Ciencia e Investigación AGRARIA

Cien. Inv. Agr. 46(1):23-29. 2019
www.rcia.uc.cl

FOOD TECHNOLOGY

DOI 10.7764/rcia.v46i1.2002

RESEARCH NOTE

Evaluation of the growth, yield and nutritional quality of pepper fruit with the application of Quitomax®

Juan José Reyes-Pérez[1,2], Emmanuel Alexander Enríquez-Acosta[2], Miguel Ángel Ramírez-Arrebato[4], Aida Tania Rodríguez-Pedroso[4], Liliana Lara-Capistrán[5], and Luis Guillermo Hernández-Montiel[3]

[1]Universidad Técnica Estatal de Quevedo. Av. Walter Andrade. Km 1.5 vía a Santo Domingo. Quevedo, Los Ríos, Ecuador.

[2]Universidad Técnica de Cotopaxi. Extensión La Maná. Av. Los Almendros y Pujilí, Edificio Universitario, La Maná, Ecuador.

[3]Centro de Investigaciones Biológicas del Noroeste S.C., Instituto Politécnico Nacional No. 195, Colonia Playa Palo de Santa Rita Sur, La Paz, Baja California Sur, México.

[4]Unidad Científico Tecnológica de Base los Palacios, Pinar del Río perteneciente al Instituto Nacional de Ciencias Agrícolas (INCA), Cuba.

[5]Universidad Veracruzana Campus Xalapa. Facultad de Ciencias Agrícolas. Circuito Universitario Gonzalo Aguirre Beltrán s/n, Zona Universitaria. Xalapa, Veracruz, México.

Abstract

J.J. Reyes-Pérez, E.A. Enríquez-Acosta, M.A. Ramírez-Arrebato, A.T. Rodríguez-Pedroso, L. Lara-Capistrán, and L.G. Hernández-Montiel. 2019. Evaluation of the growth, yield and nutritional quality of pepper fruit with the application of Quitomax®. Cien. Inv. Agr. 46(1): 23-29. The consumption of vegetables as a source of vital nutrients is very important for human health. In the present work, the effects of the application of several concentrations of Quitomax® and a control treatment on the growth, yield and nutritional value of bell pepper (*Capsicum annuum* L. variety Lical) fruit were evaluated. The treatments consisted of the foliar application of Quitomax® at 200, 300 and 400 mg ha^{-1} 20 days after transplantation. A randomized block design with four replicates per treatment was applied. The number of fruit harvested as well as their length and width, the fresh mass of the fruit, the thicknesses of the mesocarps, the mass of the peduncles with seeds, the yield, the nutritional quality including the soluble solid, vitamin C, carotenoid, and polyphenol content and the antioxidant activity of the fruit were evaluated. Quitomax at a concentration of 300 mg ha^{-1} produced significantly more pepper fruit with the largest dimensions and highest fruit mass, yield and antioxidant activity than all other treatments. Therefore, Quitomax can be used as a promissory stimulant for bell pepper crops.

Key words: Antioxidant activity, *Capsicum annum L.,* chitosan.

Introduction

The pepper (*Capsicum annuum* L.) is a vegetable that stands out for its vitamin and antioxidant content that is a highly recommended food for human health (Matsufuji *et al.,* 2007). Worldwide, 34497462 tons of peppers are produced and cultivated on 1 938788 hectares of planted land (FAO, 2018).

However, most peppers are produced with the intensive application of chemical products that are harmful to human health and the environ-

Received Jul 26, 2018. Accepted Mar 04, 2019.
Corresponding author: lhernandez@cibnor.mx

ment, and the use of these products increases every year (Reyes and Cortéz, 2017). This has led to the continuous search for new methods of production that are healthy and environmentally friendly (Márquez *et al.,* 2013).

