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EVALUATION OF GROWTH AND COMPOSITION BY SIZE OF TUBERS FROM POTATO PLANTS FOR SEED

Evaluación del crecimiento y composición por tamaño de tubérculos de plantas de papa para semilla

Eduardo Jerez Mompié✉, Roberqui Martín Martín and Donaldo Morales Guevara

ABSTRACT. The present work was carried out with the objective of evaluating the influence of foliar applications of QuitoMax® on the growth and composition of the number of tubers in a potato plantation dedicated to obtain national "seed". Imported Roman variety was used, planted on January 2015 and February 2016, using a design of randomized blocks with three replicates and three treatments: a control without application and chitosan application of two different molecular mass (Q1 of 66,4 Kd and Q2 of 124 Kd) at reason of 300 mL ha^{-1} at 30 and 50 days after planting (DAP). Destructive samplings were carried out at 60 and 70 DAP, taking 10 plants at random for each treatment to know the height of the stems and number of stems per plant, leaf surface and dry mass of leaves and stems. The tubers at harvest were separated by size, weighed and counted, estimating the total yield at t ha^{-1}. Data were processed using ANOVA and the determination of the mean and its confidence interval when necessary. The percentage of the tuber number in each size considered in relation to the total tubers in each treatment was calculated. It was found that both chitosans stimulated plant growth and yield, while tubercle distribution by size ensured a greater amount of chitosans in the calibers with adequate quality to be used as propagules and this result was reached earlier than in the control treatment.

Key words: growth, chitosan, yield, leaf area

RESUMEN. El presente trabajo se realizó con el objetivo de evaluar la influencia de aplicaciones foliares de QuitoMax® en el crecimiento y en la composición por calibres del número de tubérculos en una plantación de papa dedicada a la obtención de ´semilla´ nacional. Se empleó la variedad Romano importada, plantada en enero (2015) y febrero (2016) mediante un diseño de bloques al azar con tres réplicas y tres tratamientos, los que consistieron en un control sin aplicación y aplicación foliar a razón de 300 mL ha^{-1} de QuitoMax® de diferente masa molecular (Q1 de 66,4 Kd y Q2 de 124 Kd) a los 30 y 50 días después de la plantación (DDP). Se realizaron muestreos destructivos a los 60 y 70 DDP, tomando 10 plantas al azar por cada tratamiento para conocer la altura de los tallos y número de tallos por planta, superficie foliar y masa seca de hojas y tallos. En la cosecha los tubérculos fueron separados por tamaño, se pesaron y contaron, estimándose el rendimiento total en t ha^{-1}. Los datos se procesaron mediante un ANOVA y la determinación de la media y su intervalo de confianza cuando fue necesario. Se calculó el porcentaje del número de tubérculos en cada tamaño considerado respecto al total de tubérculos en cada tratamiento. Se comprobó que ambas quitosanas estimularon el crecimiento y rendimiento de las plantas, mientras que la distribución de tubérculos por tamaño aseguró una cantidad mayor de los mismos en los calibres con calidad adecuada para ser utilizados como propágulos y este resultado se alcanzó más temprano que en el tratamiento control.

Palabras clave: crecimiento, quitosano, rendimiento, superficie foliar

INTRODUCTION

The cultivation of potatoes (*Solanum tuberosum* L.) has been developed and widely studied throughout the world, being considered one of the main foods for human beings worldwide, surpassed only by rice, wheat and corn (1).

Instituto Nacional de Ciencias Agrícolas. Gaveta Postal 1, San José de las Lajas, Mayabeque, Cuba, CP 32700
✉ ejerez@inca.edu.cu

Oligosaccharines specifically chitosan are complex carbohydrates capable of modeling the growth and development of plants at low concentrations, so the use of these biostimulants allows a more rational use of resources (2-6), reducing production costs without affecting the quality and yields of the crops, in addition to increasing the resistance of the plants to the conditions of water stress, salinity and high temperatures; important aspects to consider in any potato production area.

The growth and development are determined by genetic and environmental factors and it is the result of the interaction between photosynthesis (7), respiration, transport of assimilates, water relations and mineral nutrition; which translates as the irreversible increase in dry matter, volume, length or area as a result of cell division, expansion and differentiation (8).

