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THE INFLUENCE OF RETARDANTS AND SUPPLEMENTARY FERTILIZATION ON THE GROWTH AND YIELD OF INDUSTRIAL POTATO

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ABSTRACT

The low productivity of potatoes in Indonesia is attributed to the use of low-quality seed tubers, limited agricultural land, and suboptimal cultivation practices. Therefore, the application of gibberellin-inhibiting growth regulators may serve as a strategy to improve potato productivity, including paclobutrazol and prohexadione-Ca. This study aimed to determine the effects of paclobutrazol, prohexadione-Ca, and supplementary fertilization on the growth and yield of G2 potato seed tubers of the Medians cultivar. The experiment was conducted from October 2025 to January 2026 at PT. Horti Agro Makro, Cisurupan District, Garut, West Java, located at an altitude of approximately ± 800 m asl. The experimental design used was a Split Plot Design. The first factor, assigned as the main plot, consisted of growth retardants: paclobutrazol at 100 ppm and prohexadione-Ca at 100 ppm. The second factor, assigned as the subplot, consisted of supplementary fertilizer treatments: Urea, Urea + ZA, Urea + $MgSO_4$, and Urea + Humate NPK. The results showed a significant interaction between paclobutrazol and Urea + $MgSO_4$ on tuber water content (76.14%). Paclobutrazol application had a significant independent effect in reducing plant height, and leaf area index, while increasing tuber weight (752.39 g). The application of Urea + $MgSO_4$ as a supplementary fertilizer significantly reduced the plant height, while increasing the tuber weight, and specific gravity.

Key words: Humic, Medians, Paclobutrazol, Urea.

INTRODUCTION

Potato (Solanum tuberosum L.) is a horticultural crop with great potential for both domestic and export markets, and it serves as a key commodity supporting food diversification programs to meet the nutritional needs of the Indonesian population (Dewi *et al*., 2024). In Indonesia, potatoes play an important role in home industries, fresh vegetable consumption, and as raw materials for large-scale food processing industries, such as flour and potato chip production (Mulyono *et al*., 2018).

The low productivity of potatoes in Indonesia is caused by the use of low-quality seed tubers, limited land availability, and suboptimal cultivation techniques. To reduce the expansion of potato cultivation into steeper highland slopes and prevent deforestation, developing alternatives for potato cultivation in medium altitudes (300–700 m asl), which offer vast available land in Indonesia, becomes essential (Hadayanti, 2021).

The Indonesian Vegetables Research Institute introduced "Medians," a superior potato cultivar capable of adapting well to medium altitudes with high productivity reaching up to 31.9 t ha^{-1}. Tuber formation in the Medians potato cultivar is highly influenced by the internal hormonal balance of the plant (Suliansyah *et al.*, 2023). High gibberellin activity causes stolons to elongate continuously and inhibits tuberization (Nuraini *et al.*, 2016). Therefore, utilizing gibberellin-inhibiting agents (retardants) like paclobutrazol and prohexadione-Ca is a strategic approach to limit vegetative growth, thereby redirecting photosynthates toward tuber formation. This regulation must be balanced with proper nutrient management through supplementary fertilizers, such as Urea combined with ZA or $MgSO_4$, to optimize plant nutrient uptake.

MATERIALS AND METHODS

This research was conducted from October 2025 to January 2026 at the experimental field of PT. Horti Agro Makro, Tambakbaya Village, Cisurupan District, Garut, West Java, at an altitude of ± 800 m asl. The experimental design employed was a Split Plot Design. The first factor, as the main plot, was the type of retardant (paclobutrazol 100 ppm and prohexadione-Ca 100 ppm). The second factor, as the subplot, was the type of supplementary fertilizer (Urea, Urea + ZA, Urea + $MgSO_4$, and Urea + Humate NPK).

The materials used in this experiment included G2 (Generation 2) potato seed tubers of the Medians cultivar obtained from PT Horti Agro Makro. The growing medium consisted of a mixture of Andisol soil, manure, NPK fertilizer (16:16:16), ZA fertilizer (21% N, 24% S), SP-36 fertilizer, $MgSO_4$, Humate NPK, paclobutrazol, prohexadione-Ca, and herbicides. The equipment utilized throughout the field preparation, cultivation, and analysis phases comprised hoes, shovels, sacks, water hoses, buckets, stirrers, trays, black-silver plastic mulch, mulch hole punchers, planting sticks (tugal), knapsack sprayers, a 2-liter hand sprayer, stakes, raffia strings, labels, rulers, measuring tapes, measuring cylinders, thermo-hygrometers, analytical and digital balances, hanging scales, a chlorophyll content meter, an oven, brown envelopes, mesh bags (waring), laboratory equipment for potato quality testing, as well as stationery and documentation tools.

