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Paclobutrazol enhances *in vitro* microtuberization through physiological regulation in Potato (*Solanum tuberosum* L.)

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Abstract

Paclobutrazol (PBZ), a triazole-based anti-gibberellin, is widely used to regulate plant growth by inhibiting gibberellin biosynthesis and promoting storage organ development. The present study evaluated the effect of different concentrations of paclobutrazol (0, 1, 2, and 5 ppm) on *in vitro* microtuberization in potato. Paclobutrazol significantly influenced both vegetative growth and microtuber development in a concentration-dependent manner. Increasing PBZ concentrations progressively reduced plant height, number of nodes, and leaf production, indicating effective suppression of gibberellin-mediated vegetative growth. In contrast, microtuber induction and development were markedly enhanced with increasing PBZ concentration. The highest concentration (5 ppm) produced the greatest percentage of microtuberizing plants (80%), maximum number of microtubers per plant (0.93), highest mean fresh weight of microtubers (299 mg), and largest microtuber diameter (8.11 mm), compared with the untreated control. These results demonstrate that paclobutrazol redirects assimilates from vegetative growth toward tuber formation, thereby enhancing both the quantity and quality of *in vitro*-produced microtubers. Overall, 5 ppm paclobutrazol proved to be the most effective treatment for promoting microtuberization under *in vitro* conditions. The findings highlight the potential application of paclobutrazol as an effective growth regulator for improving microtuber production in potato, with important implications for rapid seed multiplication, germplasm conservation, and commercial propagation programs.

Keywords: Paclobutrazol, anti-gibberellin, *in vitro* microtuberization, *Solanum tuberosum* L., plant growth regulator

Introduction

Anti-gibberellins are a group of plant growth regulators that suppress the biosynthesis or activity of gibberellins (GAs), thereby reducing stem elongation and altering plant growth and development. These compounds are widely used in agriculture and plant biotechnology to manipulate plant architecture, improve stress tolerance, and regulate developmental processes such as flowering, rooting, and tuber formation. Among the various anti-gibberellins, paclobutrazol (PBZ), a triazole-based growth retardant, has received considerable attention because of its effectiveness in modifying endogenous hormonal balance and promoting the accumulation of storage organs (Rademacher, 2000; Fletcher *et al.*, 2000) ^[17, 6]. Paclobutrazol exerts its physiological effects by inhibiting gibberellin biosynthesis. Specifically, it blocks the cytochrome P450-dependent oxidation of ent-kaurene to ent-kaurenoic acid, an early and essential step in the gibberellin biosynthetic pathway (Hedden and Graebe, 1985) ^[8]. This inhibition reduces the production of bioactive gibberellins, resulting in decreased cell elongation and enhanced assimilate partitioning toward storage tissues. In addition to suppressing gibberellin levels, paclobutrazol influences the concentrations of other phytohormones, including abscisic acid and cytokinins, while enhancing chlorophyll content, photosynthetic efficiency, antioxidant activity, and carbohydrate accumulation. These physiological and biochemical changes collectively contribute to improved plant vigor and the induction of storage organ development (Rademacher, 2000) ^[17].

In vitro microtuberization is an important biotechnological technique for the rapid production of

disease-free, genetically uniform potato propagules. Microtubers serve as valuable planting material for germplasm conservation, seed production, and breeding programs because they can be produced year-round under controlled environmental conditions. Successful microtuber induction depends on the interaction of several factors, including genotype, culture medium composition, carbon source, photoperiod, temperature, and the balance of endogenous and exogenous plant growth regulators. Among these factors, the regulation of gibberellin activity has emerged as a key determinant of tuber initiation and development (Naik and Sarkar, 2000) [13].

Gibberellins generally inhibit tuber induction by promoting stolon elongation and vegetative growth, whereas reduced gibberellin levels favor the transition from stolon growth to tuber formation. Consequently, the application of anti-gibberellins such as paclobutrazol has become an effective strategy for enhancing microtuberization under *in vitro* conditions. By suppressing gibberellin biosynthesis, paclobutrazol promotes earlier tuber initiation, increases the frequency of microtuber formation, enhances tuber size and fresh weight, and stimulates the accumulation of starch and other storage carbohydrates. These responses improve both the quality and productivity of microtubers, making paclobutrazol an important component of optimized tissue culture protocols (Naik and Sarkar, 2000; Rademacher, 2015) [13, 18].