Among the most used alternative methods is the application of organic fertilizers (Reyes-Pérez *et al.,* 2018), beneficial microorganisms such as mycorrhizae (Rosales *et al*., 2017) and bioactive products such as chitosan (Hadwiger, 2013). Chitosan is the N-deacetylated derivative of chitin and the second most abundant polysaccharide in nature.

Chitosan stimulates plant growth and the production of enzymes and secondary metabolites when applied to plants (Malerba and Cerana, 2016) or used to treat fruit (Bautista *et al.,* 2016) and increases the level of antioxidant compounds in the pepper fruit. However, most research does not take into account how its application to crops in preharvest affects the nutritional quality of the fruit.

Because the most used method to treat plants with chitosan is its foliar application, the objective of this work was to evaluate the foliar application of different concentrations of Quitomax on the growth, yield and nutritional quality of peppers.

Materials and Methods

The research was carried out at the Experimental Center "La Playita" of the Technical University of Cotopaxi, La Maná Ext., in the province of Cotopaxi, WGS 84: 0°56'27"S 79°13'25"W, in Ecuador. The climatic conditions include a maximum temperature of 23 ºC and a minimum temperature of 17 ºC with an annual average precipitation of 3029 mm.

To obtain the pepper seedlings, seeds of the Lical variety were planted in 200-well polyethylene trays that contained Sogemix MR substrate provided by Premier Horticulture Ltd., Dorval, Quebec, Canada. Irrigation was carried out daily, and one week after emergence, the plants were placed under shaded mesh to guarantee a homogeneous population. The pepper plants were transplanted into 1 kg pots containing a substrate mixture of disinfected coarse stream sand and the commercial Sogemix MR substrate in a 1:1 ratio at 25 days of age when they contained at least 10 real leaves and were at least 20 cm tall. One plant was placed in each pot, and daily watering was carried out at 80-90% of field capacity. One week after transplantation, the treatments were applied. The treatments consisted of a control, which involved the application of distilled water, and three treatment with a unique foliar spray of Quitomax® at 200, 300 and 400 mg ha^{-1} The Quitomax was obtained from the National Institute of Agricultural Sciences of Cuba to be used as a biostimulant with chitosan at a concentration of 4 g L^{-1}. Harvesting was carried out 50 days after transplantation when the color of the fruit changed from bright green to dark green. The number of harvested pepper fruit as well as their length and widths were measured with millimeter tape. In addition, the fresh mass of the fruit and mass of the stems with seeds were evaluated by weighing on a Sartorius semianalytical balance with a 0.01 g error. The thickness of the mesocarp was also measured with a Vernier caliper, and the yield of the plants was determined by extrapolation of the area of the bags to t ha^{-1}. Bags with plants were set in a plantation frame of 0.90 × 0.30 m with a plant density of 4 plants m^{-2}.

Additionally, the nutritional quality of the fruit was evaluated by determining the soluble solid content by the refractometric method, the vitamin C content by the phenol indophenol method, the carotenoid and polyphenol content by spectrophotometric methods and the antioxidant activity of the fruit.

Completely randomized blocks with four replicates per treatment were used as the experimental design. The data was processed by analysis of variance, and the means were compared by the Tukey test (P≤0.05). For statistical analyses, the Statistica v. 10.0 for Windows program was used (StatSoft, Inc., 2011).

Results and Discussion

Quitomax applied to the pepper plants at any of the concentrations used caused significant differences in the number of fruit produced and their dimensions (length and diameter of the fruit) between treatments (Table 1).