The parameters observed included growth components (plant height and leaf area index) as well as yield components (number of stolons, percentage of stolons forming tubers, tuber weight per plant, tuber moisture content, and specific gravity). The data obtained were analyzed using Analysis of Variance (ANOVA) with an F-test at a 95% confidence level, followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level.

RESULTS AND DISCUSSION

Growth parameter: plant height

The application of growth retardants effectively reduced vegetative growth of potato plants under medium-altitude conditions, preventing excessive stem elongation and promoting a more compact canopy architecture. Such morphological modification is beneficial because assimilates can be allocated more efficiently toward tuber development rather than continuous shoot growth. At 60 days after planting (DAP), untreated plants (r_0) exhibited the tallest canopy with an average height of 58.69 cm. In contrast, plants treated with 100 ppm paclobutrazol (r_1) showed the shortest stature at 45.22 cm, followed by 100 ppm prohexadione-Ca (r_2) at 51.69 cm. The reduction in plant height indicates the effectiveness of both compounds in suppressing gibberellin biosynthesis, a hormone responsible for cell division and elongation.

Paclobutrazol inhibits the oxidation of ent-kaurene into ent-kaurenoic acid through the inhibition of ent-kaurene oxidase activity, thereby restricting stem elongation. Likewise, prohexadione-Ca interferes with the final steps of active gibberellin formation by acting as a structural analogue of 2-oxoglutarate. Reduced gibberellin availability limits vegetative expansion and redirects assimilates toward storage organs (Rademacher, 2016).

Supplementary fertilization resulted in relatively similar plant heights, ranging from 49.81 to 54.48 cm. Numerically, the combination of Urea + $MgSO_4$ (p_3) supported a compact canopy while maintaining physiological activity. Magnesium functions as a central component of chlorophyll molecules and contributes to phloem loading processes, enhancing sucrose translocation from leaves to developing tubers (Koch MJ, 2018). Therefore, the integration of growth retardants and magnesium fertilization may improve assimilate partitioning efficiency in potato production systems.

Growth parameters: leaf area and leaf area index (lai)

Leaf area and leaf area index (LAI) are important indicators of crop growth because they determine the plant's capacity to intercept solar radiation and convert it into photosynthates. Leaf area represents the total photosynthetically active surface, while LAI reflects canopy density relative to land area occupied (Nurmala & Nira, 2017). Plants treated with paclobutrazol (r_1) produced a leaf area of 4,335.98 cm^2 and an LAI of 1.81, while prohexadione-Ca (r_2) resulted in 4,513.47 cm^2 and an LAI of 1.88. These values were considerably lower than those observed in untreated plants (r_0), which reached 8,769.87 cm^2 and an LAI of 3.65. The reduction in leaf area demonstrates that inhibition of gibberellin biosynthesis not only affects stem elongation but also limits leaf expansion, resulting in smaller and more compact canopies (Widhya & Gusmawan, 2019). Although supplementary fertilization generated comparable leaf area and LAI values, numerically higher LAI values were observed under Urea + $MgSO_4$ (p_3) and Urea + ZA (p_2). Adequate nitrogen availability supports chlorophyll synthesis and leaf formation, while magnesium enhances photosynthetic efficiency through its role in chlorophyll structure and enzyme activation. Consequently, balanced nutrient supply can maintain effective canopy development and support assimilate production during the transition from vegetative to tuber growth stages (Wulandari *et al*., 2014).

Yield Parameters: Number of Tubers

The highest tuber production was obtained from the combination of 100 ppm prohexadione-Ca and Urea + $MgSO_4$ (r_2p_3), which produced 17.44 tubers per plant or approximately 581.48 thousand tubers per hectare. This result indicates that growth restriction accompanied by balanced nutrient availability can enhance tuber initiation and development. Prohexadione-Ca suppresses vegetative growth by reducing active gibberellin synthesis, thereby promoting the conversion of stolons into tubers. Hamdani *et al*., (2024) reported that prohexadione-Ca may substantially increase the proportion of stolons developing into tubers compared with untreated plants. As shoot elongation decreases, assimilates become increasingly available for underground storage organ formation. The contribution of $MgSO_4$ is also essential in supporting tuber production. Magnesium plays a central role in photosynthesis and carbohydrate translocation, while sulfur contributes to amino acid synthesis and metabolic activity. Adequate magnesium availability improves sucrose movement from source leaves to sink organs, strengthening tuber development and increasing the number of tubers formed (Zhang *et al*., 2020).