One of the main links in the productive chain of the potato is the production or import of the seeds that will be used in the new plantations, so it is traditional in Cuba to obtain national "seed" from the imported, even though the yields achieved in this sense are low and do not meet the demand that it is needed to cover all areas (9).

In this sense, it is necessary to adopt several alternatives to guarantee increased yields in the "seed" producing areas based on the possibility of using different bioproducts, among them QuitoMax® (oligosaccharide from shellfish crustaceans based on polymers of chitosan) with excellent results in the increase of yields in areas dedicated to potato production for consumption, while the use of this practice would have a more ecological and friendly approach to the environment (10), that is, decreases in the use of chemical products. Other products have also been used to meet the nutritional demands of potato cultivation, including the use of mycorrhizae (11).

Based on the foregoing, the present work was carried out with the objective of evaluating the influence of foliar applications of QuitoMax® on the growth and the composition by size of the number of tubers in a potato plantation dedicated to obtaining national 'seed'.

MATERIALS AND METHODS

The work was carried out in the experimental areas of the National Institute of Agricultural Sciences (INCA) for which potato plantations were carried out in the first half of 2015 and the second of February 2016, using imported seed of the Romano variety of Dutch origin for this purpose, of caliber 35-45 mm, with a frame of plantation of 0,25 x 0,90 m, taking into account the size of the tubers, and the soil corresponds to a Red Ferralitic eutric (12).

The rest of the cultural attentions were carried out as recommended in the Technical Instructions for cultivation (13), while irrigation was performed by spraying with a Central Pivot machine.

During the conduction of the experiment the maximum, minimum and average temperatures were recorded in the Meteorological Station adjacent to the experimental area, processing the data of the three variables in a decennial manner, the results are presented in form of a graph.

The experiment was developed by means of a randomized block design with three replications and three treatments: a control without application (Control) and the foliar application of two chitosans of different molecular mass (Q1 of 66,4 Kd and Q2 of 124 Kd) which were applied at a rate of 300 mL ha^{-1} manually with backpack previously calibrated, at two moments of the crop cycle at 30 days after planting (DAP) and the other at 50 DAP.

During the experimental phase a destructive sampling was carried out at 60 and 70 DAP, taking ten plants at random for each treatment to know the behavior of some growth variables height of the stems, measured from the root neck base to the yolk terminal, to all the stems of the seedling and the data is expressed as the average of all the stems; number of stems per plant, leaf surface, calculated from the linear measurements of the leaves and the use of the equation: y = (LxA) 0,495 + 5,281, and dry mass of leaves and stems, for which they were introduced in envelopes previously identified and placed in forced air circulation oven at 80 ^{0}C for 72 hours until constant mass is obtained.

To harvest the foliage was manually removed at 70 DAP and the collection was made after 10 days, so that the tubers would ripen so that they did not lose the skin during the handling of the same.

The tubers were counted and weighed by size (<28, 28-35, 35-45, 45-55 and> 55 mm) both in the sampling done at 60 DAP and in the harvest, except that for the latter all the plants were taken corresponding to two rows of each treatment.

The data were processed by means of a double classification ANOVA, while the means were compared by Duncan's test to know the differences between treatments (14); the confidence interval of the means was also determined in some variables and were compared by t-Student to $1-\alpha = 0,05$ (n = 10). The statistical program Statgraphics (15) was used.

RESULTS AND DISCUSSION

The number of average stems per plant was slightly higher in the 2015 plantation (Figure 1), compared to 2016 and in none of the two years evaluated, there were significant differences between treatments. It must be borne in mind that the application of the bioproduct (QuitoMax®) is carried out 30 days after planting and sprouting occurs much earlier, so it is expected that these applications have no effect on this variable.

