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1.	Journal of the science of food and agriculture	61	78
2.	Journal of the Saudi Society of Agricultural Sciences	52	77
3.	Annals of Agricultural Sciences	25	38
4.	The Journal of Agricultural Science	25	36
5.	Bulgarian Journal of Agricultural Science	24	35
6.	Spanish Journal of Agricultural Research	22	32
7.	African Journal of Agricultural Research	21	31
8.	Journal of Agricultural Science and Technology (Tehran)	21	25
9.	Journal of Agricultural Science (Toronto)	20	28
10.	Russian Journal of Agricultural and Socio-Economic Sciences	20	27
11.	Chilean journal of agricultural research	20	26
12.	Turkish Journal of Agriculture-Food Science and Technology	18	25
13.	Agricultural Sciences (SCIRIP)	18	24
14.	Journal of Agriculture and Food Research	18	23
15.	Pakistan Journal of Agricultural Sciences	18	22
16.	Scientific Papers: Management, Economic Engineering in Agriculture & Rural Development	18	20
17.	Agricultural Research, India	17	27
18.	Frontiers of Agricultural Science and Engineering	17	27
19.	New Zealand Journal of Agricultural Research	17	27
20.	Indian Journal of Agricultural Sciences	17	21

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Paclobutrazol Applied on Cotyledonal Leaves and Quality of Cucumber, Squash, Melon and Watermelon Seedlings

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Abstract

The research was done to determine the effects of paclobutrazol (PBZ) through the dose of 150 mg·L⁻¹, on the quality of seedlings determined by the content of chlorophyll, height, leaf area, dry matter of roots and of the aerial part of cucumber, squash, melon and watermelon. Sowing of all species carried out on October 21, 2013 in polystyrene trays with 200 cavities filled with peat moss. Treatments were the doses of 150 mg of PBZ·L⁻¹ water and the control (distilled water). The solution with PBZ and the distilled water were applied only once with manual atomizer on cotyledonal leaves by mean of 25 shots made approximately with the same force, having put physical barriers between experimental units. In the four species (cucumber, squash, melon and watermelon) the PBZ increased the chlorophyll content in 26.0%, 14.9%, 19.4% and 26.5%, respectively, compared to the control; height decreased in 24.0%, 34.7%, 16.3% and 23.4%; leaf area decreased in 40.1, 0.5, 30.4 and 16.2%; the dry matter of roots increased in 20.0%, 62.5%, 85.7% and 19.7%; whereas in cucumber the dry matter of the aerial part increased 12.3%, in squash decreased 5.3%, and in melon and watermelon increased in the respective 22.9 and 3.3%, so that the 150 mg dose of PBZ can be used to produce seedlings with higher quality for transplant.

Keywords

Cucurbitaceae, Growth, Dose of Pbz, Dry Weight of Roots, Content of Chlorophyll

1. Introduction

Among the most cultivated cucurbits in Mexico are cucumber (*Cucumis sativus*

L.), squash (*Cucurbita pepo* L.), melon (*Cucumis melo* L.) and watermelon [*Citrullus lanatus* (Thumb.) Matsum. & Nakai]. With the first two species, in Sinaloa were sown 3442.8 and 3303.6 ha, respectively, during the Autumn-Winter and Spring-Summer periods of the agricultural cycle 2012-2013, in where the average yields respectively were obtained of 11.3 and 48.0 t·ha⁻¹; while with the last two species, during the same periods and the same cycle, 15 and 2784.5 ha, respectively, were planted to obtain the average yields respectively of 0 and 11.7 t·ha⁻¹ [1].

Pallardy [2] reported that the use of growth regulators is an alternative means to modify shoot growth and biomass accumulation. The responses that produce in plants that receive growth regulators are diverse: there is alteration of compounds in the buds, redistribution of photosynthesis products destined to the growth of the cup towards defense compounds, growth of the radical system and storage of energy [3]. Actually there are several technologies used as growth retardants, including paclobutrazol (PBZ), which is characterized by delaying cell division and elongation in tissues of the actively growing outbreak, without causing stem malformations or the leaves [4]. With said substance has been achieved to reduce shoot elongation, leaf expansion and stem diameter growth in many tree species [5], since it is an active inhibitor of gibberellic acid biosynthesis, retard the division and elongation cell, and consequently, growth in stem length of plants [6]. The retardant is absorbed passively through the leaves, stems and roots, and translocated by the xylem until the points of growth, where by inhibition of the action of gibberellin reduces cell division in the subapical part [7].