Yield parameters: tuber weight

Application of growth retardants increased tuber weight compared with untreated plants. The highest tuber weight was recorded under 100 ppm paclobutrazol (r_1), reaching 752.39 g per plant or equivalent to 25.08 t ha^{-1}, followed by prohexadione-Ca (r_2) with 704.81 g per plant. Untreated plants produced 537.37 g per plant. The increase in tuber weight is associated with the suppression of excessive vegetative growth. Paclobutrazol promotes chlorophyll accumulation and improves photosynthetic efficiency while reducing the formation of new shoots. Consequently, a greater proportion of assimilates is directed toward tuber filling and starch accumulation (Hamdani *et al*., 2018). Among supplementary fertilizer treatments, Urea + $MgSO_4$ (p_3) produced the highest numerical tuber weight, reaching 758.89 g per plant or 25.30 t ha^{-1}. Magnesium supports carbohydrate transport through the phloem, whereas sulfur contributes to protein synthesis and enzyme activity. Together, these nutrients facilitate assimilate movement from source tissues to developing tubers, enhancing biomass accumulation within storage organs (Zhang *et al*., 2020).

Quality parameters: tuber moisture content and specific gravity

Tuber moisture content and specific gravity are important indicators of processing quality because they reflect the efficiency of dry matter accumulation and starch deposition within tuber tissues. Potatoes with lower moisture content generally produce chips and French fries with a crisp texture and lower oil absorption during processing (Jan *et al*., 2021). The combination of 100 ppm paclobutrazol and Urea + $MgSO_4$ (r_1p_3) produced the lowest moisture content, reaching 76.14%. This result suggests a greater accumulation of dry matter within the tubers. Reduced vegetative growth allows a larger proportion of photosynthates to be stored as starch, thereby lowering the relative water content of tuber tissues. Specific gravity values ranged from 1.078 to 1.081 across treatments. Values above 1.080 are generally associated with high starch content and are desirable for industrial processing because they contribute to crisp texture and improved frying quality (Kusandriani, 2016). The relatively uniform specific gravity values observed in this study indicate that environmental conditions were favorable for starch accumulation. Cool soil temperatures likely enhanced assimilate partitioning and starch deposition within tuber parenchyma tissues, resulting in consistently high-quality tubers (Koch, 2018).

CONCLUSION

Based on the research findings regarding the effects of growth retardant types and supplementary fertilization on the growth and yield of industrial potato cultivar Medians at medium altitudes, the following conclusions can be drawn:

1. There is a significant interaction effect between the application of 100 ppm paclobutrazol and $MgSO_4$ supplementary fertilizer on enhancing growth parameters and industrial potato yields, a tuber moisture content of 76.14%. Meanwhile, the combination of 100 ppm prohexadione-Ca and $MgSO_4$ supplementary fertilizer showed a significant interaction on the total number of tubers, producing 17.44 tubers per plant.
2. The independent application of paclobutrazol growth retardant exerted a significant influence on the tuber growth rate (10.14), plant height (45.22 cm at 60 DAP), leaf area index (1.81), and tuber weight per plant (752.39 g).
3. The use of Urea + $MgSO_4$ as a supplementary fertilizer significantly affected the plant height (50.63 cm at 60 DAP), tuber weight per plant (758.89 g), and specific gravity (1.079).

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Tabel 4. Effect of Retardant and Supplementary Fertilizer on Plant Height at 50 DAP and 60 DAP (cm)

Treatment	50 DAP	60 DAP
Main Plot (r)		
r_0 (Without Retardant)	50,31 b	58,69 c
r_1 (Paclobutrazol 100 ppm)	35,44 a	45,22 a
r_2 (Prohexadione-Ca 100 ppm)	41,98 ab	51,69 b
Sub Plot (p)		
p_1 (Urea)	44,57 a	52,56 a
p_2 (Urea + Za)	42,96 a	49,81 a

p_3 (Urea + $MgSO_4$)	40,85 a	50,63 a
p_4 (Urea + NPK Humat)	41,93 a	54,48 a

Explanation: Means followed by the same letter within the same column and factor are not significantly different according to Duncan's Multiple Range Test (DMRT) at α= 0.05%

