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Effect of preharvest paclobutrazol and nitrogen fertilizers on the sprouting performance of 'median' potato seed G_0 tuber

Abstract. Various intensifications of potato cultivation, such as the provision of paclobutrazol and nitrogen (N) fertilizer, are thought to impact the quality of the seeds produced. This study aims to evaluate the effects of different N fertilizer doses and paclobutrazol concentrations applied in the preharvest period on the sprouting performance of G_0 potato tuber seeds after storage. Nine treatment combinations, each repeated three times, were tested, using 50%, 100%, and 150% of the recommended N dose and paclobutrazol concentrations of 50, 100, and 150 part per million (ppm), applied at 30 and 45 days after planting, respectively. The interaction effect between N fertilizer and paclobutrazol concentration was not significantly affected on all observed variables. Preharvest application of 100% N fertilizer produced the largest seedlings, indicated by the highest shoot length at 56 and 74 days after storage. Preharvest application of 150 ppm paclobutrazol produced the highest shoot length, shoot emergence rate, and seedling dry weight than other treatments. The present study implied the importance of preharvest N and paclobutrazol for improving the sprouting performance of G_0 potato seed tuber.

Keywords: Intensification · Potato cultivation · Seed · Shoot emergence rate · Shoot length

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Introduction

Potato (*Solanum tuberosum* L.) is a horticultural commodity known to have tubers with high carbohydrate content, so it is used as an alternative carbohydrate source (Kanter and Elkin 2019). In Indonesia, potatoes have been widely utilized. As the population increases, the demand for potatoes is expected to grow every year. For instance, there will be 70%in food production by 2050 due to the demand of the 9.7 billion world population (FAO et al., 2018). This situation is directly impacting the increasing need for potato seeds. According to data from the Direktorat Jenderal Hortikultura (2022), the need for potato seeds in Indonesia in 2021 reached 143,740 tons. Still, domestic production was only able to meet 8.6% or 12,361 tons, consisting of 7,045 tons of local seeds and 5,316 tons of imported seeds. In addition to the quantity aspect, the quality of potato seeds also needs to be assessed, considering that seed quality plays an important role in efforts to increase potato harvest yields.

Low potato seed quality is often caused by repeated use of seeds from the same crop (Mburu et al., 2023), which potentially leads to virus accumulation over time. In addition, low seed production is also related to the limited area available for potato cultivation, which is generally still focused on the highlands and is threatened by high land conversion. In 2023, the potato harvest area will only reach around 63 thousand hectares, or around 1.63% of the total 3.8 million hectares of agricultural land in Indonesia (BPS, 2024). Potato cultivation, which has been concentrated in tropical highlands, needs to be gradually shifted to medium plains to reduce the environmental impact—such as increased flood risk—caused by land degradation and overuse in highland regions. However, this transition poses challenges due to differences in the ecological carrying capacity of the new growing environments.

This limitation is related to environmental factors that are suitable for potato cultivation, which are also limited. Potatoes were first cultivated more than 7,000 years ago in the Andes, South America, which has a cool temperature (Momčilović, 2019). In tropical countries like Indonesia, ideal environmental conditions for potato plants are only found in highlands with an altitude of around 1,500 meters above sea level (Ademe et al., 2024). Potato development stages, such as germination, leaf initiation, and leaf area development, are greatly influenced by temperature (Adekanmbi et al., 2023). The range of temperature between 17–25°C produced normal growth and yield of potato (Enoch et al., 2017). Temperatures above 30°C can slow down tuber initiation and development, and cause physical damage to tubers (Aien et al., 2017).