Several studies have demonstrated that the effectiveness of paclobutrazol depends on its concentration, genotype, and interaction with other culture conditions, including sucrose concentration, nitrogen source, and photoperiod. Appropriate optimization of these factors can significantly improve microtuber yield while maintaining the physiological quality of the propagules. Understanding the role of paclobutrazol in regulating hormonal balance and carbon allocation therefore provides valuable insights into the mechanisms controlling tuberization and supports the development of efficient *in vitro* propagation systems for potato and other tuber-producing species (Jackson, 1999; Rademacher, 2000; Fletcher *et al.*, 2000;) [10, 17, 6].

Overall, paclobutrazol represents a promising anti-gibberellin for enhancing *in vitro* microtuberization through its ability to inhibit gibberellin biosynthesis, redirect assimilates toward storage organ development, and improve microtuber yield and quality. Continued investigation into its mode of action and its interaction with other physiological and environmental factors will contribute to the refinement of microtuber production protocols and strengthen its application in plant biotechnology, seed production, and crop improvement programs.

Materials and Methods

Effect of plant hormones on effective microtuberization in potato

Plant hormones are equally important for efficient microtuberization in potato alongside factors such as photoperiod, temperature, growth media and carbon source. They play a significant role in various stages of tuberization including stolon formation and growth, tuber induction, initiation and tuber growth. In the context of microtuberization in potato, the impact of different sources of plant hormones is noteworthy. These include a) The effects of Anti-gibberellins – Paclobutrazol. While, cytokinin has been shown to promote tuberization, GA inhibits tuberization. However, with anti-GA one would expect the reversal of tuberization inhibition and hence, tuber induction. Some of the reports in the past have also shown the positive role of auxin in inducing tuberization in potato.

Therefore, in the present investigation, the effect of Anti-GA on

microtuberization in potato was studied.

Influence of Anti-gibberellins on microtuberization in potato Anti-Gibberellins

The role of Anti-GA such as Paclobutrazol on microtuberization in *in-vitro* grown plants were investigated. The experiment was conducted with different concentrations of Paclobutrazol (control, 1ppm, 2ppm and 5ppm) to study their effect on microtuberization. Paclobutrazol, an anti-gibberellin plays a crucial role in regulating plant physiological functions by inhibiting the biosynthetic pathway of gibberellins. It accomplishes this by impeding the conversion of ent-kaurene to active gibberellins through the inhibition of the enzyme GA2 oxidases, which serves as the rate-limiting step.

The plantlets were placed on MS medium with different concentrations of Paclobutrazol (control, 1ppm, 2 ppm, 5 ppm) and observed under short day conditions. The growth observation such as plant height (cm), number of nodes, number of leaves, per cent microtuberizing plant (%), number of microtubers per plant, fresh weight of microtuber (mg) and microtuber diameter (mm) were made after 45 days and continued up to 90 days after inoculation.

Results and Discussion

Influence of Anti-gibberellins (Paclobutrazol) on microtuberization in potato

Paclobutrazol functions as a plant growth regulator that hinders cell elongation and encourages compact growth by suppressing the synthesis of gibberellins, a group of plant hormones pivotal in various aspects of plant development including microtuberization in potato (Aksenova *et al.*, 2012) [1]. The influence of paclobutrazol on microtuber organization in potato is contingent upon concentrations, exposure duration and specific developmental stages of the potato plant (Desta and Amare, 2021) [4].

Influence of Paclobutrazol on Vegetative Growth Parameters in Potato

The study delved into the impact of paclobutrazol on microtuberization in potato plants emphasizing diverse concentrations (1, 2 and 5ppm) in comparison to a control group. The findings revealed a significant disparity in plant height between the control group (13.46cm) and the paclobutrazol-treated plants (2.35cm). Notably, the plant height at a 1 ppm concentration of paclobutrazol (6.13cm) slightly exceeded that at a 2ppm concentration (2.35cm). These results suggested that, an increase in paclobutrazol concentration correlated with a decrease in plant height indicating a dose-dependent effect on potato plant growth. The alterations in plant height and overall growth could impact resource allocation within the plant potentially leading to increased microtuberization (Table 1).

