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Relationship between Photosynthetic Capacity and Carbohydrate Content of *Mangifera indica* cv. Harumanis in Response to Girdling and Paclobutrazol

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Girdling and paclobutrazol have been related with the effects on the photosynthetic capacity and carbohydrate content of plants. The physiological changes caused by these methods distress the growth and development of plants in general. A field experiment was carried out from August 2021 to June 2022 on 5 years of open-field *Mangifera indica* cv. Harumanis trees grown at Malaysian Agriculture Research and Development Institute (MARDI), Serdang, Selangor. The objective of this experiment was to understand the relationship between girdling, paclobutrazol application, combined methods and untreated trees on plant photosynthetic performances and carbohydrate content in the leaves. The treatments were performed on 1st December 2021, and the measurements of leaf gas exchanges and carbohydrate content were performed 4th weeks later on fully expanded leaves shoot, experiencing similar light exposure. In the study, the combination of girdling and paclobutrazol application resulted in a significant decrease in photosynthetic rate (Pn), stomatal conductance (g_s) and transpiration rate (Tr) but significantly increase in intercellular CO_2 concentration (Ci) and carbohydrate content.

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1. INTRODUCTION

Harumanis are one of the best mangoes in Malaysia, and they are primarily grown in the Northern Peninsular Malaysian states of Perlis and Kedah [1,2]. Harumanis mango is only available once a year during the season and is only found north of the homeland due to its sensitivity to climate conditions that necessitates a clear and consistent dry season [3] that provides prolonged hot weather for 2 to 3 months [4]. Harumanis have a distinct flavour unlike any other mango. They have a slightly creamy and milky taste and a very strong and distinct aroma, making it the most popular and receiving a steady increase in demand year after year [3,5,6].

Harumanis production is frequently associated with physiological changes in the plant caused by endogenous factors such as hormones, genetic composition, carbohydrates, and stress conditions, as well as the age of the buds [7]. Furthermore, environmental factors, primarily temperature change [8], as well as management practises such as plant growth regulator use [9], pruning [10], and irrigation [11], are frequently associated with the changes. Endogenous and environmental factors are beyond our control; thus, under management practise, girdling [12] and paclobutrazol [13] application are quite common for fruit producers, and have also shown great results in improving crop growth, yield, and quality in increasing the productivity and quality of several agricultural crops [14,15,16].

Girdling is the removal of a thin strip of bark tissue encircling a trunk or branch, obstructing the downward translocation of photosynthates and metabolites through the phloem [17,18]. Its most immediate effect is to halt assimilate movement, resulting in an accumulation of carbohydrates produced by photosynthesis along the phloem [19]. The accumulation of carbohydrate reserves in the leaves reduces photosynthetic capacity [20,21]. Girdling has a significant impact on photosynthesis because it reduces stomatal conductance [22] which affecting the rate of gas exchange and transpiration rate [23] resulting in less leaf transpiration and thus a decrease in photosynthesis rate.

Paclobutrazol (PBZ) functions as a chemical growth and development stimulator by altering associated physiological processes [24]. The use of this plant growth inhibitor on soil inhibits the biosynthesis of gibberellin, which is responsible for regulating growth and development [25]. Previous research has shown that PBZ application alters crop plant photosynthetic capacity [26,27,28] and increases carbohydrate production in leaf [29,30]. Because gibberellins are involved in the biogenesis of chloroplasts, paclobutrazol alters photosynthetic potential and, as a result, plant gas exchange [31]. Paclobutrazol also has an effect on the efficiency of carbon use in leaves, which is determined by the balance of photosynthesis and respiration [32].

Therefore, the objective of this experiment was to investigate the relationship between photosynthetic capacity and carbohydrate content of *Mangifera indica* cv. Harumanis in response to 4 methods; (i) girdling, (ii) paclobutrazol, (iii) combined methods including, and (iv) untreated tree. We hypothesized that combination of girdling and paclobutrazol would decrease photosynthetic capacity inversely proportional to carbohydrate content of *Mangifera indica* cv. Harumanis.

