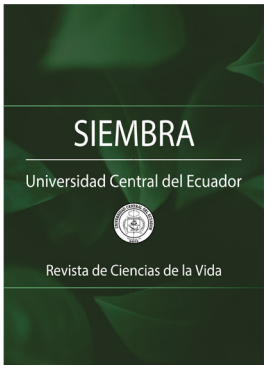
Effect of two growth regulators on the fruit crown of Ananas comosus L. Merr. cv 'MD-2'



Efecto de dos reguladores de crecimiento sobre la corona del fruto de Ananas comosus L. Merr. cv 'MD-2'

Segundo Bello-Amez[1], Antonella Roman-Aquino[2], Maira Elera-Anicama[3], Ricardo Borjas-Ventura[4], Leonel Alvarado-Huamán[5], Viviana Castro-Cepero[6], Alberto Julca-Otiniano[7]

Siembra 11 (2) (2024): e6284

Recibido: 19/02/2024 / Revisado: 26/03/2024 / Aceptado: 04/06/2024

[1] Frutas Golden. Av. Nicolás Arriola 360. 15034. San Luis, Lima, Perú.
✉ sbello@frutasgolden.com
https://orcid.org/0000-0002-2405-7138

[2] Universidad Nacional Agraria La Molina. Fitotecnia/ Agronomía. Av. Molina s/n.15024. La Molina, Lima, Perú.
✉ antonellajudithromanaquino@gmail.com
https://orcid.org/0009-0008-3764-2521

[3] Universidad Nacional Agraria La Molina. Fitotecnia/ Agronomía. Av. Molina s/n.15024. La Molina, Lima, Perú.
✉ 20191039@lamolina.edu.pe
https://orcid.org/0009-0007-1120-5270

[4] Universidad Nacional Agraria La Molina. Fitotecnia/ Agronomía. Av. Molina s/n.15024. La Molina, Lima, Perú.
✉ rborjas@lamolina.edu.pe
https://orcid.org/0000-0001-7819-1810

[5] Universidad Nacional Agraria La Molina. Fitotecnia/ Agronomía. Av. Molina s/n.15024. La Molina, Lima, Perú.
✉ leoneleduardo.alvaradohuaman@wur.nl
https://orcid.org/0000-0002-2121-2454

[6] Universidad Nacional Agraria La Molina. Biología/Ciencias. Av. Molina s/n.15024. La Molina, Lima, Perú.
✉ vcastro@lamolina.edu.pe
https://orcid.org/0000-0001-8747-2665

[7] Universidad Nacional Agraria La Molina. Fitotecnia/ Agronomía. Av. Molina s/n.15024. La Molina, Lima, Perú.
✉ ajo@lamolina.edu.pe
https://orcid.org/0000-0002-3433-9032

**Autor de correspondencia:*
rborjas@lamolina.edu.pe

SIEMBRA
https://revistadigital.uce.edu.ec/index.php/SIEMBRA
ISSN-e: 2477-8850
Frequency: half-yearly
vol. 11, issue 2, 2024
siembra.fag@uce.edu.ec
DOI: https://doi.org/10.29166/siembra.v11i2.6284

Abstract

The objective of this trial was to determine the effect of two growth regulators on the fruit crown of *Ananas comosus* L. Merr. cv 'MD-2' in San Ramón, Chanchamayo, Peru. Folicur® EW (Tebuconazole) and Big Hor (Auxin + Cytokinin + Gibberellin) were tested, both with two doses (1 and 2 %) and at 45, 55 and 65 days after flower induction treatment [FIT]. A DBCA with 13 treatments and four replications was used. Harvesting was done 170 days after FIT and crown length, crown weight, number of leaves per crown, fruit weight (with and without crown), fruit height and diameter, brix degrees, pH and titratable acidity were evaluated. Both products decreased crown growth; this effect was on crown length and weight, not on the number of leaves in the crown, always the effect of Tebuconazole was significantly greater than that of Big Hor. In no case was there an effect on fruit weight and chemical characteristics. However, in some Tebuconazole treatments, fruit diameter was significantly increased. It is recommended to continue investigating growth regulators in other varieties, different agronomic management conditions and varying climates.