Tabel 5. Effect of Retardant and Supplementary Fertilizer on Leaf Area Index

Treatment	Leaf Area Indeks (LAI)
Main Plot (r)	
r_0 (Without Retardant)	3,65 b
r_1 (Paclobutrazol 100 ppm)	1,81 a
r_2 (Prohexadione-Ca 100 ppm)	1,88 a
Sub Plot (p)	
p_1 (Urea)	2,20 a
p_2 (Urea + Za)	2,76 a
p_3 (Urea + $MgSO_4$)	2,77 a
p_4 (Urea + NPK Humat)	2,06 a

Explanation: Means followed by the same letter within the same column and factor are not significantly different according to Duncan's Multiple Range Test (DMRT) at α= 0.05%

Tabel 6. Interaction Effect of Retardant and Supplementary Fertilizer on the Number of Tubers per Plant

Retardant Treatments (r)	Supplementary Fertilizer Treatments (p)			
	p_1 (Urea)	p_2 (Urea + Za)	p_3 (Urea + $MgSO_4$)	p_4 (Urea + NPK Humat)
r_0 (Without Retardant)	13,56 a A	11,56 a A	10,78 a A	10,56 a A
r_1 (Paclobutrazol 100 ppm)	11,89 a A	11,44 a A	12,22 a A	14,00 b A
r_2 (Prohexadione-Ca 100 ppm)	13,44 a A	13,33 a A	17,44 b B	12,00 ab A

Explanation:

- Means followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the 0.05 significance level.
- Lowercase letters indicate comparisons along the vertical direction (comparing retardants within the same fertilizer).
- Uppercase letters indicate comparisons along the horizontal direction (comparing fertilizers within the same retardant).

Tabel 7. Interaction Effect of Retardant and Supplementary Fertilizer on Tuber Weight per Plant (g)

Treatment	Tuber Weight g Plant^{-1}	Tuber Weight g m$^{2-1}$	Tuber Yield (t ha^{-1})
Main Plot (r)			

r_0 (Tanpa Retardant)	537,37 a	2.239,06 a	17,91 a
r_1 (Paclobutrazol 100 ppm)	752,39 b	3.134,96 b	25,08 b
r_2 (Prohexadione-Ca 100 ppm)	704,81 b	2.936,69 b	23,49 b
Sub Plot (p)			
p_1 (Urea)	656,02 a	2.733,41 a	21,87 a
p_2 (Urea + Za)	618,68 a	2.577,85 a	20,62 a
p_3 (Urea + $MgSO_4$)	758,89 a	3.162,04 a	25,30 a
p_4 (Urea + NPK Humat)	625,83 a	2.607,64 a	20,86 a

Explanation: Means followed by the same letter within the same column and factor are not significantly different according to Duncan's Multiple Range Test (DMRT) at α= 0.05%

Tabel 8. Interaction Effect of Retardant and Supplementary Fertilizer on Moisture Content (%)

Retardant Treatments (r)	Supplementary Fertilizer Treatments (p)			
	p_1 (Urea)	p_2 (Urea + Za)	p_3 (Urea + $MgSO_4$)	p_4 (Urea + NPK Humat)
r_0 (Without Retardant)	81,10 a B	84,43 b C	78,51 ab A	78,35 a A
r_1 (Paclobutrazol 100 ppm)	80,04 a B	80,53 a B	76,14 a A	80,53 ab B
r_2 (Prohexadione-Ca 100 ppm)	81,30 a A	79,13 a A	80,02 b A	81,46 b A

Explanation:
- Means followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the 0.05 significance level.
- Lowercase letters indicate comparisons along the vertical direction (comparing retardants within the same fertilizer).
- Uppercase letters indicate comparisons along the horizontal direction (comparing fertilizers within the same retardant).

Tabel 9. Effect of Retardant and Supplementary Fertilizer on Specific Gravity

Treatment	Spesific Gravity
Main Plot (r)	
r_0 (Without Retardant)	1,078 a
r_1 (Paclobutrazol 100 ppm)	1,080 a
r_2 (Prohexadione-Ca 100 ppm)	1,080 a
Sub Plot (p)	
p_1 (Urea)	1,081 a
p_2 (Urea + Za)	1,078 a
p_3 (Urea + $MgSO_4$)	1,078 a
p_4 (Urea + NPK Humat)	1,079 a

Explanation: Means followed by the same letter within the same column and factor are not significantly different according to Duncan's Multiple Range Test (DMRT) at α= 0.05%