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Research Article
Retardant Improve Seed Tuber Yield of G0 Potato (*Solanum tuberosum* cv. Medians)

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Abstract
Background and Objective: The term G0 refers to potatoes grown from cuttings and later used as seeds. A major problem in the G0 potato seed production is the low tuber production, i.e., 2-3 tubers per plant. The low formation of tubers from stolons is caused by the existence of high gibberellin concentrations in potato plants. Thus, the present study aimed to communicate the success of plant growth retardant, in the form of gibberellin inhibitor, in altering plant growth and improving seed tuber production of G0 potato. **Materials and Methods:** This experiment was carried out from June-November, 2023 at PT Horti Agro Makro Plantation, Garut Highland, Indonesia by using a randomized complete block design to test 7 treatments of retardants, namely paclobutrazol and prohexadione-Ca. The present work analyzed plant height, leaf area, leaf area index, relative plant and tuber growth rate, tubers number and tuber weight, by using analysis of variance and Duncan's multiple range test at $\alpha = 0.05$. **Results:** The results showed that both retardants at 150 ppm concentrations displayed a significant growth inhibition on plant height and leaf area. Prohexadione-Ca with a concentration of 50 ppm could produce the highest number of tubers, while 100 ppm paclobutrazol produced the heaviest tuber per plant. **Conclusion:** Application of 50 ppm prohexadione-Ca was strongly recommended to improve the seed tuber number of G0 potato cv. Median.

Key words: Gibberellin inhibitor, paclobutrazol, prohexadione-Ca, potato seed, tuber, *Solanum tuberosum*

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a tuber plant that is widely used by people as a source of carbohydrates, after wheat, corn and rice. In fresh conditions, potatoes have the highest protein content compared to other tuber plants. To increase potato production, cultivation techniques should be improved, such as using high-quality seeds as the initial determinant factor for the success of potato plantations[1]. In 2013, the Indonesian Vegetable Crops Research Institute produced several superior potato cultivars, one of which was the Medians cultivar. Even though it is superior, its development is not without obstacles. The main problem in developing median cultivars is the low number of seeds on the market, on the other hand, market demand is quite high. The low availability of seeds on the market is caused by the low ability of cuttings to form tubers. Potato seeds grown from cuttings, then called G0 seeds, are only able to form 2-3 tubers per plant. The low level of tuber formation is related to the high content of the endogenous gibberellin hormone so growth towards tuber formation becomes less focused.

Gibberellin is a hormone in plants that functions in the process of cell elongation thereby encouraging the growth of the plant canopy, including the leaves and stem organs. Gibberellins generally regulate photosynthate translocation towards shoot growth, so they appear to be more dominant than the formation and filling of potato tubers[2,3]. Therefore, plant growth inhibitors are needed to balance the growth of potato plants toward target organs that have financial value. Reducing the dominance of canopy growth can be done by using growth inhibitors or retardants.

Retardants work by inhibiting gibberellin biosynthesis so that the endogenous gibberellin concentration becomes lower. Thus, retardants can be used to regulate plant growth patterns to maintain the balance of photosynthate translocation for the top of the plant and bottom of the plant[4]. Retardants can suppress the growth of plant height so that the results of photosynthesis are channeled to form tubers and produce a greater number and weight of potato tubers[5]. Several retardants are commonly used to regulate plant growth, namely paclobutrazol and prohexadione-Ca.

Paclobutrazol is a commercial growth inhibitor that is commonly used to stimulate the transition from vegetative to reproductive growth in fruit plants, such as oranges[6]. Administration of paclobutrazol suppresses endogenous gibberellin biosynthesis[7]. However, the use of paclobutrazol leaves long-term residues in the soil that can last up to 2 years. This could potentially disrupt crop production in the following years. On the other side, prohexadione-Ca is a retardant similar to paclobutrazol but does not leave long-term residues. Prohexadione-Ca has been reported to suppress the vegetative growth of pome trees and control tree plant height[8]. The level of success of retardants in regulating plant growth depends on the concentration of the retardant used. Providing excessive concentrations of retardant can cause a decrease in efficiency and disruption of cell function[9]. Meanwhile, the retardant concentration is too low causing a decrease in the effectiveness[10]. Therefore, the present study aimed to communicate the success of plant growth retardant, in the form of gibberellin inhibitor, in altering plant growth and improving seed tuber production of G0 potato.

