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QUITOMAX EFFECT ON GROWTH AND YIELD IN POTATO CROP (*Solanum tuberosum* L.)

Efecto del QuitoMax en el crecimiento y rendimiento del cultivo de la papa (*Solanum tuberosum* L.)

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ABSTRACT. The aim of this work was to evaluate some components of the growth and yield in potato plants (*Solanum tuberosum* L.) previously treated by foliar spray with different doses of QuitoMax (bioproduct based on chitosan polymers) at two moments of crop development. The work was conducted over three crop cycles (2009-2010, 2010-2011 and 2011-2012). At first cycle, besides the control where the product was not applied, three QuitoMax treatments were sprayed. A dose of 300 mg ha^{-1} at 30 or 50 days after planting and another treatment in which two doses of 150 mg ha^{-1} were applied at 30 and 50 days after planting. In the following two cycles in addition to control, nine treatments at doses of 100, 300 and 500 mg ha^{-1} at both 30 and at 50 days after planting were applied, another three treatments where doses of 50, 150 and 250 mg ha^{-1} were applied at the two moments above mentioned. The variables studied were the length and diameter of stems, number of leaves and tubers per plant, the average tubers fresh weight and the percentage of dry mass. Yields were estimated based on tuber fresh and dry masses. The analysis of the results showed the best response when the plants received two QuitoMax applications, highlighting the dose of 150 mg ha^{-1}, which caused a superior yield increment of 15 % in relation to control no applied.

Key words: chitosan, growth, yield, potato

RESUMEN. El objetivo del trabajo fue evaluar algunos componentes del crecimiento y el rendimiento en plantas de papa (*Solanum tuberosum* L.) sometidas a la aplicación foliar de diferentes dosis de QuitoMax (bioproducto a base de polímeros de quitosano) en dos momentos del desarrollo del cultivo. El trabajo se realizó durante tres ciclos del cultivo (2009-2010; 2010-2011 y 2011-2012). En el primer ciclo se contó con cuatro tratamientos en los que, además del control en el que no se aplicó el producto, se utilizaron dos en los que se empleó una dosis de 300 mg ha^{-1} a los 30 o a los 50 días posteriores a la plantación y otro en el que se aplicaron dos dosis de 150 mg ha^{-1} una a los 30 días y la otra a los 50 días posteriores a la plantación. En los dos ciclos siguientes se contó además del control, con nueve tratamientos en los que se aplicaron dosis de 100, 300 y 500 mg ha^{-1}, tanto a los 30 como a los 50 días posteriores a la plantación y otros tres en los que se aplicaron 50, 150 y 250 mg ha^{-1} en los dos momentos antes señalados. Las variables evaluadas fueron la longitud y diámetro de los tallos, el número de hojas por planta, el número de tubérculos por planta, la masa fresca promedio de los tubérculos y su porcentaje de materia seca. Se estimaron los rendimientos en base a las masas fresca y seca de los tubérculos. El análisis de los resultados mostró una mejor respuesta de las plantas cuando recibieron dos aplicaciones de QuitoMax, destacándose el tratamiento en el que las plantas recibieron 150 mg ha^{-1}, el que provocó un aumento del rendimiento superior a un 15 % en relación al control no aplicado.

Palabras clave: quitosano, crecimiento, rendimiento, papa

INTRODUCTION

New research aims at the use of biostimulants as substitutes of chemicals due to their beneficial effects on plants. Among the new biostimulants that start to be extended in world agriculture are those made up of polymers and other byproducts of chitosan with a high acceptance. (1). They consist in polymers

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and olygomers of glucosamine that can be partially N acetylated and vary in their mass, viscocity and acetylation degree which influence on their biological activity (2).

These compounds have different biological effects that make them desirable for agricultural purposes as: the activation of basal resistance in plants against major pathogens (3, 4, 5, 6), direct antimicrobial activity against different pathogens (2, 6), the stimulation of growth, development and yields in crops of interest (7, 8, 9), as well as their characteristics of biodegradable safe compound (1,2).

Other authors like (10) have referred to the propertis of chitosan in exogenous applications in the stability of the cell membrane and in the activation of antioxidating enzymes in plants exposed to water stress. Others (11) have found an increased antifungal activity, a reduction of the mycelial growth and reduced sporulation of the fungus *Pyricularia grisea* Sacc*;* likewise, other researchers have observed a reduction of blemishes in rice panicles (*Oryza sativa* L.) by spraying chitosan over the plants (12).

Though chitosan mechanisms to stimulate plants growth and development are not accurately known, it has been stated that they take part in physiological processes like prevention of water loss via transpiration, something important for this crop in particular, due to the great water demand to perform different functions (13).

As to foliar applications, the presence of stomata closing has been shown in chitosan sprayed plants which suggested that the stimulating growth effect after stomata closing could be related to an antitranspirant effect on the plant (14). Some authors like (15) have pointed out that foliar-applied chitosan in potato reduced the effects of water stress. In that regard, it has been said (16) that from the results in beans (*Phaseolus vulgaris* L.), one of the ways chitosan led to a reduced transpiration was by increasing abscisic acid levels (ABA) in treated leaves which influence on the partial closing of stomas.