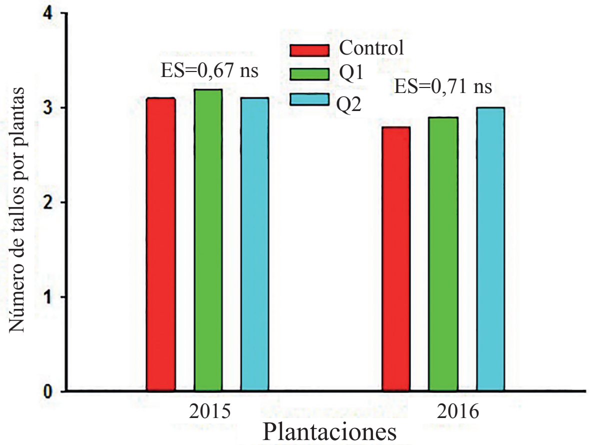


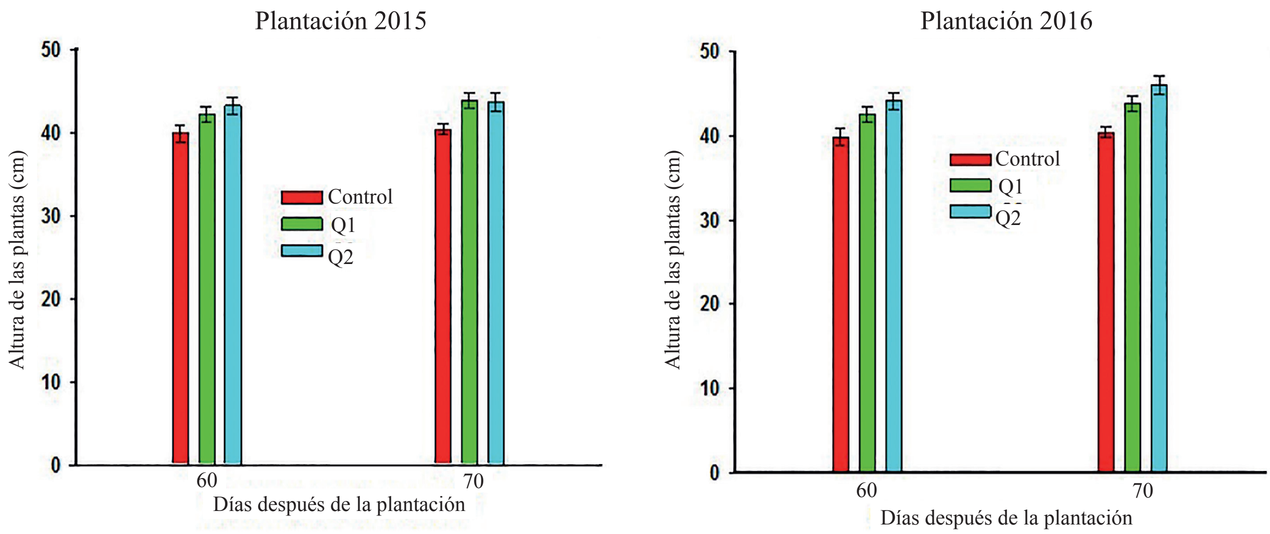
Figure 1. Number of average stems per plant in two potato plantations, of plants that were sprayed with QuitoMax® of two different molar mass (Q1 and Q2) and a control without application

Similar results were indicated earlier by the author working with another variety (16), although it has been pointed out that the effect of this variable per seedling is important in the growth and yield achieved by potato plants (17-19), on the other hand, the number of stems, if a stimulating agent has not been used to increase sprouting will depend on the size of the seed tuber that is planted (20), as well as the differences that may be presented between varieties (21).

In the height variable of the plants, an increase in the growth of the plants is generally shown in those treatments in which QuitoMax was applied at two moments of the crop cycle (Figure 2), although without significant differences between them, but with respect to control, where the plants were always smaller.

The values were similar in both moments (60 and 70 DAP) in the two years of study, which indicates that after 60 days, and perhaps before, stability in the height growth of the plants has been reached, since other growth variables at that time have already begun to decrease their growth rates, reaching even negative values (22).

The height of the plants responds to the effect of treatments that promote growth, as it is the case of chitosans, as it has been proven in different crops its action in terms of height increase in different species compared with untreated plants (10), although differences between varieties persist, given the morphological characteristics of each one of them.



