Article

Effect of gibberellins on the yield of jalapeño pepper (*Capsicum annuum* L.)

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Abstract

The pepper (*Capsicum annuum* L.) is an important crop in Mexico due to its growing demand in recent years. Therefore, alternatives should be sought to increase their production, one of them is the use of growth regulators, of which gibberellins are important growth regulators involved in mooring and fruit development, flowering, cell elongation and expansion in plants. In order to evaluate the effect of the application of gibberellins (GA_3) on the yield of jalapeño pepper produced in greenhouse, the present investigation was carried out in two successive experiments. In experiment 1, five doses of gibberellins were evaluated: 0 (control), 10, 30, 50 and 500 mg L^{-1} that were sprayed in one and two applications. The fertilization in this experiment was with nutritive solution (N, P, K and microelements). In experiment 2 the same doses of GA_3 were evaluated, also in one and two applications, but the fertilization was carried out with calcium nitrate and potassium nitrate soluble in water. In experiment 1, no increase in yield was detected. In contrast, in experiment 2, the 10 mg L^{-1} dose of GA_3 in combination with the fertilization with calcium nitrate and potassium nitrate increased the yield of jalapeño pepper. The results show gibberellins as key elements combined with low fertilization to increase pepper production.

Keywords: *Capsicum annuun* L., fertilization, phytohormones, production.

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Introduction

The pepper (*Capsicum annuum* L.) is a solanaceous plant widely cultivated in the world; The importance of this crop is based on the benefits it offers. It is used as a condiment, culinary supplement, medicine, cosmetics and ornamental plant (Ravishankar *et al.*, 2003; Hasan *et al*., 2015). In addition, the fruit of *Capsicum* has a high content of vitamin C, carotenoids and flavonoids (Kumar and Tata, 2009; Sun *et al.*, 2016). Globally, China is the largest producer of pepper, followed by Mexico (FAO, 2014).

Jalapeño pepper is the most important economic pepper in large part because of its intermediate pungency, it is used both fresh and dry. Several strategies have been established to increase production, one of which is through the use of phytohormones (Heuvelink and Korner, 2008; De Jong *et al*., 2009; Batlang *et al*., 2016). Phytohormones are widely used in agriculture to increase plant growth and yield by increasing the number of fruits, establishment of the fruit and its size. Productivity in horticulture often depends on the manipulation of the crop by chemists and it is regulated by phytohormones in the processes of plant development (Canli *et al.*, 2014; Carneiro *et al*., 2016; Kong *et al.*, 2016). Gibberellins are phytohormones that play essential functions during the stages of plant development, including germination of the seed, flowering, senescence of the fruit, improving the yield and establishment of the fruit, abscission, regulation of some metabolic processes, and have been related to tolerance to temperature or stress conditions (Kazemi, 2014; Guang-Long *et al*., 2015; Honda *et al*., 2016).

Plants of *Capsicum annuum* var. Bob-02 treated with cytokinins and gibberellic acid at concentrations of 10, 15, 20 and 25 mg L^{-1}, this increased the crop yield. The increase in yield is due to the fact that gibberellic acid is associated with an increase in the fresh weight and length of the fruit (Batlang, 2008; Sandoval-Oliveros *et al*., 2017).

Another study was carried out to determine the effect of 2 ppm of 2,4-D, 5 ppm of triacontanol (TRIA), 40 ppm of NAA and 10 ppm of GA_3 on the growth and yield of the Jwala and Suryamukhi pepper cultivars. It was found that all treatments showed an increase of 28.75%, 25.70%, 13.61% and 2.3%, respectively, on the performance compared to the control. On the other hand, the application of GA_3 (10 ppm) increased the amount of ascorbic acid in the fruit (Chaudhary *et al*., 2006; Ramírez *et al*., 2010).

The jalapeño is the pepper with more demand in the world. The importance of this crop highlights the need to increase yield per unit area in the field and greenhouse to obtain greater economic benefits for producers. The goal of this study was to determine the effect of different concentrations of GA_3 on the performance of jalapeño pepper variety Huichol under greenhouse conditions.