With all the Quitomax treatments, the resulting plants produced significantly more fruit as well as fruit with significantly greater lengths and diameters than those produced following the control treatment. When the concentration of Quitomax was increased from 200 to 300 mg ha^{-1}, the number and dimensions of the fruit increased. However, when the concentration of Quitomax was increased from 300 to 400 mg ha^{-1}, these indicators decreased significantly. Based on the data, 300 mg ha^{-1} Quitomax was the best treatment. Therefore, because all treatments used similar experimental conditions, Quitomax stimulated bell pepper var Lical fruit. It is interesting to note that Quitomax was applied to the plant leaves but affected fruit size. Therefore, this suggests that chitosan provoked a long-lasting effect on the plants' physiology. It has been suggested that its effect is related to an increase in chlorophyll content in plants due to the influence of chitosan on the metabolism of polyamines (Irriti *et al*., 2009) as well as an increase in enzymatic mechanisms in plants and fruit (Gutiérrez-Martínez *et al.,* 2017). Some authors (Pichyangkuraa and Chadchawanb 2015; Pham *et al.,* 2017) have found that the foliar application of chitosan, even chitosan at different molecular masses, promoted the growth and yield of chilies. Additionally, Quitomax promoted plant growth in crops as dissimilar to peppers as rice (Rodríguez *et al.,* 2017), potatoes and beans (Morales *et al.,* 2015, Morales *et al.,* 2016).) However, in addition to its promotion of plant growth, it also stimulates defense mechanisms in plants against biotic and abiotic stresses (Hadwiger, 2013), especially when applied in a more concentrated solution. These defense mechanisms involve biochemical and physiological processes that consume energy and plant photoassimilates (Rodríguez *et al.,* 2007). This could be attributed the decrease in the number of fruit and their dimensions when the concentration of Quitomax was increased from 300 to 400 mg ha^{-1}. Therefore, less energy and fewer photoassimilates can be used for plant growth.

Additionally, treatment with Quitomax at any concentration resulted in significantly greater fresh fruit masses, thicker mesocarps and greater masses of the peduncles with more seeds than those in the control fruit (Table 2). Foliar chitosan application in pepper plants also increased fruit quality indicators such as the mass of the fresh fruit and the thicknesses of the mesocarps. These attributes are very important for the commercialization of peppers.

Table 1. Number, length and width of pepper fruit treated with Quitomax.

Quitomax Treatment (mg ha^{-1})	Number of fruit	Length of the fruit (cm)	Diameter of the fruit (mm)
Control	11.9d	3.20d	4.24d
200	13.5c	3.62c	5.40b
300	18.7a	4.20a	6.80a
400	16.0b	3.80b	5.16b
SE	0.20	0.04	0.19

*Averages with the same letters do not show a significant difference (P≤0, 05) according to the Tukey test.

Table 2. Fresh fruit mass, thickness of the mesocarp, mass of the peduncles with seeds and yield of pepper plants treated with Quitomax.

Quitomax Treatment (mg ha^{-1})	Fresh mass of the fruit (g)	Thickness of the mesocarp (mm)	Peduncle mass with seeds (g)	Yield (t ha^{-1})
Control	46.5d	3.31d	7.70d	15.0c
200	52.5c	3.73c	9.19b	17.0c
300	81.3a	4.19a	11.0a	24.0a
400	65.5b	3.88b	8.74c	21.5b
SE	0.46	0.02	0.03	0.92

*Averages with the same letters do not show a significant difference (P≤0, 05) according to the Tukey test.

However, in terms of the agricultural yield, only 300 and 400 mg ha^{-1} Quitomax treatments were superior to the control treatment, with 300 mg ha^{-1} Quitomax on 24 (t ha^{-1}) the best treatment, as found previously in terms of the number and dimensions of the fruit.

Quitomax at a concentration of 300 mg ha^{-1} was the best treatment to achieve a greater yield of pepper fruit of agricultural quality. However, this concentration was higher than the 150 and 200 mg ha^{-1} concentrations that produced the highest yields of potatoes and beans, respectively (Morales *et al.,* 2015; Morales *et al.,* 2016), which indicates that there are differences in the best concentration of Quitomax for each crop.

Some authors (Saavedra *et al*., 2016) have also found an improvement in the agricultural quality of strawberry fruits with the preharvest foliar application of chitosan, which is similar for pepper and could be used in other crops (Wang *et al*., 2015) . Based on these data, 300 mg ha^{-1} Quitomax is the treatment of choice to achieve a greater yield of peppers and fruit with better characteristics for commercialization.