Keywords: crown size; fruit size; fruit quality; pineapple; Tebuconazole

Resumen

Este trabajo tuvo como objetivo determinar el efecto de dos reguladores de crecimiento sobre la corona del fruto en *Ananas comosus* L. Merr. cv 'MD-2' en San Ramón, Chanchamayo, Perú. Se probaron el Folicur® EW (Tebuconazole) y Big Hor (Auxina + Citoquinina + Giberelina), ambos con dos dosis (1 y 2 %) y a 45, 55 y 65 días después del tratamiento de inducción floral [TIF]. Se usó un DBCA con 13 tratamientos y cuatro repeticiones. La cosecha se hizo 170 días después del TIF y se evaluó longitud de la corona, peso de la corona, número de hojas/corona, peso del fruto (con y sin corona), altura y diámetro de fruto, grados brix, pH y acidez titulable. Ambos productos disminuyeron el crecimiento de la corona, este efecto fue sobre la longitud y el peso, no sobre el número de hojas de la corona, siempre el efecto del Tebuconazole, fue significativamente mayor que el Big Hor. En ningún caso, hubo un efecto sobre el peso y las características químicas del fruto, aunque en algunos tratamientos con Tebuconazole, el diámetro

del fruto se incrementó significativamente. Se recomienda continuar investigando los reguladores de crecimiento en otras variedades, diferentes condiciones de manejo agronómico y climas.

Palabras claves: tamaño de la corona; tamaño de fruto; calidad del fruto; piña; Tebuconazole

1. Introduction

Pineapple is a fruit whose center of origin is in in tropical America, specifically in South America, where it was used diversely by indigenous peoples (Maraví Loyola, 2018). Currently, in the world, pineapple production is led by Indonesia, Philippines, Costa Rica and Brazil (Shahbandeh, 2024). In the case of Peru, pineapple has been gaining consumer acceptance. It is among the top 30 crops on the domestic market. There were 16 000 ha of this crop in 2018 (Ministerio de Agricultura y Riego [MINAGRI], 2019). The main producing regions are Junín (42.0 %) and Loreto (13.7 %), and the main cultivar planted is Golden (Redagricola, 2021). Globally, Peru ranks 48th as a pineapple exporter (PortalFrutícola, 2021). Although practically all of it is consumed by the domestic market, this fruit has a high potential for agroexport (Servicio Nacional de Sanidad Agraria del Perú [SENASA], 2017); which is why there is increasing concern for achieving high quality standards.

Fruit quality is evaluated considering various characteristics, including the appearance and size of the crown. The latter should be in proportion to the fruit (crown length/fruit length ratio), being a desirable range between 0.33-1.5 (Paull & Chen, 2014); although this interval may change slightly, according to the Food and Agriculture Organization of the United Nations (FAO, 2011), the crown should represent between 0.59 and 1.5 times the fruit length. These data suggest the visual importance of the size of the crown, which obviously affects its commercialization and sale price. Also, and from a logistical point of view, it is important to control the size of the crown, as it is closely related to the size of the containers used for transport (Paull & Chen, 2014). However, in warm and humid conditions crown growth can be excessive.

In the past, to achieve the desired fruit size and reduce crown size, the crown meristem was removed without damaging the fruit (Bello, 1991); however, this method was delicate, tedious and costly. In that sense, in recent years, fruit and crown size have been controlled with growth regulators (Norman, 1977; Sahoo et al., 2015; Yasser-Lorente et al., 2021) which are defined as chemical compounds synthesized in laboratories capable of regulating molecular, physiological and biochemical processes, which in turn, regulate crop growth and development, i.e., these substances, working at low concentrations, can promote or limit growth (Ferguson & Lessenger, 2006; Tadeu Dias, 2019).

Among the latter, it can be mentioned auxins, cytokinins and gibberellins (Ferguson & Lessenger, 2006) whose uses range from plant propagation to increasing fruit quality and size (Borjas-Ventura et al., 2020; Rodrigues et al., 2020; Sáez Reyes, 2016). The use of these regulators in pineapple is scarce; but the few experiences have given positive results, and it is considered that, depending on the dose and composition, their application can improve fruit weight and quality (Padilla Laso, 2015). But there are chemical compounds that inhibit growth in the plant, one of these are the triazoles (Desta & Amare, 2021), which interfere in the synthesis of gibberellic acid by interrupting the oxidation of kaurene, kaurenol and kaurenal bringing about a decrease in cell division (Grossmann, 1990), and consequently a reduction in plant size without affecting other characteristics, such as yield. Among the different chemical substances belonging to the triazole group, we have Tebuconazole, a product widely used in agriculture as a fungicide. But the effect of this product on the growth of the pineapple fruit crown is poorly known, which limits its good use in the management of this crop in the field.