2. MATERIALS AND METHODS

2.1 Planting Material

This study was conducted at MARDI, Serdang, Selangor, from August 2021 to June 2022, using five years of open-field *Mangifera indica* cv. Harumanis trees grown in sedentary soil and separated by 4 m × 4 m. Thirty-six healthy trees of nearly uniform shape and size are subjected to the same fertilisation programme and other agricultural practises chosen for this study. T1- No induction (Control); T2- girdling at primary branches; T3- soil drenching at 4 ml/l paclobutrazol; and T4- girdling at primary branches + soil drenching at 4 ml/l paclobutrazol were applied to selected trees. Girdling was accomplished by removing a 10 mm wide ring of bark above 30 cm from the base of all primary branches. The commercial product paclobutrazol (25% active ingredient) was used. The treatments were carried out simultaneously on December 1, 2021, at the same morphological size of the tree that had been subjected to similar light exposure.

2.2 Photosynthetic

A portable photosynthesis system was used to measure photosynthetic rate (Pn), intercellular CO2 concentration (Ci), stomatal conductance (gs), and transpiration rate (Tr) (LI-6400XT; LI-COR, Lincoln, NE, USA). The measurements were taken on the fifth fully expanded leaves from the plant apex on the fourth week after treatment between 8:00 and 10:00 a.m.

2.3 Determination of Total Carbohydrate Content

The anthrone method was used to determine the total carbohydrate content [33]. A 100 mg sample of leaves was placed in a boiling tube. It was hydrolyzed for 3 hours in a boiling water bath with 5ml 2.5 N hydrochloric acid. It was allowed to cool to room temperature after 3 hours. The solution was then neutralised with solid sodium carbonate until the effervescence was stopped. The solution was diluted with distilled water until it reached 100 ml before being centrifuged for 10 minutes. The 0.5 ml and 1 ml supernatant were then collected, and an aliquot was taken for analysis. Meanwhile, the standard was made by taking 0 ml, 0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml, and 1.0 ml of the working standard and leaving '0' as a blank. By adding distilled water to all of the tubes, including the sample tubes, the volume was increased to 1 ml. The tubes were then filled with 4 ml of anthrone reagent and heated in a boiling water bath for 8 minutes. After that, the solution was rapidly cooled before being placed in a UV spectrophotometer (Thermo Fisher Scientific Orion AquaMate 7000) and the light absorption at 630 nm was measured. To determine the concentration of glucose in each test sample, a standard graph was created by plotting the concentration of the standard glucose on the X-axis versus absorbance on the Y-axis. Equation 1 was used to calculate the amount of carbohydrate present in the sample tube based on the graph:

Amount of carbohydrate present in 100 mg of the sample = (mg of glucose ÷ Volume of test sample) X 100

2.4 Statistical Analysis

The experiment was laid out in randomized complete block design (RCBD). Each treatment was replicated three times and each replicate was represented by three trees. The data obtained was analysed using ANOVA in SAS software (Version 9.4, SAS Institute Inc. Cary, North Carolina, USA) and differences between treatments means were compared using Duncan Multiple Range Test Difference (DMRT) at $P \leq 0.05\%$.

3. RESULTS AND DISCUSSION

The treatment reduced the photosynthetic capacity of the *Mangifera indica* cv. Harumanis' plants while increasing carbohydrate content compared to the control (Fig. 1). The combination method of girdling and paclobutrazol application resulted in the lowest net photosynthesis rate of 2.71 µmol CO_2 $m/^2/s^1$. This combination also reduced stomatal conductance, with the lowest result being 0.07 µmol$H_2O/m^2/s$. Furthermore, the combination method yielded the lowest transpiration rate of 1.66 µmol$H_20/m^2/s$. However, the intercellular CO_2 concentration of this combined method was significantly higher than the other treatments, at 312.48 µmol CO_2 mol. The combination method of girdling and paclobutrazol application increased total carbohydrate content. The highest carbohydrate content was found to be 2.62267 mg/g.