MATERIALS AND METHODS

Study area: The experiment was carried out from June to November, 2023 at PT Horti Agro Makro Plantation, Garut Highland (1100 m above sea level), Indonesia.

Study design: The planting material used is potato seeds resulting from the propagation of plantlet cuttings aged 14 days after acclimatization, produced by PT Horti Agro Macro. The planting medium is prepared from a mixture of cocopeat, husk charcoal and rotted husk in a ratio of 1:1:1. The media mixture is spread on a bed plot with a size of 1 m^2. After that, the media is flattened and watered until it reaches field capacity. After that, the media was given Furadan fumigant which contains 3% carbofuran as an active ingredient at a dose of 6 g/m^2 to sterilize the planting media from pests. Each plot is given boundaries and labels according to the experimental design. This experiment is arranged in a randomized complete block design and composed of 7 treatments, i.e., without retardant/control (A), 50 ppm paclobutrazol (B), 100 ppm paclobutrazol (C), 150 ppm paclobutrazol (D), 50 ppm prohexadion-Ca (E), 100 ppm prohexadion-Ca (F) and 150 ppm prohexadion-Ca (G). Each treatment was replicated 3 times in terms of bed plot and each bed plot was cultivated with 100 potato seeds.

Plant maintenance is started by basic fertilization that is carried out by applying SP-36 fertilizer at a dose of 125 g/m^2 and dolomite at 300 g/m^2. Planting was carried out at 08.00 am by first watering the planting medium and then making planting holes with a planting distance of 12.5×7.5 cm. There are 100 planting holes in 1 m^2. One planting hole only consists of one seed, with the planting method not being too deep, leaving a maximum of 3 nodes from the shoot. The application of paclobutrazol and prohexadione-Ca is carried out by spraying all parts of the plant leaves evenly according to the treatment. The spray volume is 5 mL per plant and is carried out at 40, 50 and 60 days after planting.

Plant maintenance includes watering, additional fertilization and controlling pests and diseases. Watering is done using tap water using with a frequency of twice a day, namely 07.00-08.00 am and 03.00-04.00 pm. Fertilization is carried out twice at th age of 5 days after planting (DAP) and 10-15 DAP. Fertilizer of 1 g/plant is given by sprinkling it around the plant roots and then covering it using a mixture of planting media (rice husks + fine cocopeat). Pest and disease control is carried out by spraying the fungicide Prospero (1 g/L), Puanmur (0.5 g/L) and insecticide Indodan (0.5 mL/L). Pesticide spraying is carried out at 3-day intervals, starting at 10 DAP until the plants are harvested. Weed control is carried out mechanically by pulling out weeds that have grown around the plantation. Soil hilling is carried out twice during the growth period, namely at 15 DAP and 25-30 DAP by adding 50 g of planting media around the plant roots. The G0 seed tuber harvesting is done when the leaves have dried and turned yellow, namely 94 DAP.

Measured variables are plant height, leaf area, leaf area index, relative plant growth rate, relative tuber growth rate, percentage of stolon forming tubers, number of tubers per plant and tubers weight per plant.

Statistical analysis: All obtained data were analyzed by analysis of variance and then continued by Duncan's multiple range test at $\alpha = 0.05$. All statistical analyses were performed in IBM SPSS STATISTICS 23 software.

RESULTS AND DISCUSSION

Application of paclobutrazol and prohexadione-Ca with different concentrations had a significant effect on plant height at 9 WAP (Table 1). The tallest plants were found in the control and most applications of paclobutrazol and prohexadione-Ca significantly suppressed plant height. In general, the higher the retardant concentration applied, the lower the plant height produced. The greatest plant height suppression was observed in the application of paclobutrazol and prohexadione-Ca 150 ppm, namely around 21% compared to the control. This was in accordance with report that the application of paclobutrazol can produce shorter plants[11]. Several previous studies stated that the inhibition of plant height growth by paclobutrazol was caused by shortening of stem segments[12]. The pressure on vegetative growth in the prohexadione-Ca and paclobutrazol treatment was caused by the inhibition of gibberellin biosynthesis by these two retardants[6].