Table 1: Effect of Paclobutrazol (PBZ) on plant growth in potato under *in-vitro* condition

Paclobutrazol (PBZ)			
Treatments	Plant height (cm)	Number of nodes	Number of leaves
Control	13.46 ^a	48.11 ^a	48.86 ^a
PBZ-1ppm	6.13 ^b	41.22 ^b	42.60 ^b
PBZ-2 ppm	3.65 ^c	26.51 ^c	28.10 ^c
PBZ-5 ppm	2.35 ^d	22.53 ^d	23.38 ^d
CD (P<0.01)	0.336 ^{**}	1.119 ^{**}	1.267 ^{**}
SE(m)	0.113	0.377	0.427
SE(d)	0.16	0.533	0.603
CV (%)	4.331	2.668	2.924

^{**} Significant at 1% level

The current experimental findings align with prior studies on various plant species demonstrating paclobutrazol's ability to diminish plant height by inhibiting gibberellin activity (Hedden and Sponsel, 2015; Rademacher, 2000) [9, 17]. The dose-dependent response observed in this experiment further substantiates the idea that, paclobutrazol's effects on plant height are contingent upon its concentration. The reduced stature induced by paclobutrazol may enhance resource allocation efficiency potentially fostering microtuber development. Research by Singh *et al.* (2015) [20] supports this notion illustrating that, paclobutrazol application can augment tuberization in potato plants. The compact growth induced by paclobutrazol may redirect resources towards tuber formation presenting an intriguing avenue for optimizing microtuber production. To conclude, this experiment offers valuable insights into the impact of paclobutrazol on microtuberization in potato with the observed reduction in plant height aligning with the known mechanism of action of this plant growth regulator.

The control group devoid of Paclobutrazol (0 ppm) demonstrated a higher count of nodes per plant (48.11) compared to plants subjected to Paclobutrazol treatments (1, 2 and 5 ppm). This suggests that, in the absence of Paclobutrazol, there is a promotion of lateral branching and node development in plants. Notably, the 1 ppm Paclobutrazol treatment exhibited a slightly higher number of nodes per plant (41.22) compared to the other treatment. Conversely, the 2 ppm and 5 ppm concentrations of Paclobutrazol led to decrease in the number of nodes per plant registering a value of 26.51 and 22.53, respectively. The Paclobutrazol treatments (1, 2 and 5 ppm) demonstrated a significant reduction in the number of nodes per plant with increasing concentrations indicating that, Paclobutrazol exerts a suppressive effect on lateral branching and overall node formation (Table 1; Plate 1).

Research by Dhital and Lim (2012) [5] highlighted the notable impact of Paclobutrazol on the number of nodes per plant and its influence on growth parameters, particularly during microtuberization in potato plants. Additionally, a valuable reference, "Regulation of Plant Growth by Paclobutrazol" by Zhou and Xi (1993) [21], discusses the comprehensive effects of Paclobutrazol on various aspects of plant growth and development. It delves into how Paclobutrazol affects hormonal regulation including the suppression of gibberellins, influencing plant architecture, internode length and node formation.

The current experimental results suggest that, control plants exhibited a higher count of leaves per plant (48.86) compared to those treated with 1 ppm Paclobutrazol (42.60). However, as the concentration of Paclobutrazol increased, there was a gradual decrease in the number of leaves with 2 ppm and 5 ppm Paclobutrazol treatments recording values of 28.10 and 23.38, respectively (Table 1; Plate 1).



Plate 1: Effect of different concentrations of paclobutrazol on microtuberization (a) plant growth

These findings align with the understanding that, Paclobutrazol, a known plant growth regulator inhibiting gibberellin biosynthesis

can influence various physiological processes in plants including the regulation of plant height, leaf development and tuberization (Hajhashemi, 2017) [7]. Other research results have indicated that, Paclobutrazol treatments can bring about alterations in plant morphology such as reduced internodal elongation and leaf expansion. The suppression of gibberellins can result in shorter and more compact plants with fewer leaves potentially explaining the observed lower leaf count in the Paclobutrazol-treated group. While paclobutrazol is acknowledged for its role in regulating plant growth and often inducing a reduction in vegetative growth, its specific impact on tuberization can exhibit variability. Some studies indicate that, decreased vegetative growth might redirect more resources toward tuberization potentially leading to an augmentation in microtuber formation. It's crucial to emphasize that, diverse potato cultivars may respond differently to paclobutrazol treatments. While, some may display increased tuberization with reduced vegetative growth, others may not manifest significant changes in tuber production (Li *et al.*, 2013) [11].