Pineapple is a crop that has been greatly technified in recent years in Peru, but there are some aspects in which more research is still needed; for example, in the use of growth regulators. Also, there is a large number of growth regulators on the Peruvian market that have not been tested on this crop, which makes it difficult to make a good choice of the molecule to use, especially among small farmers. Considering the aforementioned considerations, this study was carried out with the objective of determining the effect of two growth regulators on fruit crown size in *Ananas comosus* L. Merr. cv 'MD-2' in San Ramón, Chanchamayo, Peru.

2. Materials and Methods

This trial was carried out in the Fundo La Bretaña (840 m asl, 11°07'17" S and 75°21'10" W) located in the district of San Ramón, province of Chanchamayo, Junin region, Peru. The area is characterized by having an average temperature of 32°C and a rainfall of 1 850 mm, irregularly distributed throughout the year. It is considered that there are three periods of precipitation: high (January-April), medium (September-December) and low (May-June).

The trial lasted 16 months. Sowing started in March 2015 and harvest in March 2017, pineapple suckers cv MD2 were planted, each with an approximate weight of 300 g. The planting density was 50,000 plants per ha^{-1}. The chemical characteristics of the soil were: pH 4.6, organic material content of 1.8 %, phosphorus content of 5.5 ppm, potassium content of 201 ppm, and a CEC of 5.32 meq 100 g^{-1} of soil.

The crop was managed following commercial criteria of Fundo La Bretaña; for fertilization 500, 100, 600 and 50 kg ha^{-1} of N, P_2O_5, K_2O and MgO were applied using Urea, diammonium phosphate, potassium chloride and Sulpomag as sources. Phosphorus was applied in its entirety at the time of transplantation, while nitrogen, potassium and magnesium were applied at 2, 4, 6 and 8 months after transplantation. The Floral Induction Treatment [FIT] was applied by applying Ethrel (480 g l^{-1} of Ethephon), in 10 month-old plants, at a dose of 2 l ha^{-1}. Additionally, and together with the application of Ethrel, 2 kg of urea dissolved in 200 liters of water were applied.

In this experiment, the effect of two growth regulators was studied, for which two commercial products were used: Folicur® EW and Big Hor. The first of them has Tebuconazole as an active ingredient, which belongs to the family of triazoles (growth inhibitor or retardant); while the second has in its composition Auxins (0.13 g l^{-1}), Cytokinins (2.50 g l^{-1}), Gibberellins (0.13 g l^{-1}) that are considered growth stimulants (Ferguson & Lessenger, 2006). In addition, the product is easily found in the Peruvian market. Both products were applied at three times (45, 55 and 65 days after FIT) and at two different doses (1 % and 2 %). The details of the treatments are presented in Table 1, in each plant 10 ml of the solution was applied.

Table 1. Treatments applied to pineapple cv 'MD-2' in Chanchamayo, Peru.

Treatment	Description	Dosage	Application time [DAFIT]*
T1	Folicur® EW	1%	45
T2	Folicur® EW	1%	55
T3	Folicur® EW	1%	65
T4	Folicur® EW	2%	45
T5	Folicur® EW	2%	55
T6	Folicur® EW	2%	65
T7	Big Hor	1%	45
T8	Big Hor	1%	55
T9	Big Hor	1%	65
T10	Big Hor	2%	45
T11	Big Hor	2%	55
T12	Big Hor	2%	65
T13	Control	--	--

* DAFIT: Days after flower induction treatment

The pineapple fruits were harvested 170 days after the FIT, in each fruit the following variables were evaluated: crown length (cm), from the base to the apex of the longest leaf, crown weight (g), number of leaves in each crown, fruit weight (with/without crown), fruit height and diameter (cm), soluble solids (Brix), pH and titratable acidity (%) using 0.1 N NaOH and phenolphthalein, and 5 ml of diluted pineapple juice in 25 ml of distilled water.

In this trial, a Completely Randomized Block Design [CRBD] was used, with 13 treatments and four repetitions. Each experimental unit consisted of four rows of 16 plants each (64 plants per e. u.), of which 16 plants from the two central rows were evaluated to avoid the edge effect. For the variables number of leaves/

crown, weight of the fruit with crown and titratable acidity, a data transformation was made, because they did not meet the assumptions of normality and homogeneity of variance (Box et al., 2008). Subsequently, a comparison of means was made with the Tukey test (95 %) using the R software. In addition, the Pearson correlation coefficient was determined.