Materials and methods

The present work was carried out in two successive experiments. Experiment 1 was established in a greenhouse of the Technological Institute of Celaya (ITC) and the evaluations were carried out in the Molecular Biology Laboratory of ITC. The sowing date was February 2, 2015 and the crop cycle ended on august 1 of the same year. Jalapeño pepper seed of the variety “Huichol” provided by the State Committee of Plant Health of Guanajuato AC. (CESAVEG) was used, which first began to germinate on paper towels in plastic trays and in a growth chamber at a temperature of 26 °C with 16 h light and 8 h dark. 15 d after sowing, the seedlings were transplanted into 50 cavity plastic trays with a substrate composed of a mixture of Canadian peat "peat moss", vermiculite and expanded perlite in a ratio of 3:1:1, respectively. Finally, 20 d after the first transplant, these were re-transplanted into 30 x 30 cm plastic bags, using the same mixture of substrates in the same proportion.

In this experiment, a completely randomized two-factor experimental design was used. Factor 1 corresponded to GA_3 concentrations applied to pepper plants: 0 mg L^{-1}, 10 mg L^{-1}, 30 mg L^{-1}, 50 mg L^{-1} and 500 mg L^{-1} and factor 2 at number of applications of gibberellins to the crop: 1 application and 2 applications. The first application was made when the plants reached the stage of four true leaves (42 d after sowing) and the second application was made when the plants were in the flowering stage (87 d after sowing).

Irrigations were carried out daily with a nutrient solution 8-16, which was prepared by dissolving 100 mL of a commercial liquid fertilizer composed of 8 and 16 units of N and P, respectively, in 50 L of water. Likewise, microelements were applied every 15 d. The 500 mL of nutrient solution was dosed to each plant. The variables that were evaluated were the following: length of fruit, diameter of fruit; fresh weight of fruit, total fresh weight, dry weight of fruits, total dry weight and number of total fruits.

For experiment 2, jalapeno pepper seed of the same variety was used. Seed germination and plant transplants were the same as in experiment 1. The transplant of seedlings to trays of 50 cavities was carried out at 15 d after they were put to germinate. The transplant to plastic bags was performed at 44 d after the first transplant was performed.

This experiment was implemented according to an experimental design of two factors in random blocks. Factor 1 corresponded to GA_3 concentrations applied to pepper plants: 0 mg L^{-1}, 10 mg L^{-1}, 30 mg L^{-1}, 50 mg L^{-1} and 500 mg L^{-1} and factor 2 at number of GA_3 applications to the crop: 1 application and 2 applications. The first application of gibberellins was performed at 63 d after sowing and the second at the flowering stage (89 d after sowing).

The application of the irrigations was carried out in the same way as Experiment 1. The fertilization was carried out in each irrigation through the application of potassium nitrate (KNO_3) and calcium nitrate [$Ca(NO_3)_2$] soluble in water. The 500 mL of water was applied to each plant with the dissolved fertilizers. The variables that were evaluated were the following: number of total fruits; fresh weight of ripe fruits; fresh weight of total fruits; dry weight of ripe fruits; dry weight of total fruits; final height of plant, fresh weight of total plant and dry weight of total plant.

In both experiments the statistical analyzes were made with the statistical program SAS (SAS Institute, 2002). The mean comparisons were made by Tukey (α= 0.05). The graphics were made with the Microsoft Excel 2007® spreadsheet (Microsoft Corp., USA).

Results and discussion

For experiment 1, analysis of variance of the performance variables was performed (Table 1), these showed that the number of applications of GA_3 did not affect any of the variables evaluated. On the contrary, GA_3 application treatments affected ($p \leq 0.05$) fruit diameter, as well as ($p \leq 0.01$) fruit length, fresh fruit weight, total fresh weight, fresh fruit weight, to the total dry weight and the number of total fruits. The interaction between applications and treatments did not affect any of the variables evaluated.

Table 1. Mean squares and statistical significance of performance variables of experiment 1.

FV	GL	LF	DF	PFFR	PFTOT	PSFR	PSTOT	NFTOT
AP	1	0.29 ns	0.13 ns	440.9 ns	101.9 ns	0.68 ns	0.45 ns	20.5 ns
TR	4	2.8 **	0.34 *	21710.9 **	32589.9 **	358.3 **	1135.3 **	284.1 **
AP*TR	4	0.69 ns	0.24 ns	3254.6 ns	9425.4 ns	40.21 ns	367.7 ns	68.1 ns
Error	40	0.45	0.11	1890.5	6015.1	33.3	213.7	18
CV (%)		17.3	19.7	41.7	38.6	49.2	41.8	46.9

FV= sources of variation; AP= applications; TR= treatments with GA_3; CV= coefficient of variation; GL= degrees of freedom; LF= length of fruit; DF= diameter of fruit; PFFR= fresh weight of ripe fruits; PFTOT= total fresh weight; PSFR= dry weight of mature fruits; total dry weight; NFTOT= number of total fruits. *, **= significant with $p \leq 0.05$ and with $p \leq 0.01$, respectively; ns= not significant.