Increasing Paclobutrazol Levels Improve Microtuber Induction Efficiency

The results disclosed a discernible trend, wherein the escalation of paclobutrazol concentration corresponded to an increase in the percentage of plants exhibiting microtuberization. Notably, the treatment with higher paclobutrazol concentration (5 ppm) demonstrated a significantly elevated percentage with approximately 80% of plants displaying microtuber formation in potato in contrast to the control treatment (0 ppm paclobutrazol), where only 40% of plants exhibited microtuberization. Treatments with 1 and 2 ppm concentrations of paclobutrazol displayed slightly higher percentages of microtuberizing plants registering 50% and 55%, respectively, in comparison to the control treatment, which had only 40% of plants showing microtuberization. However, the incremental increase in paclobutrazol concentration consistently elevated the percentage of microtuberizing plants in potato (Figure 1a; Plate 1).

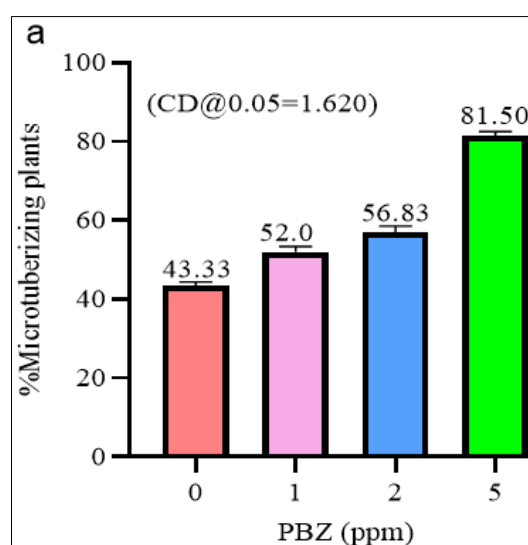


Fig 1a: Effect of different concentrations of Anti-GA (Paclobutrazol-PBZ) on micro-tuberization response in potato. (a) Per cent microtuberizing plants

Paclobutrazol is a plant growth regulator commonly used to control vegetative growth and promote flowering and fruiting in various crops. In the case of potato, the use of paclobutrazol can have a significant impact on microtuberization. Microtubers are

small, miniature tubers produced under *in vitro* or controlled environmental conditions. Results clearly shows that, higher concentration of paclobutrazol treatment (5ppm) has significantly increased the number of microtubers per potato plant (0.93) compared to the control group (0.42). However, lower concentrations of paclobutrazol treatment (1 and 2ppm) had slightly higher microtuber (0.75) and (0.82) compare to the control treatment (0.42). This experimental group treated with paclobutrazol exhibited a statistically significant higher yield of microtubers per plant, indicating a positive impact of the growth regulators on this aspect of potato development. This suggests that, paclobutrazol has a positive effect on the microtuberization process in potato. The increased number of microtubers per plant may have implications for improving the overall yield and quality of potato crops as microtubers can serve as seed tubers for subsequent planting in the field conditions (Figure 1b; Plate 2). The present findings align with previous studies such as the work by Dalimunthe *et al.* (2021) [2] shedding light on the impact of paclobutrazol on tuberization in potato encompassing various physiological processes. The study conducted by Nookaraju *et al.* (2011) [14] delved into the underlying mechanisms through which paclobutrazol influences tuberization in potato. A comprehension of these mechanisms could potentially facilitate the optimization of paclobutrazol use for enhancing tuberization in potato leading to potential improvements in potato yield.

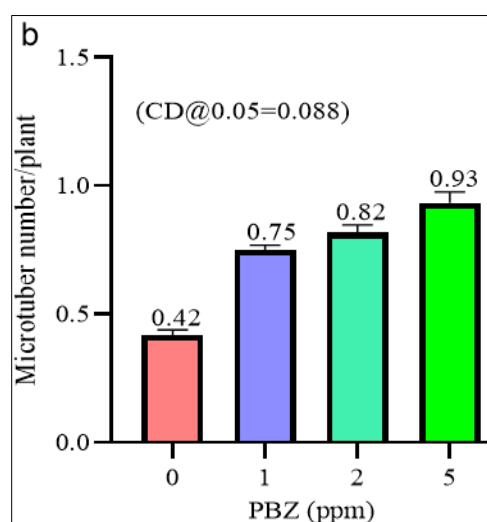


Fig 1b: Effect of different concentrations of Anti-GA (Paclobutrazol-PBZ) on micro-tuberization response in potato. (b) Micro-tuber number per plant