The bars (I) indicate the confidence interval for the means in each treatment for 1-α = 0,05 (n = 10)

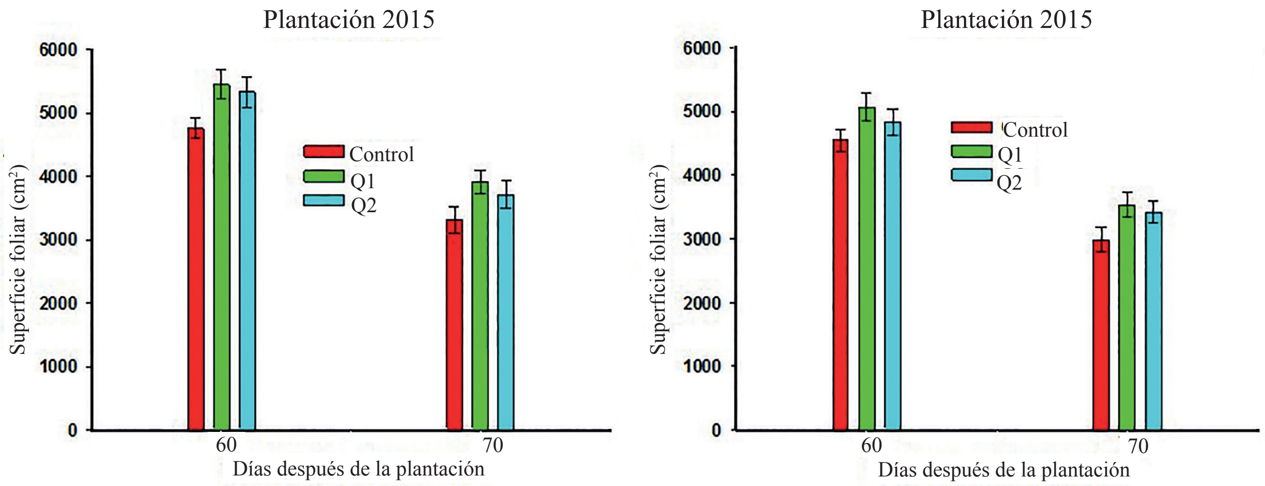
Figure 2. Height of the plants at 60 and 70 DAP, in two potato plantations in plants that were sprayed with QuitoMax® of two different molar mass (Q1 and Q2) and a control without application

The foliar area is an important index that suggests, in case of being high, a good vegetative development in the plant to produce photoassimilates, soil cover capacity to fight weeds, as well as the relationship with the rate of tuber filling since it exists a great interaction between tuberization and the foliage structure of the plant (23).

According to the results presented in Figure 3, the leaf surface was higher in the plants that were sprinkled with the bioproduct, without significant differences between treatments, although it did with respect to the control and a considerable decrease of the 60 to 70 days, which is related to the increase in the senescence of the leaves, basically.

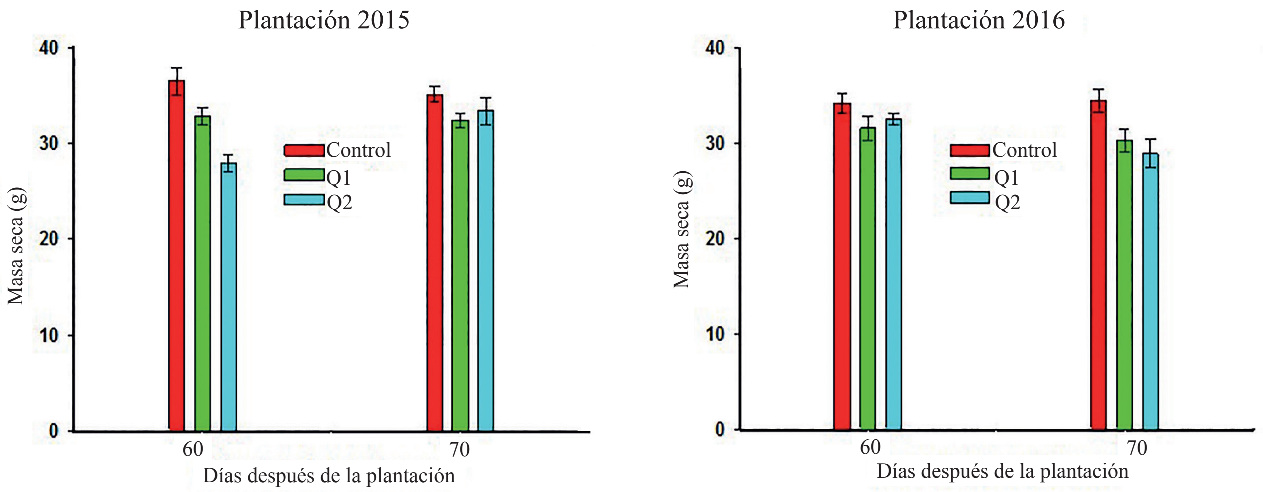
A close relationship has been established between the number of fully expanded leaves (on which the magnitude of the leaf surface depends) and the size reached by the tubers, but this must be done in a specific stage of the crop growth cycle (24).