The effect of the bioactive QuitoMax (chitosan) has been little evaluated on the growth and development of potato, but trials showing the viability of the product and the positive effects on crops at different concentrations and ways of application have been done. Hence this research has aimed at evaluating the effects of different rates and times of application of this polymer on the growth and yield of potato (*Solanum tuberosum* L.) cultivar Spunta.

MATERIALS AND METHODS

The study was conducted at the experimental farm of the National Institute of Agricultural Sciences (INCA) on a Red Ferralitic Eutric Compacted Soil (17), during three crop cyles 2009 – 2010 (first), 2010-2011 (second) and 2011-2012 (third).

The variety tested was Spunta planted at 0,25 m between plants and at 0,90 m among rows.

The treatments evaluated during the first cycle were:

- ♦ Control
- ♦ 300 mg ha^{-1} 30 days after planting.
- ♦ 300 mg ha^{-1}a los 50 days after planting.
- ♦ 150 mg ha^{-1} 30 days after planting and 150 mg ha^{-1} 50 days after planting.

Taking into account the results of the first cycle, it was considered to continue these studies using rates of the product that covered a wider spectrum than the previous one, so in the two following cycles, more rates of the product applied at the same time than in the first cycle, were tested, with the following treatments:

Control

- ♦ 100 mg ha^{-1} 30 days after planting.
- ♦ 300 mg ha^{-1} 30 days after planting.
- ♦ 500 mg ha^{-1} 30 days after planting.
- ♦ 100 mg ha^{-1} 50 days after planting.
- ♦ 300 mg ha^{-1} 50 days after planting.
- ♦ 500 mg ha^{-1} 50 days after planting.
- ♦ 50 mg ha^{-1} 30 days and 50 mg ha^{-1} 50 days after planting.
- ♦ 150 mg ha^{-1} 30 days and 150 mg ha^{-1} 50 days after planting.
- ♦ 250 mg ha^{-1} 30 days and 250 mg ha^{-1} 50 days after planting.

Seventy days after planting, variables like stem length and diameter, number of leaves per plant were evaluated, likewise, the numbers of tubers per plant, average fresh and dry mass of tubers were evaluated at harvest. From these variables, yields based on fresh and dry mass were estimated.

In the three studied crop cycles irrigation was supplied through sprinklers with a central pivot machine; cultural and phytosanitary practices were performed as per the Technical Instruction Guidelines for potatoes (18).

In all cases, a random block design with four repetitions was used and data were analyzed according to a double classification model. Averages were compared according to Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Figure 1 shows the behavior of stem length measured 70 days after planting potato plants sprayed with different rates of QuitoMax at different times of their development.

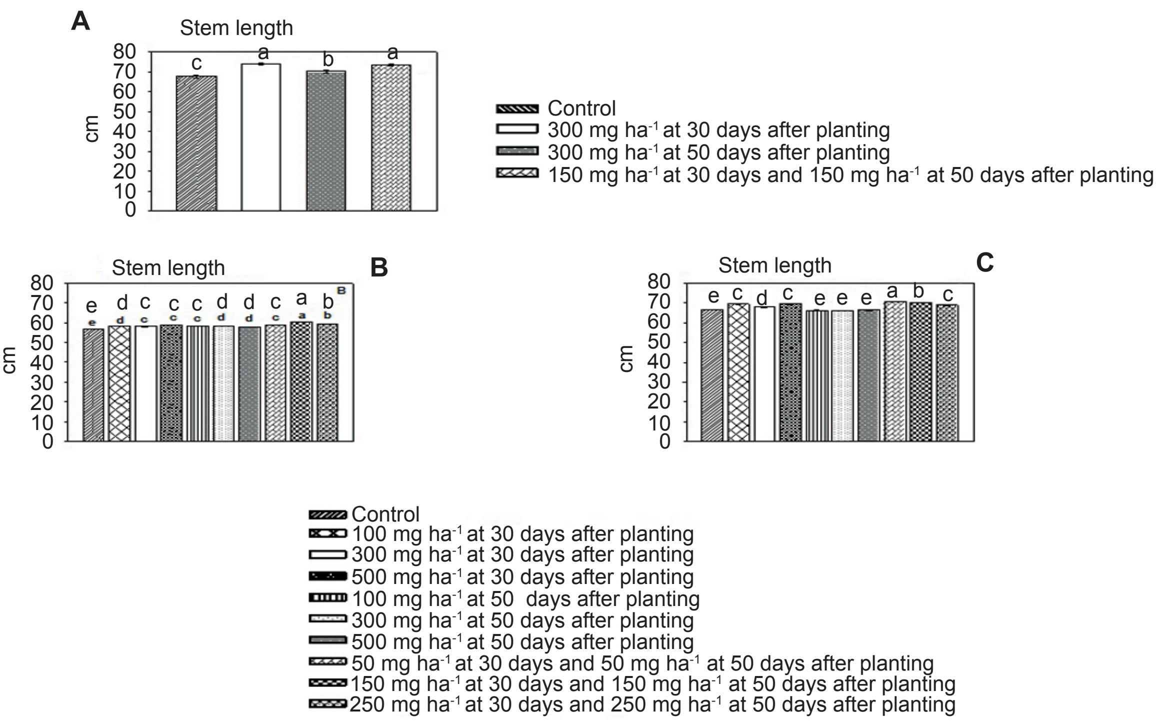
As shown in the figure, no significant differences among the plants of the treatments that received the product 30 days after planting, were found, both the complete rate as half the rate, which exceeded the other two. The stems of the plants that received chitosan application were longer than non-treated ones.