In similar, the inhibition of vegetative growth due to paclobutrazol and prohexadione-Ca treatment can also be proven by significant suppression in leaf area and leaf area index. Based on Table 2, the leaf area and leaf area index in the treatment without retardant/control were significantly different and higher than those in the paclobutrazol treatment and the prohexadione-Ca treatment. Increasing concentrations of paclobutrazol and prohexadione-Ca were associated with decreasing leaf area and index values. This was in line with research conducted by Hamdani *et al*.[11] on potato plants. Apart from that, Darmawan *et al*.[6] also revealed that there was a decrease in the leaf area of tangerine plants due to prohexadione-Ca and paclobutrazol treatment compared to the control. The use of retardants on fruit plants, such as oranges, is well known as an effort to stimulate reproductive growth. Apart from that, retardants can also be used to improve canopy quality, reducing leaf area can help improve leaf structure to avoid leaf crowns covering each other. The reduction of overlapped leaves within canopy lead to higher photosynthate due to higher positive foliage subjected to sunlight and performing photosynthesis, in contrast to negative foliage with less penetrated sunlight and low photosynthetic rate[13].

In contrast to the plant height and leaf area variables, the administration of paclobutrazol and prohexadione-Ca did not have a significant impact on the relative plant growth rate at 2-time intervals, namely 9-10 WAP and 10-11 WAP (Table 3). In both periods, plants that were applied with retardant did experience suppressed growth in height and leaf area, but the relative growth rate was still not significantly different from control plants. This indicated that the focus of growth has shifted from initially focusing on vegetative growth in increasing plant height and leaf area to other organs, i.e., stolon or tubers.

Tubers are an economically valuable target organ in potato cultivation. Engineering potato cultivation is expected to increase tuber production. Potato tubers are the result of enlargement of the stolon organ, so the percentage of stolons forming tubers is an important variable to observe. The administration of paclobutrazol and prohexadione-Ca in this study had a significant effect on the percentage of stolons forming tubers (Table 4). Giving paclobutrazol above 100 ppm or prohexadione-Ca above 150 ppm increased the percentage of stolons forming tubers, 2× greater than the control/no retardant. Retardant succeeded in changing the focus of photosynthate translocation from leaves and stems to stolons for tuber formation[14,15].

The 50 ppm prohexadione-Ca treatment produced the highest number of tubers and was significantly different compared to other treatments with a total of 12.67 tubers per plant. The best treatment succeeded in increasing the number

Table 1: Potato plant height at 9 weeks after planting in response to paclobutrazol and prohexadione-Ca application

Treatment	Plant height
A: Without retardant/control	38.3^{d}
B: 50 ppm paclobutrazol	34.13^{ab}
C: 100 ppm paclobutrazol	30.76^{ab}
D: 150 ppm paclobutrazol	30.1^{a}
E: 50 ppm prohexadione-Ca	36.67^{cds}
F: 100 ppm prohexadione-Ca	34.9^{b}
G: 150 ppm prohexadione-Ca	30.3^{ab}

Mean followed by similar letter are not significantly different based on Duncan's multiple range test at $\alpha = 0.05$

Table 2: Potato leaf area and leaf area index in response to paclobutrazol and prohexadione-Ca application

Treatment	Leaf area (cm^2)	Leaf area index
A: Without retardant/control	541.06^{c}	1.35^{c}
B: 50 ppm paclobutrazol	378.17^{ab}	0.94^{ab}
C: 100 ppm paclobutrazol	252.12^{ab}	0.63^{ab}
D: 150 ppm paclobutrazol	179.88^{a}	0.45^{a}
E: 50 ppm prohexadione-Ca	478.74^{bc}	1.19^{bc}
F: 100 ppm prohexadione-Ca	436.25^{b}	1.09^{b}
G: 150 ppm prohexadione-Ca	293.28^{ab}	0.73^{ab}

Mean followed by similar letter are not significantly different based on Duncan's multiple range test at $\alpha = 0.05$