The biomass must be considered to produce potatoes, because it is the solar energy converted into organic matter, through photosynthesis and it is related to the crop growth (25). Regarding the production of dry mass in the aerial part, the pattern of behavior in both years of study was similar (Figure 4), higher values in the control with significant differences with respect to the treatments and among the latter, there were only differences in 60 DAP sampling in the 2015 plantation.



The bars (I) indicate the confidence interval for the means in each treatment for 1-α = 0,05 (n = 10)

Figure 3. Foliar surface of the plants at 60 and 70 DAP, in two potato plantations in plants that were sprayed with QuitoMax® of two different molar mass (Q1 and Q2) and a control without application



The bars (I) indicate the confidence interval for the means in each treatment for 1-α = 0,05 (n = 10)

Figure 4. Dry mass of the aerial part of the plants at 60 and 70 DAP, in two potato plantations in plants that were sprayed with QuitoMax® of two different molar mass (Q1 and Q2) and a control without application

The production of dry matter is related to the foliar area, therefore when the latter is high a high accumulation of dry matter and a higher productivity of the crop are expected (26,27).

Apparently, and according to the results, the presence of QuitoMax® in the plant could have led to some extent the mobility of photosynthates to other plant parts, in fact it proved by applying chitosan to young potato plants (28) , that the treated ones showed a greater permeability of the membranes than those of the control, which was increased, by applying a higher concentration of the bioproduct, all of which results in a greater mobility of different compounds within the plant, as well as a possible to avoid the effects of a water deficiency. This could explain that in the treated plants there was a greater mobility of compounds towards the storage sites represented by the tubers.

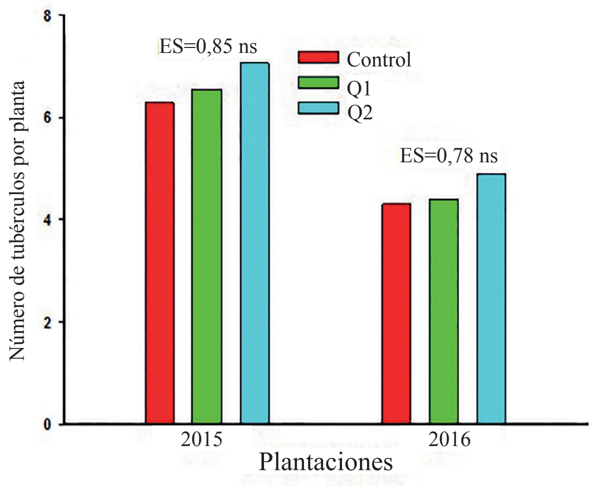
On the other hand, the distribution of assimilates is the result of growth and development, which are mutually dependent, as well as being influenced by the interaction of climatic conditions, cultural practices and genotype (7).