3. Results and Discussion

The control of the size of the pineapple fruit crown is very important since its uncontrolled growth can be detrimental to the commercialization of this tropical fruit. In this sense, this trial sought to determine the best way to control the growth of this tissue by using a growth stimulant Big Hor containingauxins, cytokinins and gibberellins and by using a growth inhibitor Folicur® EW whose active ingredient is Tebuconazole. The growth of the crown was evaluated by measuring its length, weight and the number of leaves (Figure 1). Statistical differences were only observed in the first two variables, in fact, in both cases the control treatment showed the highest values followed by Big Hor and Folicur® EW ($p \leq 0.05$).

In particular, the control treatment showed a crown length of 32.68 cm, which was around 24 % and 114 % higher than the values obtained by the plants that received Big Hor and Folicur® EW, respectively. In the case of crown weight, the control had 320.55 g, which was 22 % and 132 % higher than the weights obtained by the plants applied with Big hor and Folicur® EW ($p \leq 0.05$). Although, for both variables, the most drastic falls were those plants subjected to Folicur® EW applications: T3 (Folicur® EW: 1 % and 65 DAFIT), T5 (Folicur® EW: 2 % and 55 DAFIT), and T6 (Folicur® EW: 2 % and 65 DAFIT), as shown in Figure 1. This drop in crown length caused by Tebuconazole is related to its ability to inhibit gibberellin synthesis, by preventing the formation of ent-kaurenoic from ent-kaurene and thus stunt growth (Rademacher, 2016). Growth reduction using Triazoles has been reported for other crops such as melon (Mohsin et al., 2019), tomato (Arivalagan & Somasundaram, 2017) and passion fruit (Teixeira et al., 2019). Likewise, no symptoms of phytotoxicity were observed, and there was also a high correlation between weight and crown length (Table 2).

From these results it can be inferred that Tebuconazole applications made at 65 DAFIT (both at 1 % and 2 %) were much more efficient in reducing the weight of the crown tissue, as shown in Figures 1 and 2. According to Cunha (2005), after 60 days of floral induction, the crown begins to form. The result was similar when the Big Hor was applied, at 65 DAFIT, it also significantly decreased the length of the crown (Figure 1A); but the application of this type of product could be extended up to 70 and 100 DAFIT, as indicated by other authors (Barrantes Jiménez, 2008).

Although there was a decrease in crown height due to Tebuconazole, the number of crown leaves was statistically the same (73) for all treatments ($p \leq 0.05$). This behavior was expected since one of the characteristics of these compounds is that they do not affect the number of leaves (Grossmann, 1990).

It is interesting to note that the application of the Big Hor stimulant (auxins + cytokinins + gibberellins) inhibited crown length and weight when compared to the Control treatment ($p \leq 0.05$) (Figure 1). A similar result was observed by Barrantes Jiménez (2008) who found that applying a growth stimulator reduced the weight of the crown. This response may be due to an alteration in the flow of nutrients and sugars (Harms & Oplinger, 1988) in favor of the fruit caused by this growth regulator. In fact, an increase in the diameter of the fruit was evidenced, although it was not significant (Figure 3). On the contrary, the application of treatments T2 (Folicur® EW + 1 % + 55 DAFIT), T3 (Folicur® EW + 1 % + 65 DAFIT) and T6 (Folicur® EW + 2 % + 65 DAFIT) significantly increased the diameter of pineapple compared to the control treatment (T13) ($p \leq 0.05$), as shown in Figure 3. Regarding the chemical characteristics of the fruit (brix, pH and titratable acidity), no changes were found caused by the treatments applied at a $p \leq 0.05$ (Figure 4). This is because the products used are basically related to plant growth and not to the chemical characteristics of the fruit, although some cytokinins, such as benzylaminopurine [BAP], increase the content of capsaicin and ascorbic acid in Capsicum annum, according to what refer Borjas-Ventura et al. (2020) and Big Hor is a product that contains cytokinins (2.50 g l^{-1}), although the available commercial information does not indicate what type.