Table 3: Relative plant growth rate (RPGR) in response to paclobutrazol and prohexadione-Ca application

Treatment	RPGR 9-10 WAP (g/plant/day)	RPGR 10-11 WAP (g/plant/day)
A: Without retardant/control	0.021^{a}	0.021^{a}
B: 50 ppm paclobutrazol	0.038^{a}	0.017^{a}
C: 100 ppm paclobutrazol	0.020^{a}	0.105^{a}
D: 150 ppm paclobutrazol	0.030^{a}	0.067^{a}
E: 50 ppm prohexadione-Ca	0.005^{a}	0.073^{a}
F: 100 ppm prohexadione-Ca	0.051^{a}	0.103^{a}
G: 150 ppm prohexadione-Ca	0.032^{a}	0.067^{a}

Mean followed by similar letter are not significantly different based on Duncan's multiple range test at $\alpha = 0.05$

Table 4: Potato stolon forming tubers (%), number of tubers per plant and tuber weight per plant in response to paclobutrazol and prohexadione-Ca application

Treatment	Stolon forming tubers (%)	Number of tubers per plant	Tubers weight per plant (g)
A: Without retardant/control	106.67^{a}	3.53^{a}	42.33^{a}
B: 50 ppm paclobutrazol	105.33^{a}	9.2^{ab}	106.7^{b}
C: 100 ppm paclobutrazol	208.00^{b}	10.72^{b}	143.19^{c}
D: 150 ppm paclobutrazol	245.00^{b}	10.67^{b}	97.67^{ab}
E: 50 ppm prohexadione-Ca	273.33^{b}	12.87^{c}	118.34^{b}
F: 100 ppm prohexadione-Ca	192.67^{b}	8.79^{ab}	132.52^{bc}
G: 150 ppm prohexadione-Ca	268.00^{b}	9.37^{b}	116.75^{b}

Mean followed by similar letter are not significantly different based on Duncan's multiple range test at $\alpha = 0.05$

of potatoes by 265% compared to the control which only had 3.53 potato tubers. The 100 ppm and 150 ppm paclobutrazol treatments resulted in the number of tubers that were not significantly different, namely 10.72 and 10.67, but both were significantly lower than 50 ppm prohexadione-Ca. However, the weight of tubers per plant from 50 ppm prohexadione-Ca was significantly lower than 100 ppm paclobutrazol. This indicated that the tubers produced by 50 ppm prohexadione-Ca are smaller in size than 100 ppm paclobutrazol. The size and number of potato tubers usually depend on the level of photosynthesis in the leaves as a source and the rate of translocation to the tubers as a commercially valuable sink[16]. Compared to the weight of tubers, the variable number of tubers per plant becomes more important in the case of seed tubers, because the seed tuber of G0 potato is only used for planting material purposes, this is different case compared to potatoes for food ingredients which requires large tuber sizes.

The implication of the present work was the opportunity to gain tuber production in G0 potatoes by using plant growth retardant, specifically prohexadione-Ca. In general, paclobutrazol is widely used to regulate the growth and production of potato plants. However, this substance is considered to harm the environment, so the use of prohexadione-Ca can be used as an alternative solution. The limitation of the present work is the absence of prohexadione-Ca residue testing in potato tubers or planting media which can justify that even though they are both retardants, (with paclobutrazol) prohexadione is safer for the environment.

CONCLUSION

There is a significant effect of paclobutrazol and prohexadione-Ca administration on most of the measured G0 potato plant variables, namely plant height, leaf area, leaf area index, stolon forming tuber, number of tubers per plant and tubers weight per plant, while that effect on the relative plant growth rate is not significant. Both paclobutrazol and prohexadione-Ca at 150 ppm concentrations produced a significant growth inhibition on plant height and leaf area. However, our finding recommends 50 ppm prohexadione-Ca to improve the number of seed tuber of G0 potato more effectively and efficiently.

SIGNIFICANCE STATEMENT

There is a current fact of problem that shows a low formation of tubers in G0 potatoes due to the presence of high gibberellin concentrations within the plant. Present work success in to use of gibberellin inhibitor in the form of paclobutrazol to modify the plant growth leading to the increase of seed tuber production of G0 potato.

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