These results are attributed to the fact that 200 mg L^{-1} Quitomax did not sufficiently stimulate the metabolism of the plants, so no differences were found between this treatment and the control, while 400 mg L^{-1} Quitomax, as indicated above, induced defense processes in the plant that diverted part of the nutritive reserves dedicated to plant development.

In addition, treatment with the different Quitomax concentrations also influenced the nutritional quality of the pepper fruit (Table 3).

The treatments that included Quitomax at any of the concentrations tested produced significantly higher soluble solid, vitamin C, carotenoid, and polyphenol content and antioxidant activity in the fruit than the control treatment, but differences were also observed between treatments with different concentrations of applied Quitomax. In all of the variables evaluated, treatment with

Table 3. Soluble solid, vitamin C, and carotenoid content and antioxidant activity of pepper fruit treated with Quitomax.

Quitomax Treatment (mg ha^{-1})	Soluble solids (%)	Vitamin C (g)	Carotenoids	Polyphenols	Antioxidant Activity
Control	46.5d	3.31d	7.70d	316d	1.40d
200	52.5c	3.73c	9.19b	348b	1.47b
300	81.3a	4.19a	11.0a	381a	1.58a
400	65.5b	3.88b	8.74c	329c	1.44c
SE	0.46	0.02	0.03	4.8	0.01

*Averages with the same letters do not show a significant difference (P≤0,05) according to the Tukey test.

300 mg ha^{-1} Quitomax was superior to the other treatment concentrations. It should be noted that this concentration was also the best for the growth, yield and agricultural quality of the pepper fruit.

Regarding the other concentrations of Quitomax, 400 mg ha^{-1} Quitomax treatment resulted in higher soluble solid and vitamin C contents and lower polyphenol and carotene content and antioxidant activity than 200 mg ha^{-1} Quitomax treatment. This result could be attributed to the induction of antistress mechanisms in the plants by a concentration of 400 mg ha^{-1} Quitomax that are transmitted to the fruit that usually involve the production of enzymes and metabolites (Gutiérrez-Martínez *et al.,* 2015; Romanazzi *et al.,* 2017) such as proline and oxidative actions; this could reduce the antioxidant activity and the biostimulant effect of Quitomax, but these effects were not evaluated in this work

In any case, the fact that the application of Quitomax at any of the concentrations used increased the soluble solid content and the antioxidant power of the fruit demonstrates improvement in the nutritional quality of this agricultural product. Among the main functions of vegetable consumption, vegetables such as pepper contribute antioxidant substances such as vitamin C, carotenes or polyphenols to humans. These substances eliminate or neutralize oxidants that occurs in vital processes such as photosynthesis or respiration. These oxidants, such as reactive oxygen species, can damage or even kill cells and cause cerebrovascular or neurodegenerative diseases such as atherosclerosis, Alzheimer's disease or cancer. Antioxidants such as vitamin C, carotenes and polyphenols prevent this damage and preserve health (Wintergerst *et al.,* 2006).

The main conclusions are the following. Quitomax at a 300 mg ha^{-1} concentration produced significantly more pepper fruit with the largest lengths and diameters than the other treatments. Treatment with Quitomax at 300 and 400 mg ha^{-1} produced significantly higher fruit biomasses and a greater agricultural yield than the control treatment, and the best treatment concentration was 300 mg ha^{-1}. All treatments in which Quitomax was applied showed increased indicators of the nutritional quality of the fruit compared to those of fruit from the control treatment, and a concentration of 300 mg ha^{-1} was the best.

Acknowledgements

We acknowledge the Technical State University of Quevedo for the support granted through the Competitive Fund for Scientific and Technological Research (FOCICYT) 6th Call through the project "Evaluation of Chitosan derivatives in the sustainable production of vegetables in organic farming system".