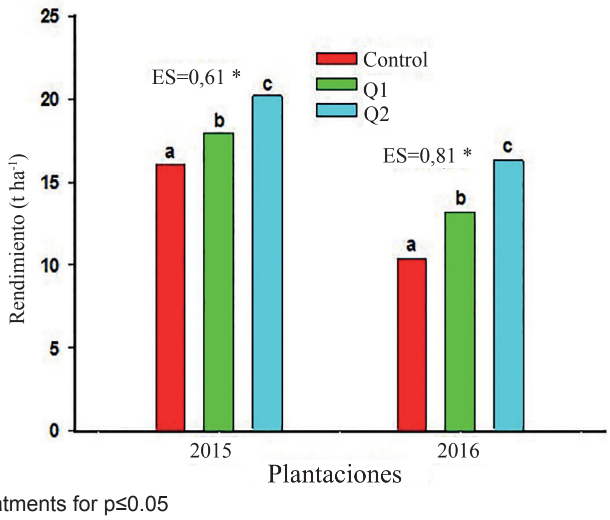
The formation of tubers in potatoes depends, among other things, on the availability of assimilates and the ability of the tubers to accumulate them. Before tuberization, photoassimilates are mainly used for the development of leaves, stems and roots; the demand strength of the leaves is greater than that of any other organ. With the beginning of tuberization, this trend changes, because as the tubers grow, their demand for assimilates increases (29).

Figure 5 shows the average number of tubers per plant, variable that was not modified by the effect of the treatments, as there were no differences between them in each plantation, although the quantity was lower in the 2016 season. Concerning yield, it was found that it was higher in the plants that were sprinkled with QuitoMax, although there were significant differences between the three treatments. The yields were lower in 2016 when compared with the 2015 planting, which is a consequence of a late planting carried out in that year as already indicated, in addition to that they were in correspondence with the number of tubers, previously analyzed and in this sense, a high correlation between both variables has been found, given that there is a high dependence of one on the other, independently that other factors can influence the result (19,30).

The planting of 2016, coincided with higher temperatures at the tuberization time and it has morphogenetic effects on the growth and development of the plant, intervenes in the formation of the tuber since there is an interaction between this environmental variable and the length of the day called photoperiod.

The effects of temperature are crucial at the beginning of the early growth of the tuber, and therefore, its filling. The favorable conditions for tuberization and tuber increase are short days and low night temperatures, temperatures between 15-19 °C are optimal to initiate tuber growth, 17 °C is an average value for good potato production. Under short-day conditions the proportion of vegetative weight in potato plants is 12 times higher than at high temperatures, but tuber production is 19 times higher at low temperatures (31).





Different letters on the bars mean significant differences between treatments for p≤0.05

Figure 5. Number of average tubers per plant and yield (t ha^{-1}) in two potato plantations, from plants that were sprayed with QuitoMax® of two different molar mass (Q1 and Q2) and a control without application

It is interesting to analyze the distribution of the percentage that follows the number of tubers by size in each of the treatments, with respect to the total of tubers per plant, which is presented in Figure 6. It can be seen that there were differences in the distribution in the evaluation made at 60 DAP, in relation to what happened at the time of harvest, but this distribution is also modified by the effect of the treatments studied.

It is noted that in both plantations at 60 DAP, the largest proportion of tubers, regardless of the treatments, occurs in the size of 35-45 mm, optimal to be used as seed tubers, but already at 70 DAP this distribution has changed, product of the logical development that the tubers are reaching over time, so that at that moment it is possible to find a certain amount of tubers in the largest size (55 mm) according to the classification used.

This behavior in the distribution ensures that from 60 DAP there is an important number of tubers that can be used as seed for the new plantation, without having to wait for 70 days as established.

There are no results in the production of seed in terms of the classification of the tubers once the plants have been sprayed with chitosan, as their influence has been evaluated to know the responses of the plants in relation to their growth and yield in the sense general. However, it has been proven that the treatment of the seed to reach a good development of the tuber will guarantee a greater number of stems, which in turn will increase the productions if the post-sowing conditions are not adverse to the crop (18). On the other hand, the Chitosans have had a lot of interest in agriculture because of their excellent biocompatibility, biodegradability and bioactivity, as well as other bioproducts (2,4).