In the two following cycles, this variable tended to increase when plants were treated with chitosan, the intermediate rate stood out above the rest of the treatments.

The best results showed up when potato plants were treated 30 days after planting, which could be explained for the fact that at that very moment plants were under a fast-growing stage.

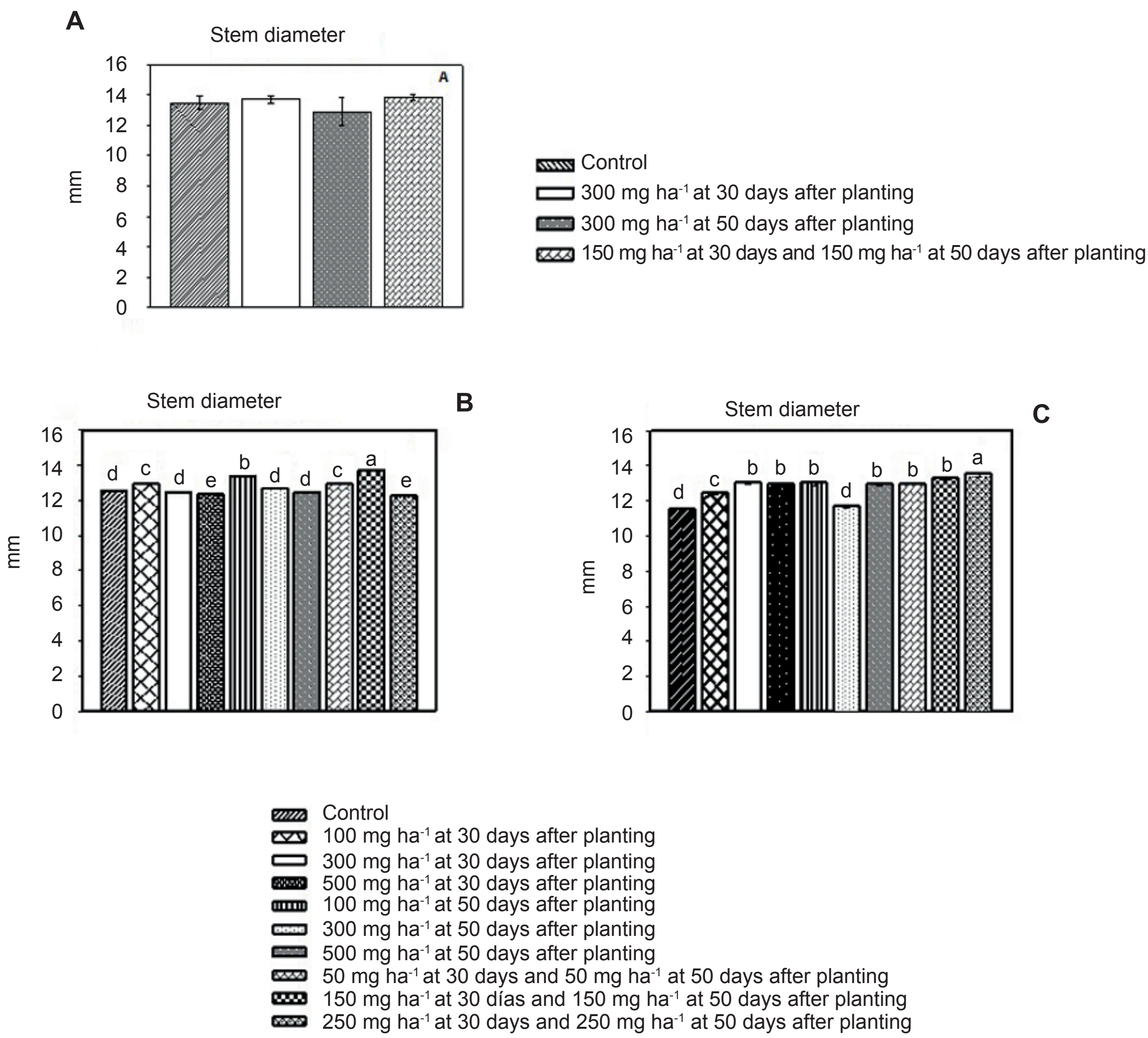
When analyzing the response of this variable, it has found favorable results in the growth expressed through the length of stems, roots, their fresh and dry masses, foliar surface and chlorophyll contents in beans (*Phaseolus vulgaris* superstryke). The most outstanding results were recorded with the lowest chitosan rates (8.

The evaluations of the first cycle (figure 2) did not show significant statistical differences among the stem diameters of the different treatments, while in the two following cycles, the best results were attained when the product was applied twice. In general, treatments receiving applications exceeded the treatment that did not receive the product (control).