Resumen

J.J. Reyes-Pérez, E.A. Enríquez-Acosta, M.A. Ramírez-Arrebato, A.T. Rodríguez-Pedroso, L. Lara-Capistrán, y L.G. Hernández-Montiel. 2019. Evaluación del crecimiento, rendimiento y calidad nutricional de pimiento con aplicación de **Quitomax®. Cien. Inv. Agr. 46(1): 23-29.** El consumo de vegetales como fuente de vital de nutrientes es muy importante para la salud humana. En el presente trabajo se evaluaron la aplicación de varias concentraciones de Quitomax® y un tratamiento control sobre variables del crecimiento, rendimiento y valor nutricional de frutos de pimiento variedad Lical. Las plantas se obtuvieron de semillas sembradas en charolas de polietilenos y a los 25 días de edad se trasplantaron a bolsas de 1 kg conteniendo como sustrato Sogemix y arena. Los tratamientos consistieron en la aplicación foliar de Quitomax® a 200, 300 y 400 mg·ha^{-1} a los 20 días después del trasplante. Se aplicó un diseño de bloques al azar con cuatro réplicas por tratamientos. Las evaluaciones realizadas fueron: el número de frutos o cosechados así como su largo y ancho, también masa fresca de los frutos, grosores de los mesocarpios y masas de los pedúnculos con semillas además del rendimiento y los variables de calidad nutricional contenidos de sólidos solubles, vitamina C, carotenoides, polifenoles y actividad antioxidante de los frutos. Los resultados mostraron que la concentración de Quitomax a 300 mg ha^{-1} produjo significativamente el mayor número de frutos de pimiento con las mayores dimensiones, mayores masas de frutos, rendimiento y actividad antioxidante de todos los tratamientos. Por lo tanto, Quitomax pudiera ser usado como un estimulante promisorio en el cultivo del pimiento

Palabras clave: Actividad antioxidante, *Capsicum annum,* quitosana.

References

Bautista, S., G. Romanazzi, A. Aparicio. 2016. Chitosan in the Preservation of Agricultural Commodities, Ed. Bautista-Baños, S. Romanazzi, G. Jimenez, A. Oxford: Academic Press, 366 pp.

FAO .2018. FAOSTAT Anuario estadístico de la FAO 2017. http://www.fao.org/faostat/es/#data/QC (accesed 28 May 2018).

Gutiérrez-Martínez, P., R.C. Ávila-Peña, D. Sivakumar and S. Bautista-Baños. 2015. Postharvest evaluation of banana fruit cv. FHIA-01 to different storage temperatures followed by an acclimation period. Fruits 70(3):173–179. doi: 10.1051/fruits/2015008.

Gutiérrez-Martínez, P., S. Bautista-Baños, G. Berúmen-Varela, A. Ramos-Guerrero, and A. M. Hernández-Ibañez. 2017. Response in vitro of Colletotrichum to chitosan. Effect on incidence and quality on tropical fruit. Enzymatic expression in mango. Acta Agron. 66(2):282–289.

Hadwiger, L. 2013. Multiple effects of chitosan on plant systems: Solid science or hype. Plant Science 28:42–49.

Irriti, M., V. Picchi., M. Rossoni., S. Gomarasca., N.Ludwing., M.Garganoand., and F.Faoro. 2009. Chitosan antitranspirat activity is due to abscisic acid dependent stomatal closure. Env. Exp. Bot., 66:493–500

Malerba, M., and R. Cerana. 2016. Chitosan Effects on Plant. Systems International Journal of Molecular Sciences Review 17(996):1–15. doi:10.3390/ijms17070996

Márquez, C., S. López, P. Cano, and A. Moreno. 2013. Fertilización orgánica: una alternativa para la producción de chile Piquín bajo condiciones protegidas. Revista Chapingo Serie Horticultura 19:279–286.