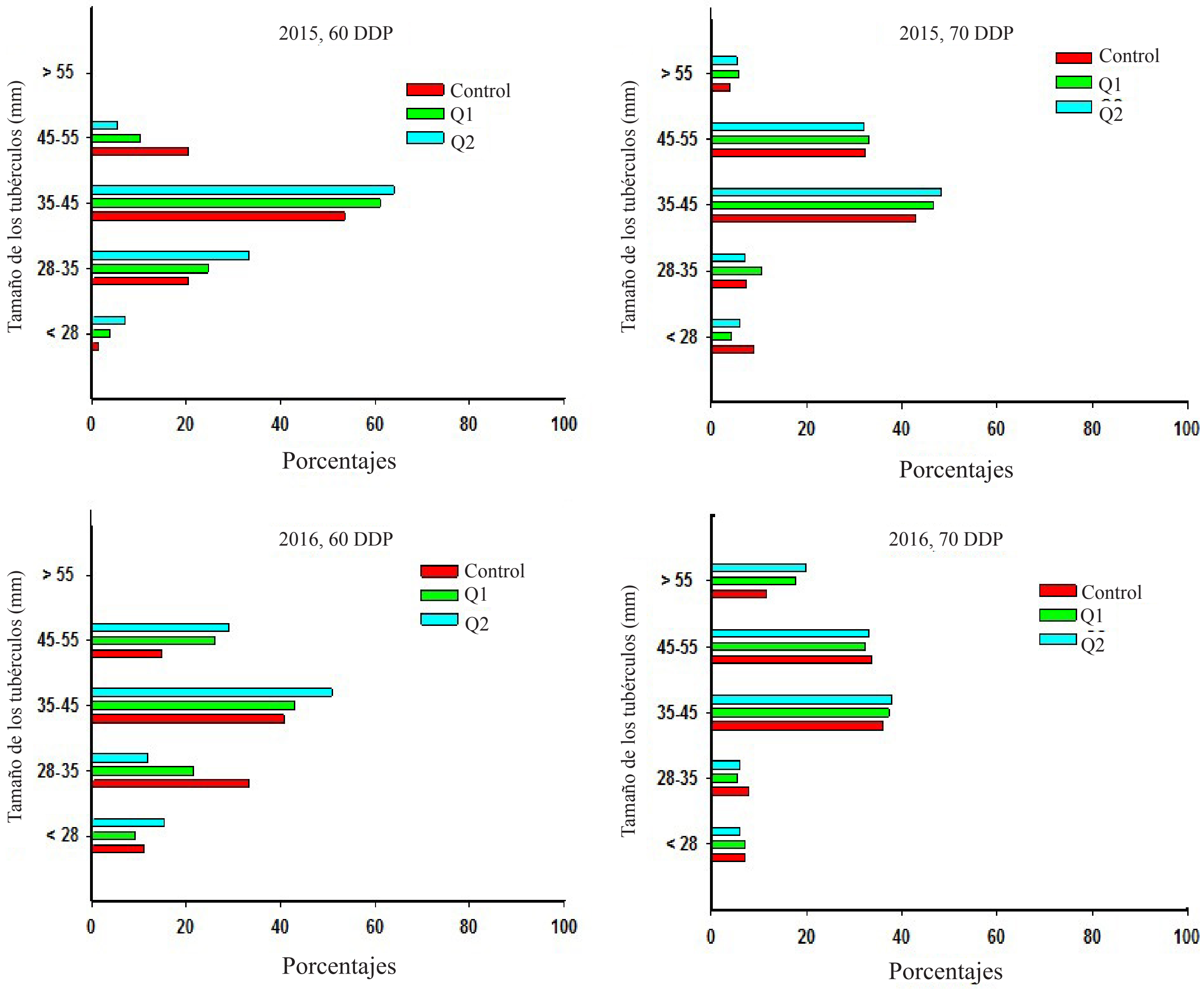


Figure 6. Percentages of the number of tubers by size with respect to the total in each treatment in two potato plantations (2015 and 2016) at 60 and 70 days after planting

Taking into account that temperatures exert a marked influence on the growth and development of potato plants, Figure 7 shows the behavior followed by them during the experimental period in both years of study.