Modification offered to support potato production in medium plains is the use of plant growth regulators/retardants such as paclobutrazol (Desta and Amare 20021; Mubarok et al., 2022) and prohexadion-Ca (Hernawati et al., 2022a). Paclobutrazol has been reported to increase potato yields (Hamdani et al., 2018), because the inhibition of gibberellin biosynthesis due to paclobutrazol directs growth more towards tuber enlargement than just vegetative growth that is too dominant, so that the dominance of vegetative growth can be suppressed, and photosynthate is translocated for tuber formation (Hamdani et al., 2024). In addition to retardants, nitrogen, as an important macronutrient for potato plant growth, also needs to be studied. Nitrogen can stimulate vegetative plant growth, and nitrogen deficiency can slow growth. Nitrogen increases vegetative growth, which results in higher assimilation to supply tuber formation and increases protein and starch content in tubers. Previous studies have proven the role of nitrogen fertilization on growth, leaf area, stomatal conductance, photosynthesis rate, number of stolons, number of tubers per plant, and potato tuber weight (Hernawati et al., 2022b). G_0 potato tubers modified with pre-harvest application of paclobutrazol and N fertilizer need to be studied further; hence, limited studies have been reported concerning their sprouting ability as seed tubers. Therefore, this study aims to analyze the sprouting performance of G0 potato tubers as the impact of preharvest administration of nitrogen fertilizer and paclobutrazol.

Materials and Methods

This study used 'Median' G_0 potato seed tubers, which were produced by PT. Horti Agro Makro, Cisurupan, Garut. The cultivation was also carried out in the same place from July to October 2023, following the maintenance instructions in the previous study (Hernawati et al. 2022b), with differences in nitrogen (N) and paclobutrazol factors. The plant was arranged in a randomized complete block design to accommodate two factors, namely N and paclobutrazol. The N fertilizer levels were 50%, 100%, and 150% of the recommended N fertilizer dose of 400 kg ZA/ha, applied separately at planting and 30 days after planting (DAP). According to the technical guidelines for potato cultivation, the seed tuber requirement per hectare is 1,200 kg, with an average tuber weight of 30 g. This corresponds to a planting density of approximately 40,000 plants per hectare (BPTP Jawa Barat, 2015). For instance, plants were treated with 5, 10, and 15 g ZA/plant for doses of 50%, 100%, and 150%, respectively. The second factor is the concentration of paclobutrazol, which consists of three levels, namely 50 ppm, 100 ppm, and 150 ppm, with an application time of 45 DAP. G_0 potato seed tubers with differences in N and paclobutrazol were harvested at the age of 90 DAP, and stored in storage boxes.

This experiment tested 9 treatment combinations, each repeated 3 times, so there were 27 storage plastic boxes. There were 10 tubers in each storage box. This storage test was conducted in the experimental room at Ciparanje Garden, Jatinangor, Sumedang, from November to December 2023. Potato tubers were stored for 60 days, after which they were cultivated in a nursery for 2 weeks. Tuber weight loss was measured by an analytical scale at 60 days after storage (DAS). Tuber weight loss (%) was calculated by subtracting the post-storage tuber weight (g) from their initial weight (g), dividing the result by the initial weight, and then multiplying by 100 to express the loss as a percentage. Shoot emergence time was defined as the breaking of dormancy, indicated when at least 50% of seed tubers produced sprouts with a minimum shoot length of 2 mm (Nuraini et al., 2019). Sprouting percentage was determined at the end of storage by calculating the proportion of tubers that have produced shoots (above a defined minimum length, e.g., 2 mm) relative to the total number of tubers observed. Shoot length (mm) was measured twice, at 56 and 74 DAS, on all emergent shoots. Shoot dry weight (g) was destructively tested on all emerged sprouts at 74 DAS, using the oven method (80 ^{0} C, 48 hours). The experimental data were tabulated in Microsoft Excel and processed statistically using the analysis of variance approach and Duncan's test using Smartstat XL V.3.6.5.3 add-in for Microsoft Excel.

Results and Discussion

Tuber weight loss . The present study revealed an insignificant interaction between the dose of N fertilizer and the concentration of paclobutrazol on the tuber weight loss. The effect of the treatment of the dose of N fertilizer and the concentration of paclobutrazol on the tuber weight loss is presented in Table 1. This incident of reduced sweet potato weight is related to the loss of photosynthates for the purposes of forming and enlarging the emergent shoots. The longer the storage period, the higher the loss of potato tuber weight (Degebasa, 2020).