The application of paclobutrazol treatments (1, 2 and 5 ppm) and control exerted a significant influence on the microtuberization process in potato. The mean fresh weight of microtubers harvested from 5ppm paclobutrazol-treated plants was 299 mg markedly higher than that of microtubers from untreated control plants (25.83 mg). Plants treated with 1 ppm of paclobutrazol (155mg) and 2 ppm of paclobutrazol (161.97mg) exhibited significantly higher weights compared to the control and lower weights compared to the higher concentration of paclobutrazol-treated plants (5 ppm), respectively. The results underscored that, the mean fresh weight of microtubers per plant was significantly higher in the paclobutrazol-treated group (299 mg) compared to the untreated control group (25.83 mg). This suggests that paclobutrazol not only enhances the quantity of microtubers but also contributes to their overall weight indicating potential enhancements in potato yield (Figure 1c; Plate 2).

The reduction of gibberellin levels induced by paclobutrazol has

been linked to heightened sink strength in tuberizing tissues leading to increased nutrient accumulation and subsequently, resulting in higher fresh weights of tubers. The larger and heavier microtubers produced under paclobutrazol treatment may contribute to improved seed quality potentially leading to better crop establishment and yield in subsequent generations. In summary, the application of paclobutrazol significantly enhances the fresh weight of microtubers in potato (Davis *et al.*, 1991; Fletcher *et al.*, 2000) [3, 6].

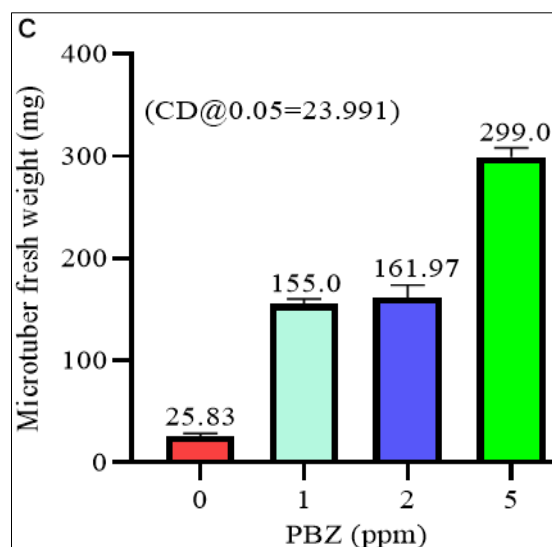


Fig 1c: Effect of different concentrations of Anti-GA (Paclobutrazol-PBZ) on micro-tuberization response in potato. (c) Micro-tuber fresh weight (mg)

Paclobutrazol Enhances Microtuber Growth in Potato

In the current investigation, it was observed that, potato plants treated with a higher concentration of paclobutrazol exhibited a notable increase in microtuber diameter (8.11 mm) compared to the control group (3.83 mm). The average microtuber diameter was found to be significantly higher in plants treated with paclobutrazol (8.11 mm) indicating a positive impact of the growth regulator on tuber development. A concentration of 1 ppm paclobutrazol showed a slightly higher diameter (6.63 mm) compared to the control (3.83 mm); however, increasing the concentration of paclobutrazol gradually increased the microtuber diameter (6.69 mm). Hence, a higher concentration of paclobutrazol shows a positive correlation between the microtuber diameter in potato plants (Figure 1d; Plate 2).

This study investigated the influence of varying concentrations of paclobutrazol on microtuberization in potato specifically focusing on the resultant microtuber size. Notably, microtubers obtained from plants treated with higher concentrations of paclobutrazol (5 ppm) exhibited a significant increase in size. This suggests that, paclobutrazol plays a stimulatory role in the tuberization process potentially promoting cell division and enlargement during microtuber development. In conclusion, the application of paclobutrazol at higher concentrations positively influences microtuber size in potato (Figure 1d; Plate 2).