The previous results show that the treatments with GA_3 affected the commercial and biological performance of jalapeño pepper variety huichol produced in greenhouse, since all the variables studied showed significant differences. The application of GA_3 reduces the fall of flowers and fruits which increases the production of pepper, since it increases the growth of plants and improves the yield by increasing the number and mooring of fruits and the increase in size of these (Batlang, 2008; Carneiro *et al*., 2016; Mesejo *et al*., 2016).

The increase in the number of flowers per plant by the application of products with phytoregulators with respect to the control treatment, may be due to the fact that the applied products contain gibberellins, which are chemical substances able to promote the formation of flowers in certain specific environmental conditions. temperature and light that control their formation (Ramírez-Luna *et al*., 2005).

The comparison of means of Tukey (Table 2), showed that the treatment of GA_3 that presented the greatest effect in all the variables evaluated was the treatment of 0 mg L^{-1} (control) following in descending order in terms of the response of the treatments of 10 mg L^{-1}, 30 mg L^{-1}, 50 mg L^{-1} and 500 mg L^{-1}; that is, there is a greater effect of the lowest dose (without GA_3) at the highest dose. Therefore, the control treatment (0 mg L^{-1}) showed the highest fruit yield followed by that of 10 mg L^{-1} which is statistically similar to this one. The previous behavior is attributed to the fact that in this experiment an optimum fertilization was provided with macro and micronutrients in the crop, which contributed greatly to a greater mooring of fruits and the effect of the gibberellins was mainly directed to the foliage.

Table 2. Comparison of Tukey means of performance variables of experiment 1.

Treatment	LF	DF	PFFR	PFTOT	PSFR	PSTOT	NFTOT
0 mg L^{-1}	4.4 a	1.8 a	172.3 a	277.5 a	21.04 a	49.9 a	25.1 a
10 mg L^{-1}	4.2 a	1.8 a	128.8 ab	240.2 ab	13.9 ab	41.2 ab	22.4 ab
30 mg L^{-1}	3.8 ab	1.7 ab	86.5 bc	189.2 ab	10 bc	32.5 ab	15.1 ab
50 mg L^{-1}	3.7 ab	1.6 ab	79.7 bc	151.9 b	7.5 bc	26.4 b	14.1 b
500 mg L^{-1}	3.1 b	1.3 b	53.9 c	145.4 b	6.1 c	24.3 b	13.5 b
DMS	0.8	0.4	55.5	99	7.3	18.6	10.8
CV (%)	17.3	19.7	41.6	38.6	49.1	41.8	46.9
Average	3.9	1.7	104.3	200.8	11.7	34.9	18

DMS= minimum significant difference; CV= coefficient of variation; LF= length of fruit; DF= diameter of fruit; PFFR= fresh fruit weight; PFTOT= total fresh weight; PSFR= fruit dry weight; PSTOT= total dry weight; NFTOT= number of total fruits. Stocks with the same letters are not statistically different (Tukey, 0.05).

In relation to the above, Ramírez-Luna *et al*. (2005) mention that in Pepper 'Habanero' the greater induction of mooring of flower and fruit by the application of evaluated products without any of the three main phytoregulators, was attributed to the influence of other components in products such as, macro and micro nutrients, as well as the presence of other compounds, which contributed to having healthier and well-developed plants. These same authors point out that the product called Maxigrow has very high levels of N, P, K and Ca that can participate in the endogenous formation of hormones in the plant, thus inducing a greater flowering. Heuvelink and Körner (2001) point out that the fresh weight of chili pepper fruits harvested from plants treated with auxins was always lower than the control.