Matsufuji, H., Ishikawa, K., Numomura, O., Chino, M., and Takeda M. 2007. Anti-oxidant content of different coloured sweet peppers, white, green, yellow, orange and red (*Capsicum annuum* L.). International Journal of Food Science & Technology. 42:1482–1488. doi: 10.1111/j.1365-2621.2006.01368

Morales, D., J. Dell Amico, E. Jerez, Y. Díaz, and R. Martín. (2016). Efecto del Quitomax® en el crecimiento y rendimiento del frijol (*Phaseolus vulgaris* L.). Cultivos Tropicales 37:142–144.

Morales, D., L. Torres, E. Jerez, A. Falcón, and J. Dell Amico. (2015). Efecto del Quitomax en el crecimiento y rendimiento del cultivo de la papa (*Solanum tuberosum*, L.). Cultivos Tropicales 36:133–143.

Pham Dinh Dzung, Dang Van Phu, Bui Duy Du, Le Si Ngoc, Nguyen Ngoc Duy, Hoang DacHiet, Dang HuuNghia, Nguyen Tien Thang, Bui Van Le, and Nguyen Quoc Hien (2017) Effect of foliar application of oligochitosan with different molecular weight on growth promotion and fruit yield enhancement of chili plant, Plant Production Science, 20:4, 389-395. doi: 10.1080/1343943X.2017.1399803

Pichyangkuraa, R. and S. Chadchawanb. (2015). Biostimulant activity of chitosan in horticulture. Sci. Hort. 196:49–65.

Reyes, G., and D. Cortéz. (2017). Intensidad en el uso de fertilizantes en América Latina y el Caribe (2006–2012).Bioagro 29:45–52.

Reyes-Pérez J.J, R. Luna, V. Vázquez-Morán, D. Zambrano-Burgos, and J. Torres .2018. Efecto de abonos sobre la respuesta productiva en el tomate (*Solanum lycopersicum*, L). Rev. Fac. Agron. (Luz) 35:26–39.

Rodríguez, A.T., M.A., Ramírez, R.M. Cárdenas, A.N. Hernández, M.G. Velázquez, S. Bautista. (2007). Induction of defense response of *Oryza sativa* L against *Pyricularia* (Cooke) Sacc. by treating seeds with chitosan and hydrolyzed chitosan. Pesticide Biochemistry and Physiology 89:206–215.

Rodríguez-Pedroso A.T., M. Ramírez-Arrebato, A. Falcón-Rodríguez, S. Bautista-Baños, E. Ventura-Zapata, and Y. Valle-Fernández. 2017. Efecto del Quitomax® en el rendimiento y sus componentes del cultivar de arroz (*Oryza sativa* L.) var. INCA LP 5. Cultivos Tropicales 38:156–159.

Romanazzi, G., E. Feliziani, S. Bautista-Baños, and D. Sivakumar. 2017. Shelf life extension of fresh fruit and vegetables by chitosan. Critical Reviews in Food Science and Nutrition. 5726–5731 pp. doi:10.1080/10408398.2014.900474.

Rosales, P.R., P.J. González Cañizares, J.F. Ramírez Pedroso, and J. Arzola Batista. 2017. Selección de cepas eficientes de hongos micorrízicos arbusculares para el pasto guinea. Cultivos Tropicales 38:24–30.

Saavedra, G.M., N.E. Figueroa, L.A. Poblete, S. Cherian, and C.R. Figueroa 2016. Effects of preharvest applications of methyl jasmonate and chitosan on postharvest decay, quality and chemical attributes of *Fragaria chiloensis* fruit. Food Chem. 190:448–453.

Wang, M., Y Chen, R. Zhang, W. Wang, X. Zhao, Y. Du, and H. Yin. 2015. Effects of chitosan oligosaccharides on the yield components and production quality of different wheat cultivars (*Triticum aestivum* L.) in Northwest China. Field Crops Res. 172:11–20.

Wintergerst E, S. Maggini, D. Hornig .2006. .Immune-enhancing role of vitamin C and zinc and effect on clinical conditions. Ann NutrMetab. 50:85–94.