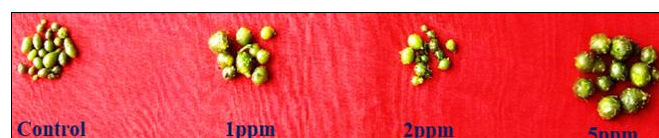


Plate 2: Effect of different concentrations of paclobutrazol on microtuberization (b) microtubers.

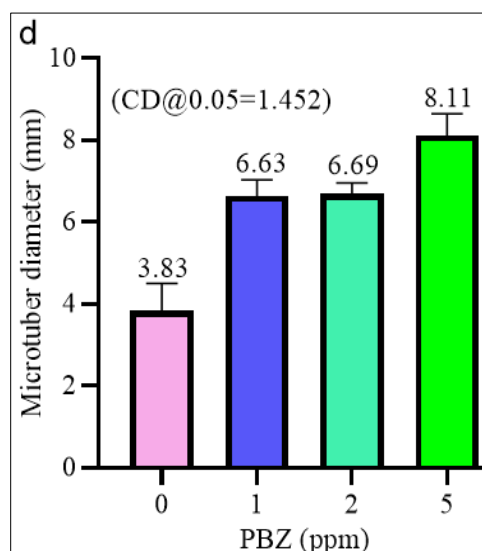


Fig 1d: Effect of different concentrations of Anti-GA (Paclobutrazol-PBZ) on micro-tuberization response in potato. (d) Micro-tuber diameter (mm).

A study conducted by Rademacher (2000) ^[17] demonstrated a similar results in potato where paclobutrazol application not only increased the number of tubers but also enhanced their size. The authors proposed that, the modulation of hormonal pathways by paclobutrazol played a key role in determining tuber characteristics. The observed increase in microtuber size with higher concentrations of paclobutrazol aligns with previous studies reporting the positive effects of this plant growth regulator on tuberization in potato (Pumisutapon and Topoonyanont, 2017) ^[16].

Paclobutrazol application resulted in reduced plant height, leaf area and dry weight. Conversely, it increased the number of tubers and tuber weight per plant. In summary, the application of paclobutrazol at 50 ppm is an optimal approach for enhancing potato plant productivity at medium altitudes (Nurain *et al.*, 2018) ^[15]. As a gibberellin biosynthesis inhibitor, paclobutrazol accelerated during *in vitro* tuber initiation, increasing the uniformity of the tuberization period. However, at high concentrations (10-1000 mg/l), this retardant strongly decreased the mass and number of microtubers (Simko, 1994) ^[19]. Early application of paclobutrazol reduced stem length, the number of tubers per plant and sugar content of potato. Furthermore, it increased starch content and yield compared to late application of paclobutrazol treatments (Mabvongwe *et al.*, 2016) ^[12].

Conclusion

The present study demonstrated that paclobutrazol, an anti-gibberellin, significantly influenced *in vitro* microtuberization in potato by suppressing vegetative growth and promoting tuber development. Increasing concentrations of paclobutrazol resulted in a dose-dependent reduction in plant height, number of nodes, and leaves, confirming its inhibitory effect on gibberellin-mediated shoot growth. Conversely, higher paclobutrazol concentrations enhanced the percentage of microtuberizing plants, number of microtubers per plant, fresh weight, and microtuber diameter, with 5 ppm proving to be the most effective treatment. These findings indicate that inhibition of gibberellin biosynthesis redirects assimilates from vegetative growth toward storage organ formation, thereby improving microtuber induction and development. Overall, the results suggest that 5 ppm paclobutrazol is an effective concentration for enhancing *in vitro* microtuberization in potato and could be incorporated into

optimized microtuber production protocols for seed potato multiplication and germplasm conservation. Further studies involving different potato genotypes and combinations with other plant growth regulators are recommended to refine species- and cultivar-specific microtuberization strategies.