This finding is partially agrees with previous reports on mango [34]. It is well known that paclobutrazol interferes with the hormone abscisic acid's production [35]. A stress hormone that causes stomatal closure is one of abscisic acid's most crucial roles [36]. Based on the degree of stomatal aperture, stomatal conductance calculates the rate of gas exchange through the leaf stomata. A plant may close its leaf stomata under stress in an effort to preserve water and minimise water loss. But in doing so, the plant also limits how much CO_2 it can absorb. In plants, CO_2 is an essential component of the process of photosynthesis. Therefore, a decrease in CO_2 restricts photosynthetic. Furthermore, in addition to this treatment with the girdled branches, which increase in a general decrease in this common adaptation response of plants to the onset of artificial stress by stem girdling conditions, which followed a trend similar to photosynthetic activity [37]. Similar to the present study, the removal of the sink demand of roots typically results in decreased stomatal conductance and transpiration, and accumulation of abscisic acid in leaves [38], which affects carbon status and leads to a decrease in photosynthetic results [39].

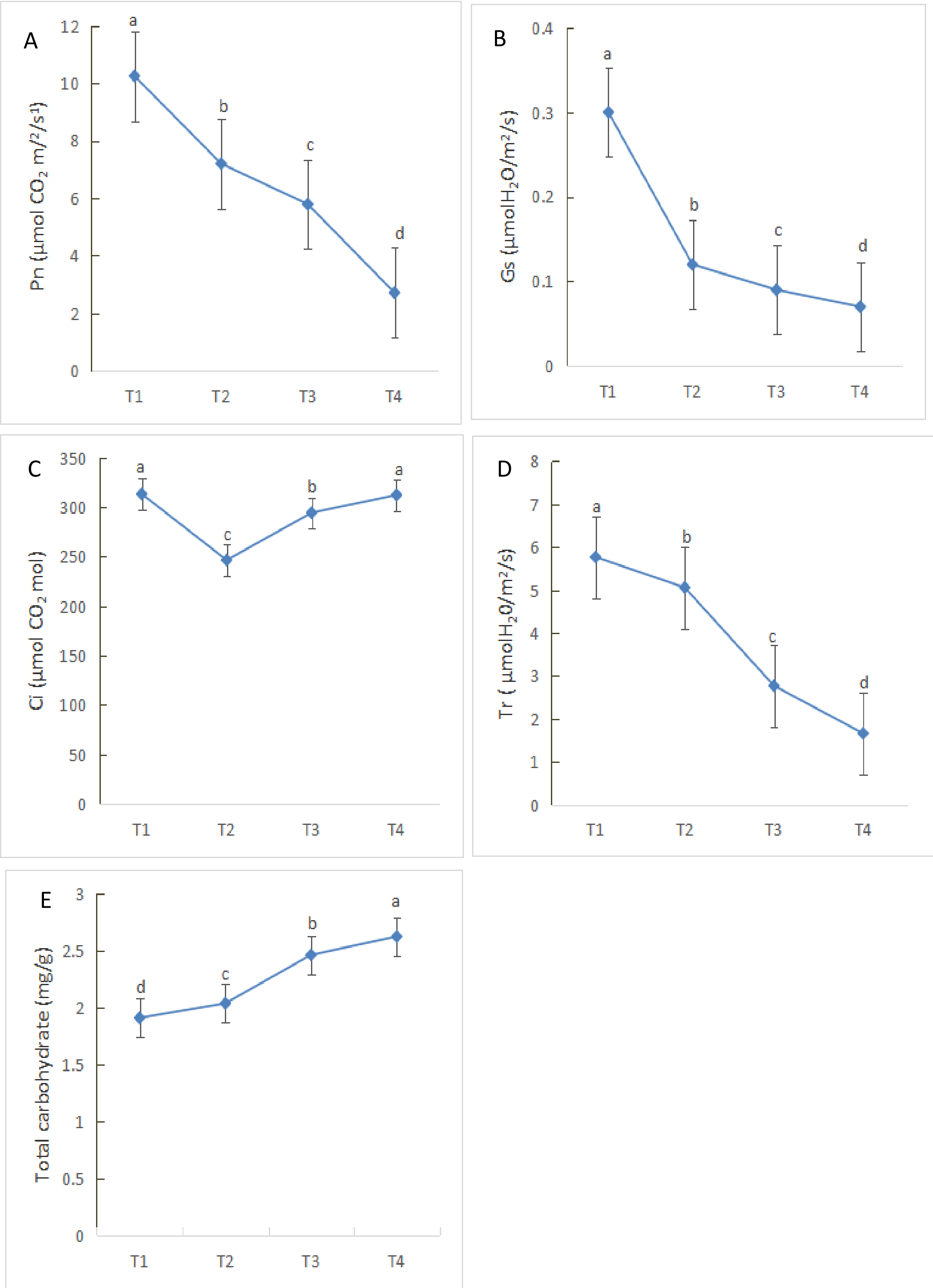

Fig. 1. Net photosynthesis rate (A), stomatal conductance, intercellular CO_2 levels (C), transpiration rate (D) and total carbohydrate (E) at T1- No induction (Control); T2- girdling at primary branches; T3- soil drenching at 4 ml/l PBZ and T4- girdling at primary branches + soil drenching at 4 ml/l PBZ. Bars are mean for standard error. Different letters above bars indicate significant differences using Duncan Multiple Range Test Difference (DMRT) at P≤ 0.05

The findings of this study, which are consistent with earlier reports, strongly suggested that girdling and paclobutrazol can increase the production of carbohydrates in the leaf [40,41] (Wu et al. 2018). The early termination of growth caused by the action of paclobutrazol as a gibberellin biosynthesis inhibitor is known to reduce vegetative growth rate, which leads to the buildup of carbohydrates [42,43]. Carbohydrates serve as a main source of energy for growth and differentiation of plant organs during flowering and fruit development (Hazis et al. 2018). Girdling alters the distribution of carbohydrates in the body by preventing assimilates from passing through the phloem. The buildup and depletion of carbohydrates above and below the girdling zone, respectively, cause a number of changes in growth and development [44]. In addition, when the vegetative sink decreased, the transfer of carbohydrates to the shoot increased [45-48].