(A- First cycle, B- Second cycle and C- Third cycle). Different letters indicate significant statistical differences for p<0,05

Figure 1. Stem length (cm) in potato plants treated with different rates of QuitoMax at different times of crop growth



(A- First cycle, B- Second cycle and C- Third cycle). Different letters indicate significant differences for $p<0,05$

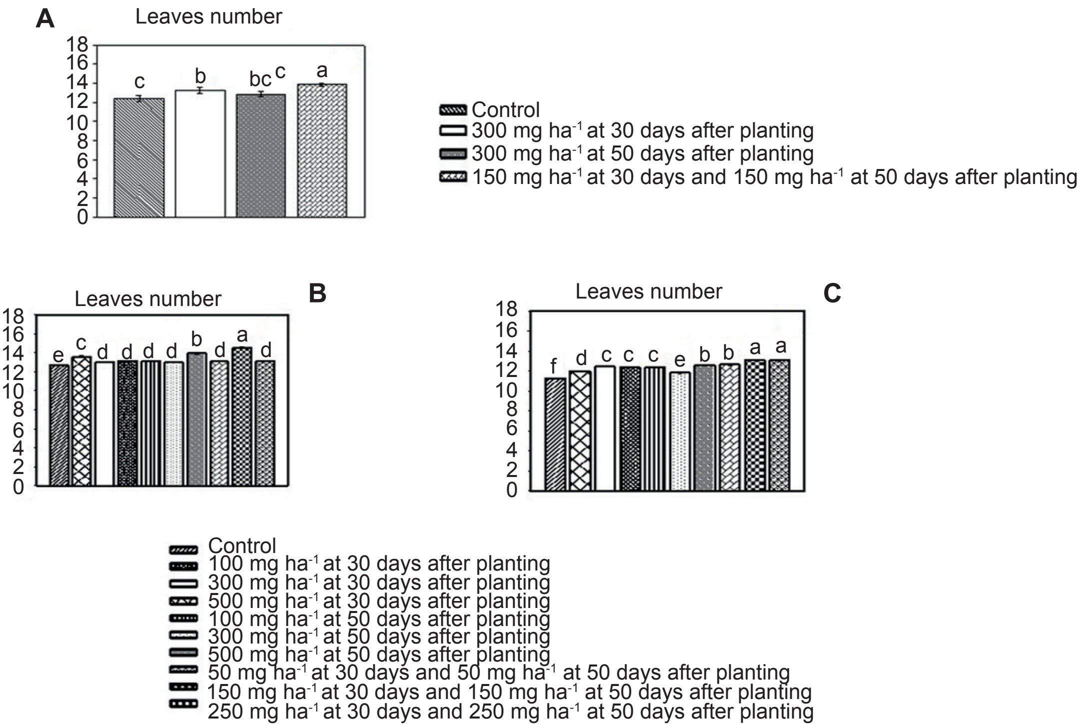
Figure 2. Stem diameter (cm) in potato plants treated with different rates of QuitoMax at different times of their development

Studies made using different forms of application, pointed out that the product stimulated growth and yield of rice (*Oryza sativa* L.) and when the evaluation of the growth in potato plants treated with chitosan under *in vitro* conditions was done (19), results showed positive effects in some growth variables like a higher number of leaves and stem length and diameter (20).

As shown in Figure 3, QuitoMax stimulated the number of leaves per plant of the Spunta cultivar. In the three evaluated cycles, Chitosan applied at two crop stages at the rate of 150 mg.ha^{-1} 30 days after planting and the same rate 50 days later, came to be the best treatment of all by favoring the formation of a higher number of leaves.

From these results, it can be said that in the variables mentioned above, there was a greater development of the foliar surface, indicative of a higher photosynthetic activity to produce photoassimilates as energy source to guarantee good growth and development of the tubers during tuberization.

Evidences indicate that the interception of the photosynthetically active radiation needed for the production of biomass and the corresponding contribution to the increased size of tubers mass, depended on the number of leaves and their size, plus the behavior of the different climatic variables where temperatures play a major role since they affect the photosynthetic process. The highest photosynthesis rates were found in the range of 15^{o}C to 25 ^{o}C notably declining the assimilation of CO_2 to higher ranges (21).



(A- First cycle, B- Second cycle and C- Third cycle). Different letters indicate significant differences for p<0,05

Figure 3. Number of leaves in potato plants treated with different rates of QuitoMax at different times of their development

Evaluation of chitosan effect on yield and its components

The statistical analysis allowed showing that QuitoMax influenced the number of tubers per plant (Figure 4). In the first crop cycle, there were not significant differences among treatments, but when comparing them with the means found in the control, they differed for a probability of 95 % confidence interval; means were around six and eight tubers per plant.