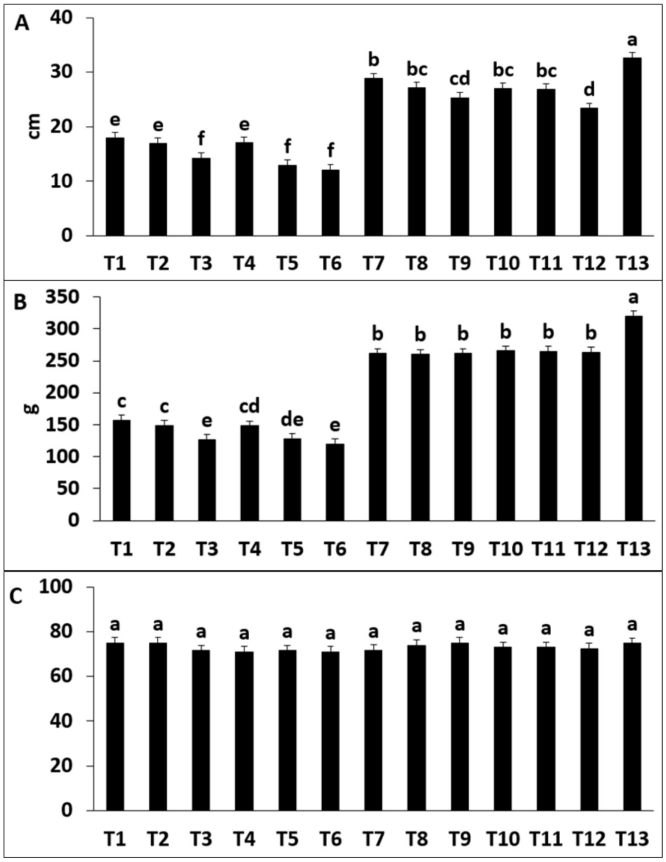


Figure 1. Effect of two regulators on pineapple crown growth cv. MD2, crown length (A), crown weight (B) and number of leaves per crown (C), in the province of Chanchamayo, Peru.*

* T1: [Folicur® **EW (1** %), 45 DAFIT]; T2: [Folicur® **EW (1** %), 55 DAFIT]; T3: [Folicur® **EW (1** %), 65 DAFIT]; T4: [Folicur® **EW (2** %), 45 DAFIT]; T5: [Folicur® **EW (2** %), 55 DAFIT]; T6: [Folicur® **EW (2** %), 65 DAFIT]; T7: [Big Hor (1 %), 45 DAFIT]; T8: [Big Hor (1 %), 55 DAFIT]; T9: [Big Hor (1 %), 65 DAFIT]; T10: [Big Hor (2 %), 45 DAFIT]; T11: [Big Hor (2 %), 55 DAFIT]; T12: [Big Hor (2 %), 65 DAFIT]; T13: Control. DAFIT: Days after flower induction treatment. Different letters indicate statistical difference (Tukey test 95%).

Figure 2. Size of the pineapple fruit crown cv. MD2 in the control without application (A) and due to the effect of the application of Tebuconazole at 2% and 65 days after the FIT (B), in Chanchamayo, Peru.

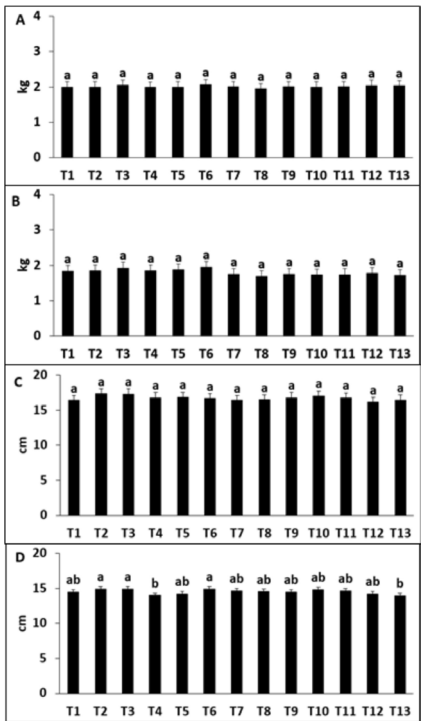


Figure 3. Effect of two growth regulators on the characteristics of the fruit of pineapple cv. MD2 in fruit weight with crown (A), fruit weight without crown (B), fruit length (C) and fruit diameter (D) in the province of Chanchamayo, Peru.*