4. CONCLUSION

In conclusion, girdling and paclobutrazol together dramatically lower stomatal conductance and transpiration, which affect net photosynthesis rate, while simultaneously raising the carbohydrate content in the leaves of *Mangifera indica* cv. Harumanis.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Nasron N, Ghazali NS, Shahidin NM, Mohamad AA, Pugi SA, Razi NM. Soil suitability assessment for Harumanis mango cultivation in UiTM Arau, Perlis. Proceeding of the advanced geospatial and surveying conference. Malaysia. Perlis. 2020;012007.
2. Sani MA, Abbas H, Jaafar MN, Bahagia MAG. Morphological characterisation of Harumanis mango (*Mangifera indica* Linn.) in Malaysia. International Journal of Environmental and Agriculture Research. 2018;4(1):45.
3. Muhamad Hafiz MS, Hartinee A, Dalila N, Zul Helmey MS, Razali M, Siti Aisyah A, Wan Mohd Reza WI, Shaidatul Azdawiyah AT. Effect of multilocation production on the reproductive growth, yield, and quality of Harumanis mango. International Journal of Current Advanced Research. 2019; 8(04):18175-18180.
4. Uda MNA, Subash C, Gopinath B, Hashim U, Asyraf H, Afnan MN, Aminudin A, Bakar MAA, Sulaiman MK, Parmin NA. Harumanis mango: Perspectives in disease management and advancement using interdigitated electrodes (IDE) nano-biosensor. Proceeding of the 2nd Joint Conference on Green Engineering Technology and Applied Computing; Thailand. Bangkok. 2020;864.
5. Nur Afiqah A. Growth, physiological and biochemical responses as affected by paclobutrazol for flowering induction on water induced stress mango plants (*Mangifera indica* L. cv. Harumanis). [Masters thesis]. Universiti Putra Malaysia; 2015.
6. Rosidah M, Faridah H, Jamaliah MY, Norzaidi MD. Examining market accessibility of Malaysia’s Harumanis mango in Japan: Challenges and potentials. Business Strategy Series. 2010; 11(1):3-12.
7. Cho LH, Yoon J, An G. The control of flowering time by environmental factors. The Plant Journal. 2017;90(4):708-719.
8. Halder B, Bandyopadhyay J. Evaluating the impact of climate change on urban environment using geospatial technologies in the planning area of Bilaspur, India. Environmental Challenges. 2021;5: 100286.
9. Malshe KV, Haldankar PM, Patil SS. Effect of foliar application of plant growth regulators on seasonal variation in physiological behavior in mango cv. Alphonso. International Journal of Current Microbiology and Applied Sciences. 2020;9(6):1629-1642. Available:https://doi.org/10.20546/ijcmas.2020.906.201.
10. Hahn F, Valle S, Navarro-Gomez C. Pruning and water saving management effects on mango high-density and mature orchards. Agronomy. 2022;12:2623.