According to the trend followed by these variables, it is noted that in 2015, they were more favorable for the initial stages of plant growth and the subsequent behavior of the same in variables such as the leaf surface, which was higher year with respect to 2016, which also led to a higher value of the foliar surface. The average number of tubers per plant was also higher, causing the yields to be higher in that year (2015) in particular.

In this sense, temperature and photoperiod have been pointed out as the most important elements of the climate that influence the growth and development of the potato and in this specific case (32), the behavior followed by average temperatures, above the optimum range established also did not favor a better development of the plantation that allows them to achieve high yields (33), as happened in the plantation carried out in 2016, since high temperatures delay the formation of tubers (34). On the other hand, the behavior of dry mass production and its mobility within the plant depending on the demand sites, also depend on the behavior of temperatures (35).

In works developed in the country, they agree with other authors when they state that under similar conditions of temperature behavior (31), the crop cycle is shortened, so that some physiological processes are produced in an accelerated manner, which has a negative effect in yields, especially in the 2016 plantation.

On the other hand, it has been corroborated that the overall production of the plantation depends to a large extent on the multiple interactions between climate elements and potato plants (36).

CONCLUSIONS

Chitosan applied in the form of foliar sprays to potato plants stimulated yield compared to control plants, while allowing a greater number of tubers to be counted, earlier than in the control, at the size of 35-45 mm, suitable for new plantings. In the same way, the evaluated growth variables are favored with applications of this bioproduct.

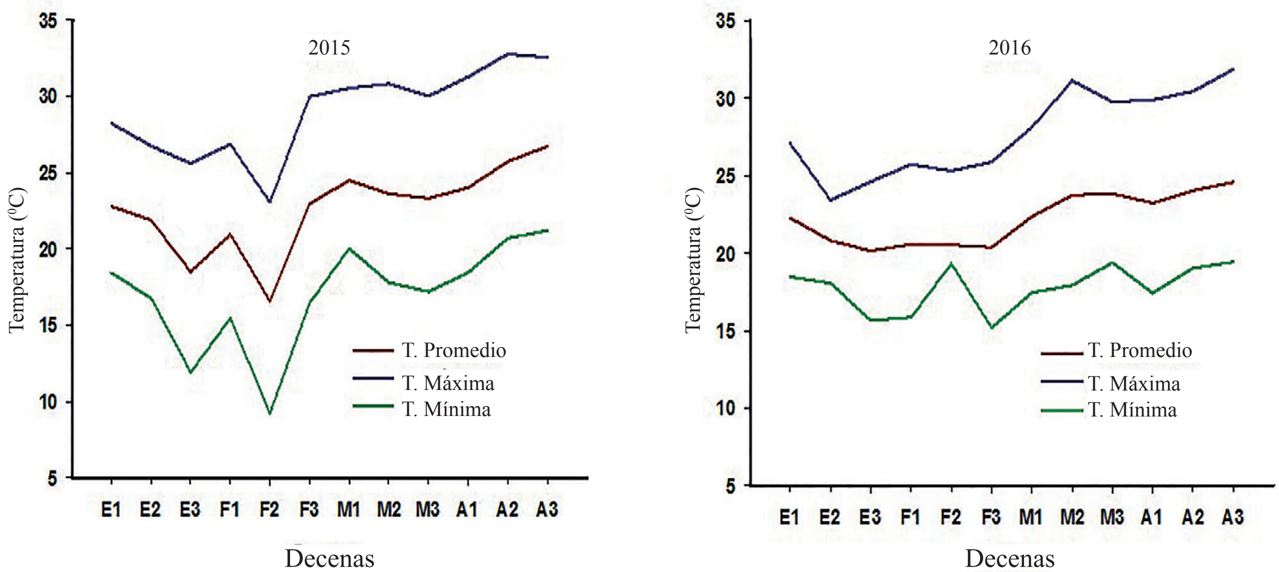


Figure 7. Behavior of the average, maximum and minimum temperatures (decadal averages) corresponding to the period in which the experiments were carried out in the two years of study

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