It has also been reported that between growth regulators is the paclobutrazol (PBZ), an inhibitor of gibberellins that is applied as solution to the soil where the roots of the trees are located, which once absorbed and translocated to the cup, this causes a reduction of the growth in length and diameter of new shoots [8]-[13].

With several research job, the effectiveness of PBZ to increase roots growth has been demonstrated [14]; increase the number, length and diameter of roots in cucumber, when the seeds are soaked in solution with 40 mg·L⁻¹ of PBZ, but the hypocotyl length is reduced [15]. In seedlings of bell pepper and eggplant, the dose of 150 mg·L⁻¹ increased the fresh and dry matter of roots and dry matter of the aerial part [16].

In dose of 1.0 mg·L⁻¹ applied to the soil or 25 mg·L⁻¹ in foliar application, the PBZ has caused decrease in plant height, is it increase the stem diameter and roots development, improved the photosynthetic activity and the balance of water and with it the quality of plants for transplant, and is accelerate the formation and harvest of tomato fruits (*Lycopersicon esculentum* Mill.) cultivar “Precador”, without leaving residues of PBZ in the fruits [17].

With the reduction in plant growth that cause the PBZ, is increases the storage of carbohydrates (reserve substances of plants) and also is increases the production

of chlorophyll and with this the of carbohydrates [18]. However, in the tree called white poplar (*Populus alba* L.), specie that in urban environments is use with ornamental purpose, the PBZ (0.4 and 0.8 g per plant with severe pruning), it significantly affected the growth of trunk, leaves and the ratio of total sugars/reducers, although the effect was lost in the next growth stage, perhaps because chlorophyll fluorescence (Fv/Fm) values were decreased, the PBZ did not improve plant vitality [19]. Contrary at this last, several authors have reported that PBZ increases the vitality of plants, understood this as the ability to tolerate stresses of biotic or abiotic origin [18] [20] [21]. In oil palm (*Elaeis guineensis* Jacq.), the PBZ increases leaf greenness and total chlorophyll content [22], equal that in maize and wheat [23].

In field production systems, the cucumber is managed in direct sowing, but in greenhouse conditions, to advance the harvest and take advantage of market windows, evade rodents and more efficiently use the high-cost hybrid seed, it is frequent produce seedlings for transplant [24], which must be vigorous to ensure a good establishment and high production. The vigor is evaluated with the stem diameter, root growth, leaf area and dry matter in *Solanum lycopersicon* Mill. [24] [25]. For transplant are important the morphological measurements of seedlings, such as root length and height of seedlings, to ensure high presence of plants in the field or greenhouse [26].

The objective of the research was to determine the effects that produce the paclobutrazol through the 150 mg·L⁻¹ dose in the seedling quality, determined by the chlorophyll content, height, leaf area, dry matter of roots and of the aerial part of cucumber, squash, melon and watermelon.

2. Materials and Methods

The present study was carried out in the greenhouse of the Faculty of Agronomy of the Autonomous University of Sinaloa, Mexico, located between the geographical coordinates 24°37'29"LN and 107°26'36"LO, km 17.5 of the road Culiacan-Eldorado, during the period autumn-winter of the agricultural cycle 2013-2014, where was used cucumber of the cultivar "Alcázar", squash cultivar "Adelita", melon cultivar "Saturn" and watermelon of the cultivar "Jubilee", Sowing was done on October 21, 2013, in polystyrene trays with 200 cavities filled with peat moss (Sogemix-VTM, Quebec, Canada). Seedlings were irrigated with the necessary frequency, with 1.0 g·L⁻¹ of N, using urea as a source of nutrition.