As mentioned above, some results from other authors agree that fruit binding can also be strongly influenced by the formation of endogenous hormones induced by the levels of nutritional elements such as N, P and K that some commercial products have used in production of pepper. In this experiment the nutritive solution used in irrigation was the one that had the macroelements such as N and P and the addition of K through the water-soluble potassium nitrate to said solution, in addition to the addition of microelements, so that can consider that in experiment 1 the N, P, K and microelements played an important role in the behavior of the variables, so that fertilization had a greater influence on performance than the application of GA_3 in different doses. In relation to the above, there are no results reported in the literature that show the doses of N, P, K and other elements that when combined with gibberellins cause their effect not to be noticed, as in the present work, so that Study these behaviors in future research.

The highest values of the variable fruit length (Table 2) were 4.4 and 4.2 cm for the concentration of 0 mg L^{-1} and 10 mg L^{-1}, respectively. These were statistically similar. Similarly, the highest values of the variable fruit diameter were 1.8 cm for the concentration of 0 mg L^{-1} and 10 mg L^{-1}. The applications of 0 mg L^{-1} and 10 mg L^{-1} showed the best response in these variables, since they presented the largest and longest fruits.

Based on the results of experiment 1, the evaluation of experiment 2 was performed. Analysis of variance of the yield and biological variables evaluated in the second experiment (Table 3), showed that the GA_3 treatments affected ($p \leq 0.01$) to the number of total fruits, to the fresh weight of ripe fruits, to the fresh weight of total fruits, to the dry weight of ripe fruits, to the dry weight of total fruits, to the final height of the plant and to the dry weight of the total plant. The fresh weight of the total plant did not show significant differences. On the other hand, the number of applications affected ($p\leq 0.01$) the fresh weight of mature fruits, the fresh weight of total fruits, the dry weight of mature fruits and the dry weight of total fruits. Also, the interaction treatments x applications affected ($p\leq 0.01$) only the number of total fruits.

Table 3. Mean squares and statistical significance of yield and biological variables of experiment 2.

FV	GL	NFTO	PFFRM	PFFRT	PSFRM	PSFRT	AFPL	PFPLT	PSPLT
T	4	675.3**	25020.5**	21461.3**	206.3**	307.1**	1922.6**	14409.6ns	2303.3**
AP	1	8.7ns	73478.6**	81894.6**	254.7**	438.4**	444.4ns	12807.8ns	195.9ns
T*AP	4	263.3**	2128.2ns	3108.7ns	1.9ns	25.9ns	220.4ns	2387.8ns	248.8ns
Error	78	54.3	2143.9	2583.9	26.6	53.1	213.2	5799.8	164.5
CV (%)		33.4	34.5	30.9	38.3	40.7	17.7	24.7	27.7

FV= source of variation; T= treatments with GA_3; AP= applications, CV= coefficient of variation; GL= degrees of freedom; NFTO= number of total fruits; PFFRM= fresh weight of ripe fruits; PFFRT= fresh weight of total fruits; PSFRM= dry weight of ripe fruits; PSFRT= dry weight of total fruits; AFPL= final plant height; PFPLT= fresh weight of total plant; PSPLT= total plant dry weight. *, **= significant with $p\leq 0.05$ and with $p\leq 0.01$, respectively; ns= not significant.

The comparison of Tukey's means of GA_3 treatments (Table 4), showed that with the treatment of 500 mg L^{-1} the highest number of total fruits (27.6 fruits), the highest final plant height (92 cm) was obtained and the highest total plant dry weight (58.2 g). On the other hand, the highest fresh weight of ripe fruits was obtained with the control treatment 0 mg L^{-1} with 169.4 g. Whereas with the treatment of 10 mg L^{-1} of GA_3, the highest weight of fresh weight of total fruits (199.6 g), the highest dry weight of mature fruits (18.1 g) and the highest dry weight of total fruits were obtained (23.4 g). This may be due to the greater number of flowers produced that tied in fruits.

Table 4. Comparison of Tukey's means of yield and biological variables of jalapeño pepper from experiment 2.

