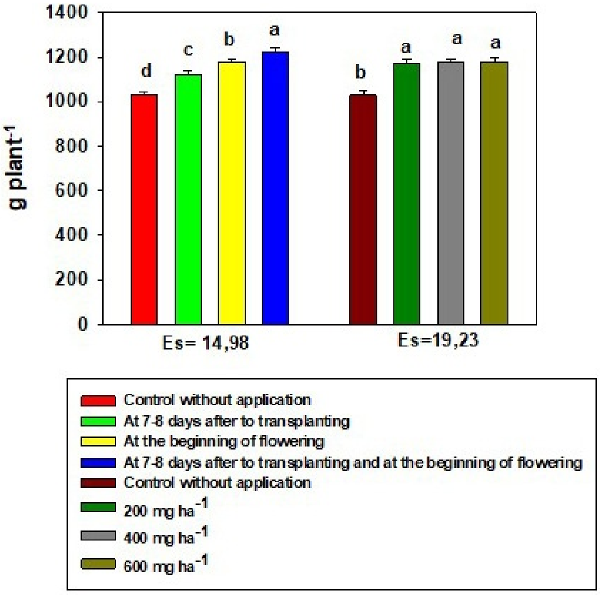


**Figure 2.** Effect of a mixture of chitosan polymers on the estimated yield (g plant-1) of tomato plants

On the other hand, when analyzing the behavior of this variable according to the doses of biostimulant applied, it was possible to verify the beneficial effect of the product in the formation of a greater leaf area and yield, although the differences in both variables were not very different between them.

Similarly, very little effect of the factors studied on the increase in the number of fruits per plant was observed, while fruit mass was not favored in any of the variants studied.

**Table 2.** Effect of a mixture of chitosan polymers on efficiency (%) on fruit number and mass, leaf area and yield of tomato plants

| Treatments | Number of fruits | Mass of fruits | Leaf area | Yield |
|---|---|---|---|---|
| **Timing** | | | | |
| At 7-8 days after transplanting | 5 | -3 | 10 | 14 |
| At the beginning of flowering | 6 | -2 | 15 | 16 |
| At 7-8 days after transplanting and at the beginning of flowering | 6 | -1 | 25 | 34 |
| **Dose** | | | | |
| 200 mg $ha^{-1}$ | 5 | -4 | 17 | 19 |
| 400 mg $ha^{-1}$ | 6 | 0 | 17 | 22 |
| 600 mg $ha^{-1}$ | 6 | -2 | 17 | 23 |

## CONCLUSIONS

- From the results found, it can be concluded that the application of a mixture of chitosan polymers, at the beginning of flowering, favors the accumulation of dry matter, leaf area, the formation of a greater number of fruits and the yield of tomato plants, which allows suggesting that the application of this biostimulant be done at the beginning of flowering.
- I sincerely thank the referee for the suggestions made (marked in red), which I consider help to make the wording more flexible in different paragraphs, many thanks.

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