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Conflict of Interest

The authors disclose no conflict of interest

References

1. Aksenova NP, Konstantinova TN, Golyanovskaya SA, Sergeeva LI, Romanov GA. Hormonal regulation of tuber formation in potato plants. *Russian Journal of Plant Physiology*. 2012;59(4):451-466. doi:10.1134/S1021443712040024.
2. Dalimunthe RH, Setiadi H, Lubis K, Damanik RI. Effect of paclobutrazol in microtuberization of potato (*Solanum tuberosum* L.) cultivar Granola Kembang and Repita. *Earth and Environmental Science*. 2021;782(4):042058. doi:10.1088/1755-1315/782/4/042058.
3. Davis TD, Curry EA. Chemical regulation of vegetative growth. *Critical Reviews in Plant Sciences*. 1991;10:151-188.
4. Desta Bizuayehu, Getachew Amare. Paclobutrazol as a plant growth regulator. *Chemical Biology and Technologies in Agriculture*. 2021;8:1.
5. Dhital SP, Lim HT. Microtuberization of potato (*Solanum tuberosum* L.) as influenced by supplementary nutrients, plant growth regulators, and *in vitro* culture conditions. *Potato Research*. 2012;55(2):97-108. doi:10.1007/s11540-012-9212-y.
6. Fletcher RA, Gilley A, Sankhla N, Davis TD. Triazoles as plant growth regulators and stress protectants. *Horticultural Reviews*. 2000;24:55-138.
7. Hajhashemi S. Physiological, biochemical, antioxidant and growth characterizations of gibberellin and paclobutrazol-treated sweet leaf (*Stevia rebaudiana* B.) herb. *Journal of Plant Biochemistry and Biotechnology*. 2018;27:237-240. doi:10.1007/s13562-017-0428-4.
8. Hedden P, Graebe JE. Inhibition of gibberellin biosynthesis by paclobutrazol in cell-free systems from *Cucurbita maxima* endosperm. *Journal of Plant Growth Regulation*. 1985;4:111-122.
9. Hedden P, Sponsel V. A century of gibberellin research. *Journal of Plant Growth Regulation*. 2015;34(4):740-760. doi:10.1007/s00344-015-9546-1.
10. Jackson SD. Multiple signaling pathways control tuber induction in potato. *Plant Physiology*. 1999;119(1):1-8.
11. Li HM, Tang CM, Xu ZG. The effects of different light qualities on rapeseed (*Brassica napus* L.) plantlet growth and morphogenesis *in vitro*. *Scientia Horticulturae*. 2013;150:117-124.
12. Mabvongwe O, Manenji BT, Gwazane M, Chandiposha M. The effect of paclobutrazol application time and variety on

- growth, yield, and quality of potato (*Solanum tuberosum* L.). Advances in Agriculture. 2016. doi:10.1155/2016/1585463.
13. Naik PS, Sarkar D. Microtuber production and performance of potato under controlled conditions. *Biologia Plantarum*. 2000;43(1):127-131.
 14. Nookaraju A, Kappachery S, Yu JW, Park SW. Rhizobacteria influence potato tuberization through enhancing lipoxygenase activity. *American Journal of Potato Research*. 2011;88(6):441-449. doi:10.1007/s12230-011-9210-7.
 15. Nurain A, Mubarak S, Hamdani JA. Effects of application time and concentration of paclobutrazol on the growth and yield of potato seed of G2 cultivar medians at medium altitude. *Journal of Agronomy*. 2018;17(3):169-173.
 16. Pumisitapon P, Topoonyanont N. Moderate-abiotic stress increase *in vitro* tuberization and microtuber growth of potato. *Acta Horticulturae*. 2017;1155:215-220. doi:10.17660/ActaHortic.2017.1155.30.
 17. Rademacher W. Growth retardants: Effects on gibberellin biosynthesis and other metabolic pathways. *Annual Review of Plant Physiology and Plant Molecular Biology*. 2000;51:501-531.
 18. Rademacher W. Plant growth regulators: Backgrounds and uses in plant production. *Journal of Plant Growth Regulation*. 2015;34(4):845-872.
 19. Simko I. Effect of paclobutrazol on *in vitro* formation of potato microtubers and their sprouting after storage. *Biologia Plantarum*. 1994;36(1):15-20.
 20. Singh A, Siddappa S, Bhardwaj V, Singh B, Kumar D, Singh BP. Expression profiling of potato cultivars with contrasting tuberization at elevated temperature using microarray analysis. *Plant Physiology and Biochemistry*. 2015;97:108-116. doi:10.1016/j.plaphy.2015.09.014.
 21. Zhou W, Xi H. Effects of mixtalol and paclobutrazol on photosynthesis and yield of rape (*Brassica napus*). *Journal of Plant Growth Regulation*. 1993;12(3):157-161. doi:10.1007/BF00189647.