Factors	NFTO	PFFRM	PFFRT	PSFRM	PSFRT	AFPL	PSPLT
Treatments of GA_3							
0 mg L^{-1}	12.1 c	169.4 a	178.4 ab	12.9 bc	14.3 c	65.5 b	27.7 b
10 mg L^{-1}	20.3 a	164.6 a	199.6 a	18.1 a	23.4 a	81 a	47 a
30 mg L^{-1}	24.3 ab	142.9 ab	183.5 ab	15.5 ab	21.2 ab	86.6 a	51.5 a
50 mg L^{-1}	25.7 ab	112.6 bc	145.5 bc	10.6 c	15.7 bc	87.8 a	46.7 a
500 mg L^{-1}	27.6 a	80.7 c	113.3 c	10 c	14.9 bc	92 a	58.2 a
Number of applications							
1 application	21.7 a	162.6 a	194.2 a	15.1 a	20.1 a	80.4 a	44.7 a
2 applications	22.3 a	105.5 b	133.9 b	11.7 b	15.7 b	84.8 a	47.7 a
CV (%)	33.4	34.5	30.9	38.3	40.7	17.7	27.7
Average	22	134.1	164.1	13.4	17.9	82.6	46.2

NFTO= number of total fruits; PFFRM= fresh weight of ripe fruits; PFFRT= fresh weight of total fruits; PSFRM= dry weight of ripe fruits; PSFRT= dry weight of total fruits; AFPL= final plant height; PSPLT= total plant dry weight; CV= coefficient of variation. Stocks with the same letters are not statistically different (Tukey, 0.05).

In this regard, Ouzounidou *et al*. (2010) point out that GA_3 showed better results than other growth regulators in terms of plant height and number of fruits per plant. On the other hand, Ramírez-Luna *et al*. (2005) mention that in the greenhouse the plants reached greater height, allowing the plant to increase its branching and as a consequence they had a better possibility of producing a greater quantity of flowers by a reduction in the percentage of loss of these. However, although the plants with the highest dose of GA_3 showed the highest height, the highest dry weight of the plant and the highest number of fruits per plant (greater mooring), the size and weight of fruits was lower than the other treatments.

The above can be due to the fact that the plants of this concentration allocate the greatest amount of assimilated to the elongation of stems, formation and growth of leaves and other organs and not to fruits. From the above it can be deduced that the low doses of gibberellic acid are the adequate ones to obtain a balance between mooring and size of fruits.

As mentioned above, in experiment 2 the 10 mg L^{-1} dose of GA_3 was the one that showed the best response in the yield variables as fresh weight of total fruits that was 12% higher than the control, dry weight of mature fruits superior to 29% with respect to the witness and dry weight of total fruits superior 39% with respect to the witness, possibly because this dose is the suitable one to favor the mooring of jalapeño fruits produced in greenhouse and so that these also are larger. These results coincide with one of the doses evaluated by Batlang (2008) and who points out that concentrations of 10, 15, 20 and 25 mg L^{-1} of accel (BA plus GA_{4+7}) increased the performance in pepper and this performance was influenced by the increase in the weight of fresh fruit and length of fruit, as well as the size of fruit and was attributed to gibberellins and their role in cell division.

Similarly, Abd and Faten (2009) point out that foliar application of GA_3 at a concentration of 25 mg L^{-1} of GA_3 produced the highest total yield of chili pepper produced in the open field. These last authors also mention that the main role of GA_3 is in the growth of plants and fruit yield, which is due to the elongation and increase of tissues in the plants which results in the increase of crop yield components.

On the other hand Ouzounidou *et al*. (2010); Chaudhary *et al*. (2006) found that there was an improvement in growth and performance in pepper with the GA_3 application compared to the control and attributed that this improvement may be due to a more efficient use of assimilates for reproductive growth (flowering and fruit mooring), a higher photosynthetic efficiency, an increase in the source in the plant, a reduction in respiration, an increase in translocation and the accumulation of sugars and other metabolites.

In the present work, the increase in yield was basically due to the weight of the fruits (Table 4) and the size of the fruits (data not shown), which coincides with Batlang (2008), who points out that the increase due to the treatments of growth regulators was generally accompanied by the increase in fresh fruit weight and fruit length. As can be seen, in the present work other intermediate doses between 10 and 30 mg L^{-1} were not evaluated, but according to the results of Batlang (2008); Abd and Faten (2009) and our results, it is possible that the adequate dose so that gibberellins have good response in the culture of pepper is between the range of 10 to 30 mg L^{-1} of GA_3, so in subsequent investigations can be made assessments of these doses to know their effect on performance.

Experiment 2 also showed that the distribution of dry matter in the fruits was greater in the control treatment (0 mg L^{-1}) with 52% of the total dry matter followed in descending order of the other treatments with 50%, 41%, 34% and 26% for the doses of 10, 30, 50 and 500 mg L^{-1}, respectively (Table 4). These results show that the largest amount of assimilates destined for fruit growth corresponded to the control and as the GA_3 dose increased there was a decrease in the assimilated partition destined for fruit growth.