The experimental design was randomized complete blocks with four replicates, where each experimental unit consisted of 100 plants (half tray) and the sample of 20 randomly selected plants. Treatments were the dose of 150 mg·L⁻¹ of PBZ (that in other researches and species was the most appropriate in the effects caused) and distilled water (control). The dose of PBZ and distilled water were applied on October 30, 2013, only once through 25 shots with a hand spray on the cotyledonal leaves of the seedlings. Eight days after application (daa) of PBZ, the chlorophyll content was evaluated with a Spad-502 chlorophyll

estimator (Minolta Co., Ltd. Japan), the evaluation was performed in the middle of 20 selected cotyledonal leaves random; the height was measured at 12 daa, from the base of the stem until the apical bud of the plant. The leaf area was evaluated in the first true leaf at 20 daa, and was calculated agree with the formula: leaf area = (length \times width) \times 0.851 [27]. At 46 daa the roots and aerial part of the seedlings were dried in a stove at 72°C for 48 h until constant weight, to then determine the dry weight on a precision scale. Statistical analyzes were performed using the MINITAB statistical package 16, through analysis of variance and comparison of means with the Tukey test ($P \leq 0.05$).

3. Results

In the chlorophyll content of cucumber leaves significant differences were detected (Tukey, 0.05), such that in those plants treated with PBZ an increase of 26% was observed with respect to the control (**Table 1**), while height decreased in 24% and leaf area 40.1%, compared to the respective control averages. In dry matter of the roots and aerial part, the PBZ was effective to induce greater accumulation, 20% more in roots and 12.3% more in the aerial part.

In squash (**Table 2**), the content of chlorophyll and dry matter of roots increased 14.9% and 62.5%, respectively; the height decreased 34.7%, but the leaf area and dry weight of the aerial part were statistically equal, with respect to the averages that were obtained in the control.

In **Table 3** it can be observed that the chlorophyll content of the melon leaves had their greatest expression in the seedlings treated with PBZ, since in relation with the control increased 19.4%; but the same seedlings had 16.3% less height and 30.4% less leaf area. However, the dry matter of roots it increased on 85.7%, and although the dry matter of the aerial part was expressed without statistical differences, said biomass increased by 22.9%, in comparison to the average of dry matter of the control seedlings.

In watermelon seedlings, the PBZ caused a 26.5% increase in the chlorophyll content in comparison with controls seedling (**Table 4**); also caused that the height and leaf area to decrease 23.4% and 16.2%, respectively; however, the dry matter of the roots increased 19.7% and of the aerial part 3.3%.

4. Discussion

The increase of leaf chlorophyll content in the four species (cucumber, squash, melon and watermelon), coincides with the reported by Percival and Albalushi

Table 1. Influence of paclobutrazol (PBZ) in the content of chlorophyll, height, leaf area and dry matter of roots and aerial part of cucumber seedlings.

Treatments	Chlorophyll (Spad units)	Height (cm)	Leaf area (cm ²)	Dry matter of roots (g)	Dry matter of aerial part (g)
Control (water)	33.1b	11.7a	16.2a	0.10b	0.57b
PBZ (150 mg·L ⁻¹)	41.7a	8.9b	9.7b	0.12a	0.64a

Different letters in the same column indicate significant differences (Tukey, $P \leq 0.05$).

Table 2. Influence of the paclobutrazol (PBZ) in the content of chlorophyll, height, leaf area and dry matter of roots and aerial part of squash seedlings.

Treatments	Chlorophyll (Spad units)	Height (cm)	Leaf area (cm ²)	Dry matter of roots (g)	Dry matter of aerial part (g)
Control (water)	43.0b	15.0b	16.7a	0.08b	1.21a
PBZ (150 mg·L ⁻¹)	49.4a	9.8a	16.6a	0.13a	1.15a

Different letters in the same column indicate significant differences (Tukey, $P \leq 0.05$).

Table 3. Influence of the paclobutrazol (PBZ) in the content of chlorophyll, height, leaf area, dry matter of roots and aerial part of melon seedlings.

Treatments	Chlorophyll (Spad units)	Height (cm)	Leaf area (cm ²)	Dry matter of roots (g)	Dry matter of aerial part (g)
Control (water)	32.0b	13.5a	7.9a	0.07b	0.61a
PBZ (150 mg·L ⁻¹)	38.2a	11.3b	5.5b	0.13a	0.75a

Means with different literal in the same column are statistically different (Tukey, $P \leq 0.05$).

Table 4. Influence of the paclobutrazol (PBZ) in the content of chlorophyll, height, leaf area, dry matter of roots and aerial part of watermelon seedlings.