* T1: [Folicur® **EW (1** %), 45 DAFIT]; T2: [Folicur® **EW (1** %), 55 DAFIT]; T3: [Folicur® **EW (1** %), 65 DAFIT]; T4: [Folicur® **EW (2** %), 45 DAFIT]; T5: [Folicur® **EW (2** %), 55 DAFIT]; T6: [Folicur® **EW (2** %), 65 DAFIT]; T7: [Big Hor (1 %), 45 DAFIT]; T8: [Big Hor (1 %), 55 DAFIT]; T9: [Big Hor (1 %), 65 DAFIT]; T10: [Big Hor (2 %), 45 DAFIT]; T11: [Big Hor (2 %), 55 DAFIT]; T12: [Big Hor (2%), 65 DAFIT]; T13: Control. DAFIT: Days after flower induction treatment. Different letters indicate statistical difference (Tukey test 95%).

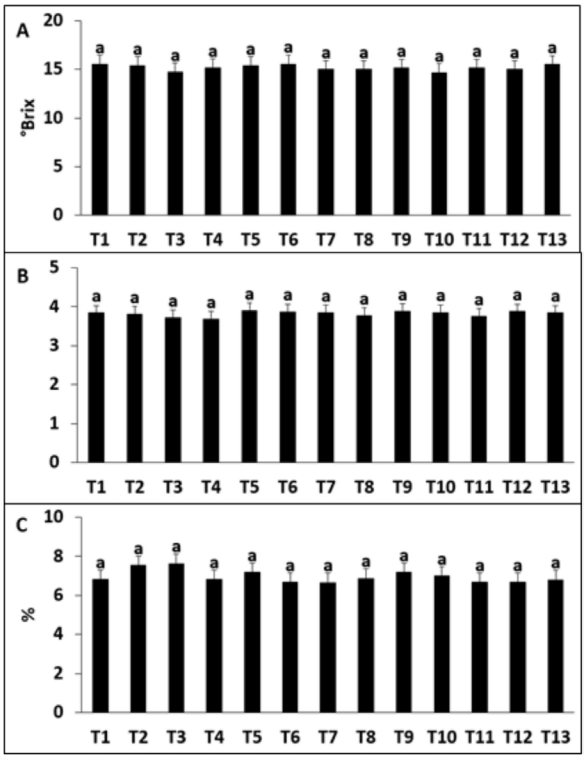


Figure 4. Effect of two growth regulators on the chemical characteristics of pineapple fruit cv. MD2, brix (A), pH (B) and titratable acidity (C), in the province of Chanchamayo, Peru.

* T1: [Folicur® **EW (1 %), 45 DAFIT]; T2: [**Folicur® **EW (1 %), 55 DAFIT]; T3: [**Folicur® **EW (1 %), 65 DAFIT]; T4: [**Folicur® **EW (2 %), 45 DAFIT]; T5: [**Folicur® **EW (2 %), 55 DAFIT]; T6: [**Folicur® **EW (2 %), 65 DAFIT]; T7: [Big Hor (1 %), 45 DAFIT]; T8: [Big Hor (1 %), 55 DAFIT]; T9: [Big Hor (1 %), 65 DAFIT]; T10: [Big Hor (2 %), 45 DAFIT]; T11: [Big Hor (2 %), 55 DAFIT]; T12: [Big Hor (2%), 65 DAFIT]; T13: Control.** DAFIT: Days after flower induction treatment. Different letters indicate statistical difference (Tukey test 95%).

Table 2. Correlations between the variables of fruit size, crown length and fruit quality of pineapple cv. MD2 in Chanchamayo, Peru.*

	CW	NL-C	CL	FWwC	FWwoC	FL	FD	Brix	pH	TAc
CW	-	0.25	**0.96**	-0.05	0.48	-0.21	-0.19	-0.09	0.06	-0.22
NL-C	-	-	0.28	-0.01	-0.18	0.02	0.07	0.10	0.02	0.08
CL	-	-	-	-0.07	-0.48	-0.22	-0.17	-0.09	0.03	-0.22
FWwC	-	-	-	-	**0.84**	0.07	-0.15	-0.02	0.11	0.05
FWwoC	-	-	-	-	-	0.26	-0.01	0.02	0.00	0.21
FL	-	-	-	-	-	-	0.32	0.00	-0.18	0.32
FD	-	-	-	-	-	-	-	0.10	-0.03	0.30
Brix	-	-	-	-	-	-	-	-	0.06	0.13
Ph	-	-	-	-	-	-	-	-	-	-0.06
TAc	-	-	-	-	-	-	-	-	-	-

* CW: Crown weight. NL-C: Number of crown leaves. CL: Crown length. FWwC: Fruit weight with crown. FWwoC: Fruit weight without crown. FL: Fruit length. FD: Fruit diameter. TAc: Titratable acidity.