Possibly the plants treated with gibberellins destine assimilated proportionally with the increase in the dose of GA_3 for the elongation of stems, growth of leaves and other organs of the plants, which causes that the proportion of assimilates that could be destined for the fruit growth. However, in this investigation despite the fact that, in the control treatment, the dry weight of total fruits represents the highest proportion of dry matter, this was lower than all treatments with gibberellins. Similar results were found by Heuvelink and Körner (2001) in pepper plants treated with exogenous auxins since only 50% of the total dry weight was distributed to fruits compared to 58% for the control treatment plants.

With regard to the number of applications of GA_3 (Table 4), it was found that a single application of gibberellins showed the best response in the fresh weight of ripe fruits (162.6 g), in the fresh weight of total fruits (192.4 g), in the dry weight of ripe fruits (15.1 g) and in the dry weight of total fruits (20.1 g). On the other hand, Ouzounidou *et al*. (2010) indicate that the sprinkling of GA_3 to pepper plants at two and three weeks intervals after germination increases yield and improves the quality of *Capsicum*. However, in this investigation it was found that a single application of GA_3 with the lowest dose (10 mg L^{-1}) is sufficient to observe an effect on performance, there being no significant difference in the application stage since the first was at 61 d and the second at 83 d (flowering stage). Possibly this difference in the results is due to the type of pepper with different response.

As described in the materials and methods section, the fertilization provided in this experiment was based on potassium nitrate (KNO_3) and calcium nitrate [$Ca(NO_3)_2$] soluble in water and applied to the roots, N in together with the GA_3, it contributed to crop yield.

In experiment 2 it is observed that GA_3 has a greater effect on yield than fertilization, although the function of N, P and K and other major and minor elements in pepper plants is deficient, since the yield obtained in the experiment is the result of the joint effect of gibberellins and fertilization. Belakbir *et al*. (1998) found that the application of GA_3 to chili pepper increased the concentration of Ca in the fruits, giving them firmness. It should be mentioned that, in general, the fruits harvested in the present work showed great firmness in both experiments, a result that can be attributed to the Ca applied in the fertilization.

On the other hand, Azofeifa and Moreira (2008) found that the nutrient that was absorbed by Jalapeño pepper plants throughout the crop cycle was K, followed in decreasing order by N, Ca, S, P and Mg. Likewise, they point out that at the end of the cycle, the plant accumulates K, Ca and Mg mainly in the aerial part and the regulation of this behavior is regulated by the fruiting event. For all the above, it can be inferred that the application of calcium nitrate in fertilization contributed greatly along with the GA_3 in the yield and quality of jalapeño pepper in this work.

Finally, when comparing the variables of yield of fresh weight and dry weight of total fruits in both experiments, it was found that the value of the fresh weight of total fruits of experiment 2 with the dose of 10 mg L^{-1} of GA_3 was higher 14% with respect to experiment 1 with the 0 mg L^{-1} dose of GA_3 (control). Similarly, the dry weight value of total fruits of experiment 2 with the 10 mg L^{-1} dose of GA_3 was higher than that of experiment 1 by 10% at the 0 mg L^{-1} dose of GA_3 (control). The previous results show that with a low dose of GA_3 and a fertilization with potassium nitrate and calcium nitrate, higher yields are obtained than using the nutrient solution in the production of greenhouse jalapeño pepper. This could offer an advantage to producers in the saving of agricultural inputs, since production costs would be cheaper to obtain a good production in the cultivation of pepper (Sun *et al*., 2016).

As already mentioned, in the present work the dose of GA_3 that showed the best response with a fertilization based on KNO_3 and $Ca(NO_3)_2$ was that of 10 mg L^{-1}, which is the lowest that was evaluated, so this is recommended for use in the production of jalapeño pepper in the greenhouse. However, it is necessary to continue researching the combination of GA_3 doses with the fertilization doses to generate knowledge in these aspects and thereby obtain a technological package of production for this crop.

Conclusions

The results of this work could be considered for commercial production, since gibberellins could be used as an input that combined with relatively low fertilization could help increase yield, which would ultimately result in significant savings in agricultural inputs.

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