Treatments	Chlorophyll (Spad units)	Height (cm)	Leaf area (cm ²)	Dry matter of roots (g)	Dry matter of aerial part (g)
Control (wate)	27.9b	12.4a	11.7a	0.1525b	0.7525a
PBZ (150 mg·L ⁻¹)	35.3a	9.5b	9.8b	0.1825a	0.7775a

Means with different literal in the same column are statistically different (Tukey, $P \leq 0.05$).

[18], since they also found more chlorophyll in plants treated with PBZ; is also related to what [17] reported in how much to that with the PBZ is induced improvement in the photosynthetic activity of tomato seedlings, since the increase the chlorophyll in the seedlings the photosynthetic process also increased; also have relation with the results of Partida *et al.* [23], since they observed more chlorophyll in plants of maize, wheat (cultivars “Río Colorado”, “Baviacora” and “Romoga F-96”), and bell pepper cultivar. “Taranto” but disagrees with the results reported by Martínez *et al.* [19], since they observed decreased of values of chlorophyll fluorescence (Fv/Fm).

The estimated decreases in seedling height coincide with the results of Kever *et al.* [8], Burch *et al.* [5], Singh [9], George and Nissen [10], Williams *et al.* [11], Bai *et al.* [12] and Grochowska *et al.* [13], since these authors have reported that the PBZ, once absorbed and translocated to the canopy of the plants, causes reduction of the growth in length of new shoots. Likewise, with the results published by Giovinazzo *et al.* [28], as these authors observed that PBZ reduced the size of tomatoes seedlings of the cultivars “Francysset”, “Pavia” and “Montego” tomatoes by 45%, of equal form with the of Velázquez *et al.* [29], who found that in tomato plants of the cultivar “Rio Grande” the PBZ retarded growth when foliarly applied at doses of 100, 150 or 200 mg·L⁻¹ in plants of two

to four true leaves. The results that Balamani and Poovaiah [30] obtained in potato also have relation with those of this investigation, since they reported that at using PBZ the height of plants decreased; likewise, with the results of Flores *et al.* [31], which they observed decreased height of potato plants, after applying 150 mg·L⁻¹ of PBZ, when the plants had 30 days old after the emergency.

The decreases of the leaf size here exposed coincide with those of Burch *et al.* [5], since they found that the PBZ, in addition to reducing shoot elongation, reduced leaf expansion in many tree species. The estimated results on dry matter of roots and of the aerial part have relation with those of Partida *et al.* [16], since in pepper seedlings they found that the PBZ at doses of 100, 150 or 250 mg·L⁻¹ increased the length of the roots, with 100, 150, 200, 250, 300 or 350 mg·L⁻¹ increased the dry matter of them, while the dry matter of the aerial part only increased with the dose of 150 mg·L⁻¹; in eggplant also they found that with 100, 300 or 350 mg·L⁻¹, the PBZ increased the dry weight of roots and of the aerial part.

In the dry matter aspect of roots, the results also have relation with the of Watson [14], since this author refers that the PBZ increased the growth of roots; likewise, with the Berova and Zlatev [17], who observed that with 1.0 mg·L⁻¹ applied to the soil or with 25 mg·L⁻¹ in foliar application, the PBZ increased the development of roots in tomato seedlings. However, the results of this research differ from reported by Wood [32], through which is reported that the PBZ reduced the root growth in pecan trees [*Carya illinoensis* (Wangenh) C. Koch], which perhaps it was because of the difference in species and the dose applied.

As reported by Wien [24], these results can be used to advance harvest, take advantage of market windows, evade rodents and more efficient use of hybrid seed, when producing seedlings for transplant with the vigor that give plant height, stem diameter and the growth of roots, since according to Leskovar [26], the length of roots and height of seedlings allow to ensure high presence of plants in the field or greenhouse. sswWs

5. Conclusion

The dose of 150 mg·L⁻¹ of PBZ caused a decrease in height of cucumber, squash, melon and watermelon seedlings, and was effective to increase the chlorophyll content in its leaves and dry matter of roots; in only three of the species the leaf area decreased and the dry matter of the aerial part increased, since in squash did not diminish the leaf area and neither was it increased the dry matter of the aerial part, in such a form that the dose of 150 mg·L⁻¹ of PBZ can be used to apply in the cotyledonal leaf stage and produce seedlings with higher quality and probability of success for establishment in the production systems.

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