4. Conclusion

The two products studied decreased crown growth; however, this effect was on length and weight and not on the number of leaves in the crown. In all cases the effect of Tebuconazole was significantly higher than that of Big Hor. In none of the cases was there an effect on the weight and chemical characteristics of the fruit, although in some treatments with Tebuconazole, the diameter of the fruit increased significantly. The results are interesting for future commercial use, but it is recommended to continue investigating the effect of growth regulators on other pineapple varieties, as well as different agronomic management and climate conditions.

Acknowledgments

The authors thank to Frutas Golden company for its support during the assessment.

Contributor roles

- Segundo Bello-Amez: conceptualization, methodology.
- Antonella Roman-Aquino: data curation, validation.
- Maira Elera-Anicama: data curation, validation.
- Ricardo Borjas-Ventura: writing – original draft.
- Leonel Alvarado-Huamán: writing – original draft.
- Viviana Castro-Cepero: conceptualization, methodology.
- Alberto Julca-Otiniano: conceptualization, methodology.

Ethical implications

Ethics approval not applicable.

Conflict of interest

The authors declare that they have no affiliation with any organization with a direct or indirect financial interest that could have appeared to influence the work reported.

References

Arivalagan, M., & Somasundaram, R. (2017). Alteration of phtosynthetic pigments and antioxidant systems in tomato under drought with Tebuconazole and Hexaconazole applications. *Journal of Scientific Agriculture*, *1*, 146-157. https://doi.org/10.25081/jsa.2017.v1.52

Barrantes Jiménez, S. (2008). *Efecto del Agrokin Plus® en el rendimiento y calidad externa e interna de la fruta de piña (Ananas comosus) (L.) Merr. híbrido MD-2 en Upala*. Instituto Tecnológico de Costa Rica. https://hdl.handle.net/2238/2888

Bello, S. (1991*). Cultivo de piña en la selva central del Perú*. Serie Técnica- Informe Técnico 0.2/2.3 N° 15. Instituto Nacional de Investigación Agraria y Agroindustrial.

Borjas-Ventura, R., Julca-Otiniano, A., & Alvarado-Huamán, L. (2020). Las fitohormonas una pieza clave en el desarrollo de la agricultura. *Journal of Selva Andina Biosphere*, *8*(2), 150-164. https://doi.org/10.36610/j.jsab.2020.080200150

Box, G. E., Hunter, J. S., & Hunter, W. G. (2008). *Estadística para investigadores* (2ª ed.). Editorial Reverté. https://www.reverte.com/libro/estadistica-para-investigadores-2a-edicion_89275/

Cunha, G. A. P. da. (2005). Applied aspects of pineapple flowering. *Bragantia*, *64*(4), 499-516. https://doi.org/10.1590/S0006-87052005000400001

Desta, B., & Amare, G. (2021). Paclobutrazol as a plant growth regulator. *Chemical and Biological Technologies in Agriculture, 8*(1), 1. https://doi.org/10.1186/s40538-020-00199-z

Ferguson, L., & Lessenger, J. E. (2006). Plant growth regulators. In J. E. Lessenger (ed.), *Agricultural Medicine* (pp. 156-166). Springer-Verlag. https://doi.org/10.1007/0-387-30105-4_15

Food and Agriculture Organization of the United Nations [FAO]. (2011). *Standard for pineapple*. CXS 182-1993. Codex Alimentarius. https://www.fao.org/input/download/standards/313/CXS_182e.pdf

Grossmann, K. (1990). Plant growth retardants as tools in physiological research. *Physiologia Plantarum*, *78*(4), 640-648. https://doi.org/10.1111/j.1399-3054.1990.tb05254.x

Harms, C. L., & Oplinger, E. S. (1988). Plant growth regulators: Their use in crop production. Publication 303. *University of Minnesota*. https://hdl.handle.net/11299/207537

Maraví Loyola, J. Y. (2018). *Caracterización de fincas productoras de kión, piña y plátano en la microcuenca Cuyani - Pichanaki (Junín, Perú).* Universidad Nacional Agraria La Molina. https://hdl.handle.net/20.500.12996/3577