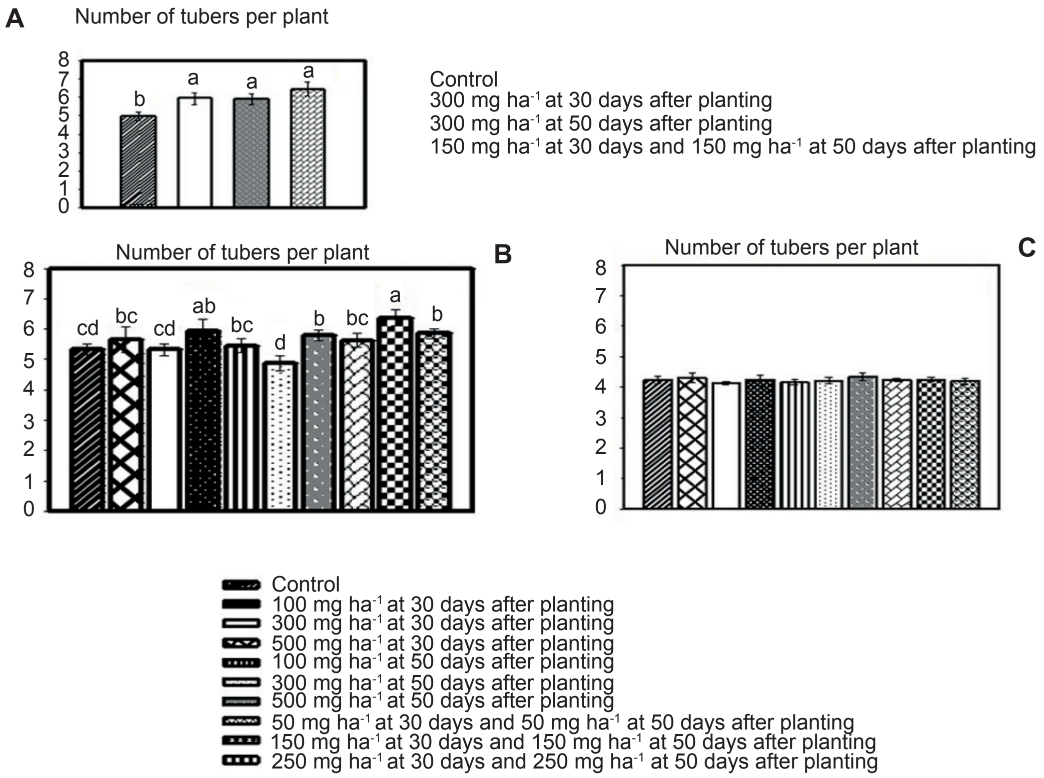
Regarding the analysis of the second cycle, there were significant differences between the rate and application times of the polymer. The highest quantity of tubers was recorded in plants sprayed with rates of 150 mg ha^{-1} 30 and 50 days after planting. In the third cycle, though there were differences between some treatments, it was impossible to define a clear tendency as to rates and times of application.

The results showed for this variable, could be explained for the fact that foliar-applied chitosan increased hormonal levels as gibberellins and abscissic acid (ABA) **(15)**, products very much related to tuberization and dry mass distribution in potato (*Solanum tuberosum* L.).

The response shown by Quitomax treated plants in growth could be related to increased resistance of these plants to fungal diseases on roots, similar to that reported by other authors in tomato crop (22). Similarly positive responses in the growth of young corn plants (*Zea mays* L.) exposed to different types of stress to be treated with chitosan (23) were found.

In the first crop cycle (Table I) there were significant differences in the behavior of commercial tubers from different treatments; the most outstanding variant was the one including the foliar application of 150 mg.ha^{-1} 30 and 50 days after planting. This variant produced the highest number of tubers according to commercial size.

It is interesting that in the two following cycles, this variant showed the best results significantly differing from the rest of the treatments. Likewise, the control treatment showed the lowest number of tubers which allowed deducing that QuitoMax notably contributed to tubers growth, something very closely linked to yield per surface unit.



(A- First cycle, B- Second cycle and C- Third cycle). Different letters indicate significant statistical differentes for p<0,05

Figure 4. Number of tubers in potato plants treated with different rates of QuitoMax at different times of crop development

Table I. Number of commercial tubers (above 35 mm) per plant in different crop cycles of potato

Treatments	Crop cycle 2009-2010 No. Tubers	I.C.	Crop cycle 2010-2011 No. Tubers	I.C.	Crop cycle 2011-2012 No. Tubers	I.C.
Control	4,53 b	0,19	4,70 c	0,22	5,23 d	0,15
100 mg ha^{-1} at 30 days after planting			4,93 bc	0,29	5,23 d	0,13
100 mg ha^{-1} at 50 days after planting			4,63 c	0,18	5,53 c	0,07
300 mg ha^{-1} at 30 days after planting	5,50 a	0,30	5,00 bc	0,37	5,33 d	0,08
300 mg ha^{-1} at 50 days after planting	5,27 a	0,27	4,78 c	0,12	5,60 c	0,03
500 mg ha^{-1} at 30 days after planting			4,20 d	0,20	5,33 d	0,04
500 mg ha^{-1} at 50 days after planting			4,95 bc	0,20	5,78 a	0,03
50 mg ha^{-1} at 30 days and 50 mg ha^{-1} at 50 days after planting			5,13 b	0,15	5,70 b	0,04
150 mg ha^{-1} at 30 days and 150 mg ha^{-1} at 50 days after planting	5,97 a	0,35	5,65 a	0,26	5,78 a	0,03
250 mg ha^{-1} at 30 days and 250 mg ha^{-1} at 50 days after planting			4,90 bc	0,13	5,73 ab	0,02

Different letters represent significant differences among means. The last column shows confidence intervals