Available:https://doi.org/10.3390/agronomy 12112623.
11. Venkata Subbaiah K, Reddy NN, Reddy MLN. Effect of paclobutrazol and other chemicals on yield and quality of mango cv. Banganpalli. International Journal of Science, Environment and Technology. 2017;6(3):1809-1819.
12. Prates AR, Zuge PGU, Leonel S, Souza JMA, Avila JD. Flowering induction in mango tree: updates, perspectives and options for organic agriculture. Pesquisa Agropecuaria Tropical. 2021;51. Available:https://doi.org/10.1590/1983-40632021v5168175
13. Kumar A, Ram S, Bis L, Singh C. Paclobutrazol boost up for fruit production: A review. International Journal of Energy and Environmental Science. 2020; 1(1):019-031.
14. Azizi S, Rana VS, Sharma S, Chauhan J, Kumar V. Effect of girdling on yield and quality of kiwifruit (*Actinidia deliciosa Chev*.) raised through different propagation methods. Indian Journal of Ecology. 2022; 49(2):496-501.
15. Ran J, Guo W, Hu C, Wang X, Li P. Adverse effects of long-term continuous girdling of jujube tree on the quality of jujube fruit and tree health. Agriculture. 2022;12(7):922.
16. Shivashankara KS, Geetha GA, Roy TK. Influence of girdling on flower sex ratio, biochemical constituents, and fruit set intensity in mango (*Mangifera indica* L.). Biologia Plantarum. 2019;63:432-439.
17. Bottcher C, Boss PK, Harvey KE, Burbidge CA, Davies C. Peduncle-girdling of Shiraz (*Vitis vinifera* L.) bunches and sugar concentration at the time of girdling affect wine volatile compounds. Australian Journal of Grape and Wine Research. 2018;24:206–218.
18. Isogimi T, Matsushita M, Nakagawa, M. Species-specific sprouting pattern in two dioecious Lindera shrubs: The role of physiological integration. Flora. 2014;209:718–724.
19. Gawankar MS, Haldankar PM, Salvi BR, Parulekar YR, Dalvi NV, Kulkarni MM, Saitwal YS, Nalage NA. Effect of Girdling on Induction of Flowering and Quality of Fruits in Horticultural Crops: A review. Advanced Agricultural Research and Technology Journal. 2019;3(2):201-215.
20. Zepeda AC, Heuvelink E, Marcelis LFM. Non-structural carbohydrate dynamics and growth in tomato plants grown at fluctuating light and temperature. Frontiers in Plant Science. 2022;3:968881.
21. Asao S, Ryan MG. Carbohydrate regulation of photosynthesis and respiration from branch girdling in four species of wet tropical rain forest trees. Tree Physiology. 2015; 35:608–620.
22. Williams LE, Retzlaff WA, Yang W, Biscay PJ, Ebisuda N. Effect of Girdling on leaf gas exchange, water status, and non-structural carbohydrates of field- grown *Vitis vinifera* L. (cv. Flame Seedless). American Journal of Enology and Viticulture. 2000;51(1): 49-54.
23. Lopez R, Brossa R, Gil L, Pita P. Stem girdling evidences a trade-off between cambial activity and sprouting and dramatically reduces plant transpiration due to feedback inhibition of photosynthesis and hormone signaling. Frontiers in Plant Science. 2015;6:285.
24. Abdalla N, Taha, N, Bayoumi Y, Ramady HE, Syalaby TA. Paclobutrazol applications in agriculture, plant tissue cultures and its potential as stress ameliorant: A mini review. Environment, Biodiversity and Soil Security. 2021; 5(1):245–257
25. Desta B, Amare G. Paclobutrazol as a plant growth regulator. Chemical and Biological Technologies in Agriculture. 2021;8(1).
26. Zhao I, Zhao J, Lai H, Chen BC, B Mengjie ZM, Zhao YL, Liu Y, Xiangdong L, Li X, Yang DYD. Effects of paclobutrazol application on plant architecture, lodging resistance, photosynthetic characteristics, and peanut yield at different single-seed precise sowing densities. The Crop Journal; 2022. Available:https://doi.org/10.1016/j.cj.2022.05.012
27. Nyan TM, Yahya A, Izham A, Ranj SN. Gas exchange, growth and flowering of lagerstroemia indica treated with different concentration and application techniques of paclobutrazol. Asian Journal of Plant Sciences. 2017;16(1):37-44.
28. Roseli ANM, Ying TF, Ramlan MF. Morphological and physiological response of *Syzygium myrtifolium* (Roxb.) walp. to paclobutrazol. Sains Malaysiana. 2012;41(10):1187–1192.
29. Xu LJ, Liu HX, Wu J, Xu CY. Paclobutrazol improves leaf carbon-use efficiency by increasing mesophyll conductance rate,

while abscisic acid antagonizes this increased rate. Photosynthetica. 2020; 58(3):762-768.