Ministerio de Agricultura y Riego [MINAGRI]. (2019). *Plan nacional de cultivos. Campaña Agrícola 2019 – 2020*. MINAGRI. http://repositorio.minagri.gob.pe:80/jspui/handle/MINAGRI/565

Mohsin, S. M., Hasanuzzaman, M., Bhuyan, M. H. M. B., Parvin, K., & Fujita, M. (2019). Exogenous Tebuconazole and Trifloxystrobin regulates reactive oxygen species metabolism toward mitigating salt-induced damages in cucumber seedling. *Plants*, *8*(10), 428. https://doi.org/10.3390/plants8100428

Norman, J. C. (1977). Chemical regulation of growth, flowering and fruiting in 'Sugarloaf' pineapple. *Scientia Horticulturae, 7*(2), 143-151. https://doi.org/10.1016/0304-4238(77)90054-1

Padilla Laso, W. G. (2015). *Uso de biorreguladores en el crecimiento y maduración de frutos de piña MD2 (Ananas comosus)*. Universidad Técnica Estatal de Quevedo. https://repositorio.uteq.edu.ec/handle/43000/2384

Paull, R. E., & Chen, C. C. (2014). *Pineapple: Postharvest quality-maintenance guidelines*. Fruit, Nut, and Beverage Crops F_N32. University of Hawai'i at Mānoa. https://www.ctahr.hawaii.edu/oc/freepubs/pdf/F_N-32.pdf

PortalFrutícola. (2021). *Exportaciones de piña peruana lideran mercados en 2020*. https://www.portalfruticola.com/noticias/2021/03/16/exportaciones-de-pina-peruana-lideran-mercados-en-2020/

Rademacher, W. (2016). Chemical regulators of gibberellin status and their application in plant production. In P Hedden, & S. G. Thomas (eds.), *Annual Plant Reviews* (pp. 359-403). Wiley. https://doi.org/10.1002/9781119312994.apr0541

Redagricola. (2021). *Perú bate su record de exportaciones de piña*. https://www.redagricola.com/pe/peru-bate-su-record-de-exportaciones-de-pina/

Rodrigues, M., Baptistella, J. L. C., Horz, D. C., Bortolato, L. M., & Mazzafera, P. (2020). Organic plant biostimulants and fruit quality—A review. *Agronomy*, *10*(7), 988. https://doi.org/10.3390/agronomy10070988

Sáez Reyes, M. N. (2016). *Usos de giberelinas de síntesis en la fruticultura chilena*. Universidad de Chile. https://repositorio.uchile.cl/handle/2250/150997

Sahoo, A. K., Kar, I., Mohanty, A., Panda, R., & Bhoyar, R. K. (2015). Use of plant growth regulators and fertilizer for regulating the flowering and quality of pineapple fruit - A review. *IJBRITISH*, *2*(1), 30-37.

Servicio Nacional de Sanidad Agraria del Perú [SENASA]. (2017). *MINAGRI: Calidad irregular de la piña limita su potencial exportador*. https://www.senasa.gob.pe/senasacontigo/minagri-calidad-irregular-de-la-pina-peruana-limita-su-potencial-de-exportacion/

Shahbandeh, M. (2024). *Leading countries in pineapple production worldwide in 2022 (in 1,000 metric tons)*. STATISTA. https://www.statista.com/statistics/298517/global-pineapple-production-by-leading-countries/

Tadeu Dias, J. P. (2019). Plant growth regulators in horticulture: practices and perspectives. *Biotecnología Vegetal*, *19*(1), 3-14. https://revista.ibp.co.cu/index.php/BV/article/view/596

Teixeira, E. C., Matsumoto, S. N., Silva, D. da C., Pereira, L. F., Viana, A. E. S., & Arantes, A. de M. (2019). Morphology of yellow passion fruit seedlings submitted to triazole induced growth inhibition. *Ciência E Agrotecnologia*, *43*, e020319. https://doi.org/10.1590/1413-7054201943020319

Yasser-Lorente, G., Rodríguez-Hernández, D., Camacho-Rajo, L., Carvajal-Ortiz, C. C, De Ávila-Guerra, R., González-Olmedo, J., & Rodríguez-Sánchez, R. (2021). Biobras-16 application effect on the growth and quality of pineapple fruits 'MD-2'. *Cultivos Tropicales, 42*(2), e06. https://ediciones.inca.edu.cu/index.php/ediciones/article/view/1590