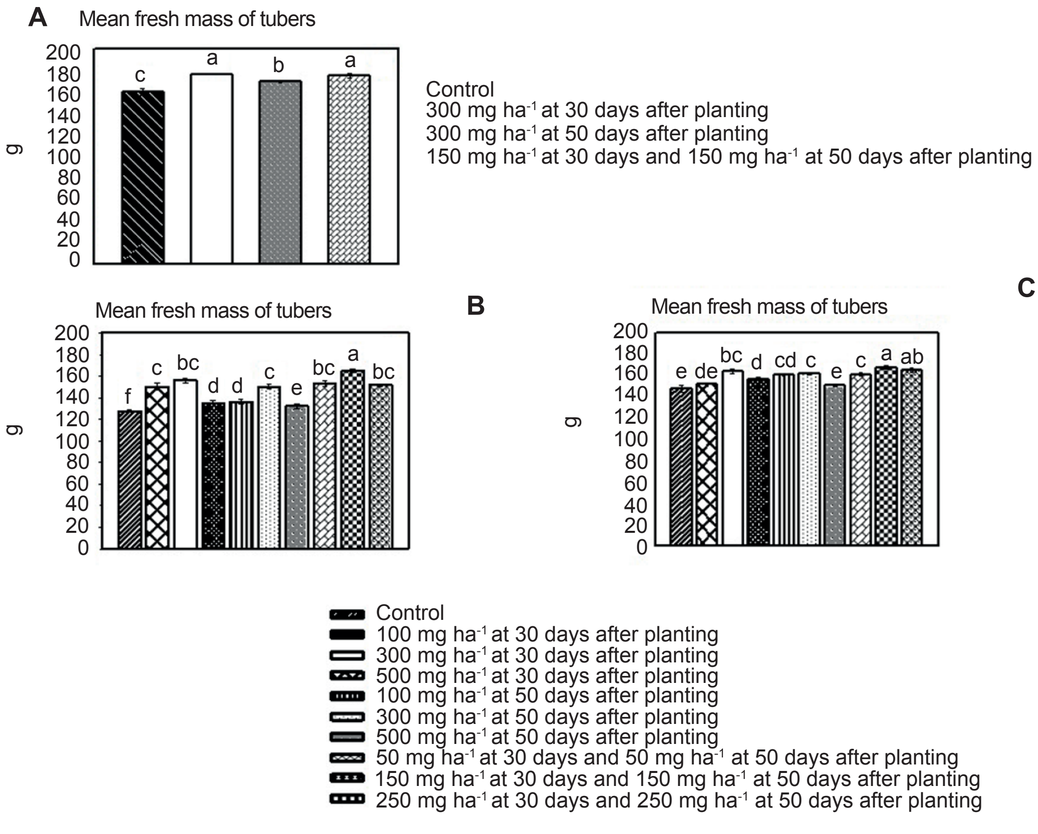
Another important issue in the production of this crop is the quality of the tuber, not only represented by the quantity involved in commercial categories (size >35 mm) and its mass, but for the internal quality of the tubers and its dry matter content. This latter, is closely related to their chemical composition influenced by different factors as variety, climate, management system, agricultural year, origin, physiology and storage (18).

On the other hand, the inductive effects of these compounds on roots growth has been proven (6) and perhaps this stimulus, has been able to express at the level of some modifications taking place in the roots of the plant as the specie under study for runners, out of which, through a swelling process, tubers are produced.

The behavior of the tubers fresh mass in the first crop cycle (Figure 5), did not show statistical significant differences among the means of the treatments where applications of the product were made 30 days after planting, however, the highest fresh mass of tubers was recorded in the plants treated with 150 mg ha^{-1} 30 and 50 days after planting, a behavior that was corrected in the two following crop cycles as shown in the figure. In general, when two applications were made (30 and 50 days) bigger size tubers were produced.

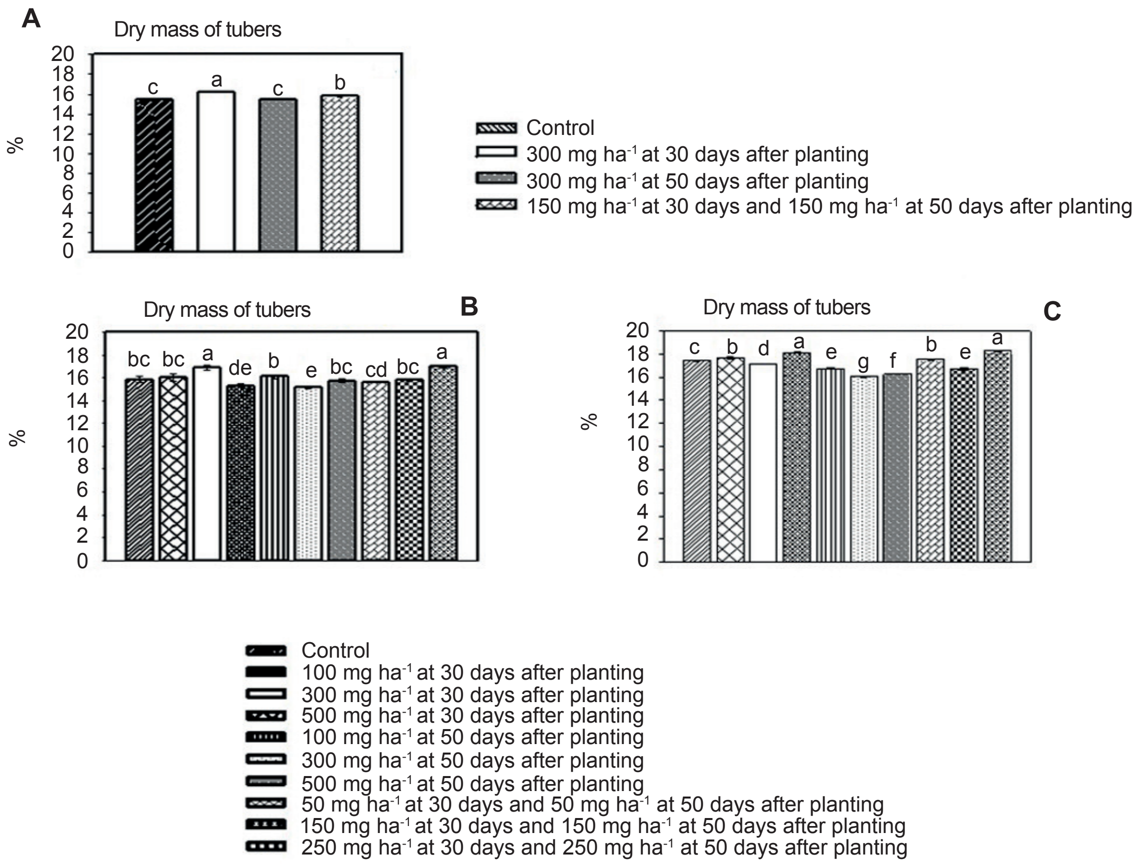
It can be pointed out that the average tubers mass found in this research was usually higher than those reported by other authors (24**),** when studied the response of this crop to different combined treatments of irrigation and fertilization under the conditions of Catania, Italy, where the crop cycle is slightly higher which favors a higher accumulation of photoassimilates in the tuber.