30. Upreti KK, Prasad SRS, Reddy YTN, Rajeshwara AN. Paclobutrazol induced changes in carbohydrates and some associated enzymes during floral initiation in mango (*Mangifera indica* L.) cv. Totapuri. Indian Journal of Plant Physiology. 2014;19(4):317-323.
31. Rodrigues LCA, Castro EM, Pereira FJ, Malileque IF, Barbosa JPRAD, Rosado SCS. Effects of paclobutrazol on leaf anatomy and gas exchange of *Toona ciliata* clones. Australian Forestry. 2016; 79(4):241-247.
32. Christiaens A. Factors affecting flower development and quality in rhododendron simsii. [PhD Thesis]. Ghent University, Ghent, Belgium; 2014.
33. Hedge JE, Hofreiter BT. Determination of total carbohydrates by anthrone method, In: Whistler RL, Be Miller JN, editor. Carbohydrate chemistry 17. New York: Academic Press; 1962.
34. Sarker BC, Rahim MA. Influence of paclobutrazol on growth, yield and quality of mango. Bangladesh Journal of Agricultural Research. 2018;43(1).
35. Opio P, Tomiyama H, Saiyo T, Ohkawa K, Ohara H, Kondo S. Paclobutrazol elevates auxin and abscisic acid, reduces gibberellins and zeatin and modulates their transporter genes in Marubakaido apple (*Malus prunifolia Borkh*. var. ringo Asami) rootstocks. Plant Physiology and Biochemistry. 2020;155(1):502-511.
36. Bharath P, Gahir S, Raghavendran AS. Abscisic acid induced stomatal closure: An important component of plant defense against abiotic and biotic stress. Frontier of Plant Science. 2021;12(1):615114.
37. Agurla S, Gahir S, Munemasa S, Murata Y, Raghavendra AS. Mechanism of stomatal closure in plants exposed to drought and cold stress. Advances in Experimental and Biology. 2018;1081:215-232.
38. Tang GL, Li XY, Zeng FJ. Different causes of photosynthetic decline and water status in different stages of girdling in *Alhagi sparsifolia Shap*. (Fabaceae). Brazilian Journal of Botany. 2016;39(2):19-529.
39. Urban L, Alphonsout L. Girdling decreases photosynthetic electron fluxes and induces sustained photoprotection in mango leaves. Tree Physiology. 2007;7:354-352.
40. Sousa K, Lopes PRC, Cavalcante I, Filho JC, Silva LDS, Pereira ECV, Silva JTL., Impact of paclobutrazol on gibberellin-like substances and soluble carbohydrates in pear trees grown in tropical semiarid. Revista de la Facultad de Ciencias Agrarias. 2022;54(1):46-56.
41. Hua S, Zhang Y, Yu H, Lin B, Di H, Zhang D, Ren Y, Fhang, Z. Paclobutrazol pplication effects on plant height, seed yield and carbohydrate metabolism in canola. International Journal of Agriculture and Biology. 2014;16(3):471-479.
42. Ashraf N, Ashraf M. Response of growth inhibitor paclobutrazol in fruit crops. (Prunus, Intech Open: Ed. Kuden A, Ali A) 2020:92883.
43. Wieland WF, Wample RL. Effects of paclobutrazol on growth, photosynthesis and carbohydrate content of 'delicious' apples. Scientia Horticulturae. 1985;26: 139-147.
44. Chai L, Li Q, Wang H, Wang C, Xu J, Yu H, Jiang W. Girdling alters carbohydrate allocation to increase fruit size and advance harvest in tomato production. Scientia Horticulturae. 2021;276:109675.
45. Quentin A, Close D, Hennen L, Pinkard, E. Down-regulation of photosynthesis following girdling, but contrasting effects on fruit set and retention, in two sweet cherry cultivars. Plant Physiology and Biochemistry. 2013;73:359-367.
46. Azis NH, Aznan AA, Jaafar MN, Azizan FA, Ruslan R, Rukunudin IH. Assessment of carbohydrate contents in Perlis Harumanis mango leaves during vegetative and productive growth. Proceeding of the International Conference on Advanced Manufacturing and Industry Applications; 2018 August 15-17; Malaysia. Sarawak. 2018;012025.
47. Shaidatul Azdawiyah AT, Muhamad HafizMH, Mohd Aziz R, Zul Helmey MS, Muhammad Zamir AR, Wan Mahfuzah WI, Mohammad Hariz AR, Mohd Ghazali R, Syarol Nizam AB, Mohd Alif OM. Effects of environmental temperature and precipitation pattern on growth stages of *Mangifera indica* cv. Harumanis mango. Journal of Agricultural Science. 2020; 12(12).
48. Wu Y, Sun M, Zhang J, Zhang L, Ren Z, Min R, Wang X, Xia Y. Differential effects

of paclobutrazol on the bulblet growth of oriental lily cultured *In vitro*: Growth behavior, carbohydrate metabolism, and antioxidant capacity. Journal of Plant Growth Regulation. 2019;38(2):359-72.

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