The behavior of the dry mass of tubers (Figure 6) did not show a well-defined tendency among treatments when the polymer was applied (QuitoMax), resulting in some cases below to the control's. It could indicate that the behavior of this variable is more related to other factors as perhaps grove management with predominance for water and nutrients.



(a- First cycle; b-Second cycle and c-Third cycle). Different letters indicate significant differences for $p<0,05$

Figure 5. Tubers' fresh mass (g) in potato plants treated with different rates of QuitoMax at different times of crop development



(A- First cycle, B- Second cycle and C- Third cycle). Different letters indicate significant differences for p<0,05

Figure 6. Tubers dry mass (%) in potato plants treated with different rates of QuitoMax at different times of crop cycle

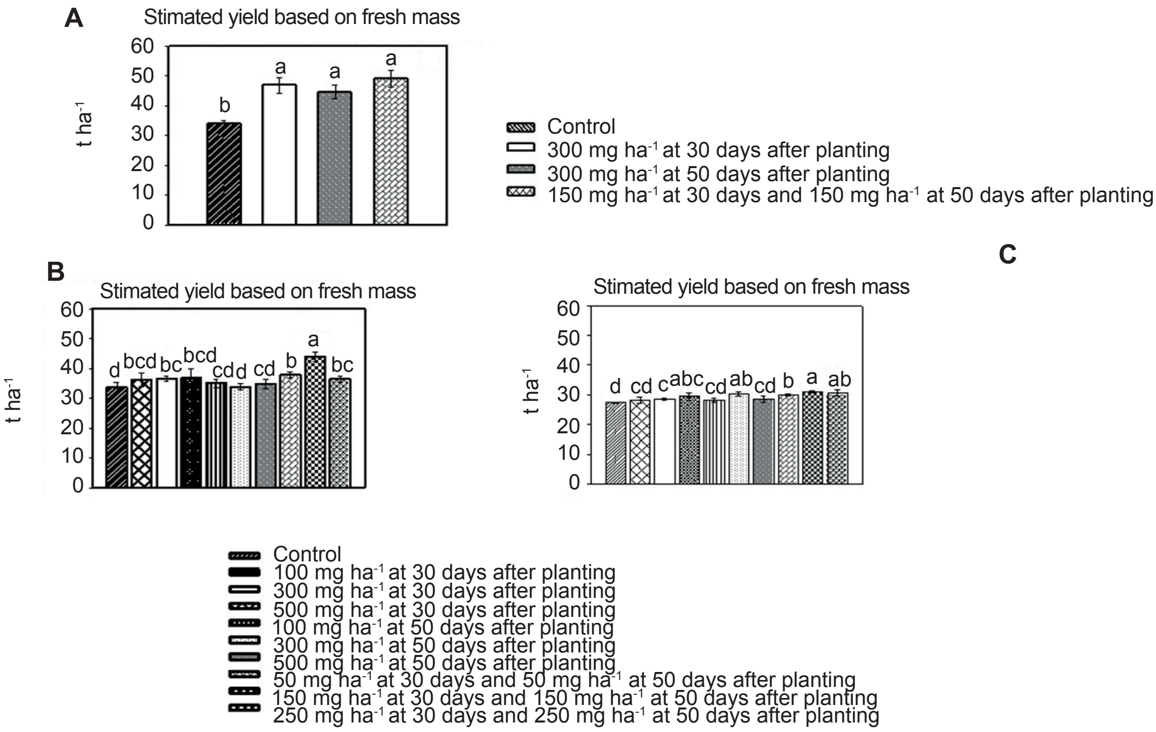
The estimated yield based on tubers fresh mass per surface unit is shown in Figure 7. The statistical analysis of the first crop cycle did not show significant statistical differences among the means of the treatments in which QuitoMax was applied, but when comparing it to the control, there were differences among their means reaching a yield of 48,95 t ha^{-1}, when two applications of 150 mg ha^{-1} at 30 and 50 days after planting, were made.

When analyzing the results of the second and third cycles, there were significant differences among the means of the variants studied. The best treatment was that including the application of 150 mg ha^{-1} 30 days after planting and the same rate 50 days after planting reaching yields of 44,01 and 42, 86 t ha^{-1} in the second and third cycle, respectively.

Yields above 40 t ha^{-1} have been reported by studying different irrigation and soil strategies under the conditions of Denmark (25), a fact that is interesting from the point of view that the application of this product at those rates and times are able to put on the same level groves developed under edaphoclimatic conditions where plants have a superior life cycle while they are higher than those reported by other authorswho studied the effects of irrigation and fertilization under Italy's conditions (24).

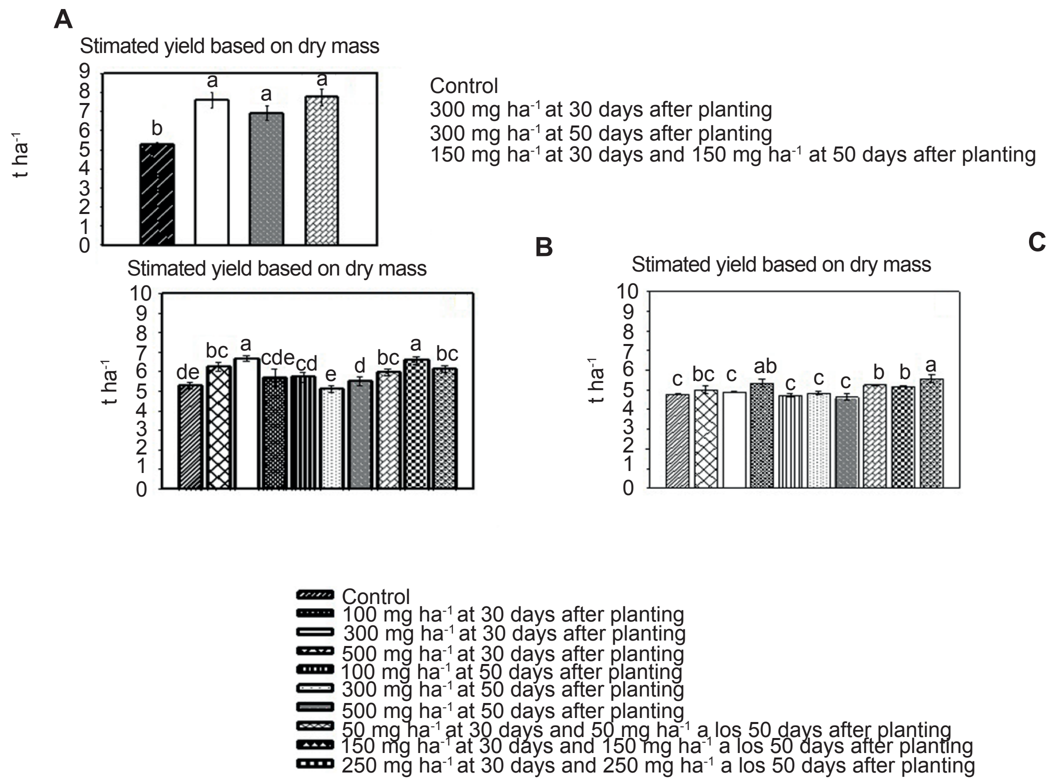
Concordant results as to increased growth and yields of rice (*Oryza sativa* L) by applying chitosan to seeds at planting time followed by foliar applications during the development of the crop (19).

The statistical analysis (Figure 8) of yield behavior based on the dry mass of the tubers indicated significant differences among the means of the variants where this polymer was applied at different development times of the crop and the control's, a closely related response to the yield of each variant, not being so for the percentage of dry matter in tubers.



(A- First cycle, B- Second cycle and C- Third cycle). Different letters indicate significant differences for p<0,05

Figure 7. Estimated yield based on fresh mass (t ha^{-1}) in potato plants treated with different rates of QuitoMax at different times of crop cycle



(A- First cycle, B- Second cycle and C- Third cycle). Different letters indicate significant differences for p<0,05

Figure 8. Estimated yield based on dry mass (t ha^{-1}) in potato plants treated with different rates of QuitoMax at different times of crop cycle

As shown in the figure, yield based on dry matter was higher when plants received QuitoMax applications 30 and 50 days after planting. The treatment with rates of 150 mg ha^{-1} stood out for recording the highest values in the three crop cycles evaluated. In that regard, it seems there is a complementarity between these two applications, firstly in strengthening the plant against the possible entry of diseases (26) and secondly stimulating the movement of assimilates towards the tuber, which positively contributes to the accumulation of dry matter in this organ (27).

CONCLUSIONS

As conclusion, the results of this research indicate that the rate of 150 mg.ha^{-1} 30 days after planting and a similar rate 50 days after planting too, are enough to stimulate physiological processes in potato which is translated into a higher growth and development of this plant.

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