Table 1. Percentage of tuber weight loss in response to dfifferent preharvest nitrogen and paclobutrazol applications

Treatment	Tuber Weight Loss (%) at 60 DAS
Preharvest Nitrogen (N)	
N_1 : 50%	4.04 a
N_2 : 100%	4.76 a
N_3 : 150%	4.48 a
Preharvest Paclobutrazol (P)	
P_1 : 50 ppm	4.38 a
P_2 : 100 ppm	4.06 a
P_3 : 150 ppm	4.04 a

Means followed by the same letter within the same column and factor are not significantly different, based on Duncan’s test at 0.05 significance. DAS – days after storage.

Sprouting percentage. There was an insignificant interaction effect between the dose of N fertilizer and the concentration of paclobutrazol on the sprouting percentage of potato tuber (Table 2). Similarly, the single factor of preharvest N also showed an insignificant effect on sprouting performance. It is likely that the preharvest N fertilizer range of 50–150% remains adequate to support healthy potato growth and yield, as indicated by relatively uniform tuber size. Tuber size, in turn, reflects the carbohydrate reserves available for sprout development. Potato tubers are actually vegetative reproductive organs, not true seeds, and therefore are equipped with meristem tissue

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buds, which are temporarily dormant. Once dormancy is broken, the tuber's eye buds become physiologically active, triggering cell division and elongation in the apical meristem. This growth process is supported by the tuber's nutrient reserves, which are primarily stored in the form of starch. This starch is enzymatically broken down into soluble sugars by amylase. These nutrient reserves serve as the source of growth during the early stages of shoot development.

In contrast, preharvest paclobutrazol had a significant effect on sprouting performance, with the 150 ppm treatment (P_3) showing significantly better results than the 50 ppm treatment (P_1). However, both P1 and P3 were not significantly different from the 100 ppm treatment (P_2). Sprouting performance is related to the accumulation of starch contained in potato tubers; the more paclobutrazol is applied to potato plants, the more starch is contained in the seeds of the potato. The starch is then hydrolyzed into glucose as a food reserve by hydrolytic enzymes such as α-amylase, whose activity can be triggered by the gibberellin hormone (GA_3). Furthermore, glucose is broken down through the Krebs cycle to produce energy in the form of ATP. This energy plays a role in potato metabolism so that it can stimulate seed germination.

Table 2. Shoot growing rate of potato seed tuber in response to different preharvest nitrogen and paclobutrazol applications

Treatment	Shoot Growing Rate (%)
Preharvest Nitrogen (N)	
N_1 : 50%	64.44 a
N_2 : 100%	67.67 a
N_3 : 150%	68.29 a
Preharvest Paclobutrazol (P)	
P_1 : 50 ppm	57.72 a
P_2 : 100 ppm	68.81 ab
P_3 : 150 ppm	76.31 b

Means followed by the same letter within the same column and factor are not significantly different, based on Duncan's test at 0.05 significance.

Shoot emergence time. Neither the interaction between preharvest N and paclobutrazol, nor their individual effects, significantly affected the time of shoot emergence (Table 3). Potato seeds that were stored for 60 days had already undergone an emergent shoot growth at 50-54 DAS. The timing of shoot emergence is related to the dormancy breaking of potato seeds (Nuraini et al., 2019). Dormancy breaking of seed tubers is related to tuber size, as tuber size is a proxy for photosynthate sufficiency to support subsequent sprout growth (Park et al., 2021). Because this study produced relatively similar seed tuber sizes, dormancy breaking did not differ significantly. We suspect that shoot emergence in potato tubers is more predominantly influenced by endogenous dormancy-regulating mechanisms and post-harvest environmental conditions than pre-harvest interventions.

Table 3. Shoot emergence time of potato seed tuber in response to different preharvest nitrogen and paclobutrazol applications

Treatment	Shoot Emergence Time (DAS)
Preharvest Nitrogen (N)	
N_1 : 50%	53.56 a
N_2 : 100%	52.75 a
N_3 : 150%	50.81 a
Preharvest Paclobutrazol (P)	
P_1 : 50 ppm	54.88 a
P_2 : 100 ppm	52.33 a
P_3 : 150, ppm	50.88 a

Means followed by the same letter within the same column and factor are not significantly different, based on Duncan's test at 0.05 significance. DAS – days after storage.

Emergent shoot length. Shoot length measurements were carried out on tubers stored periodically at 56 DAS and 2 weeks later in the nursery stage (74 DAS). Similar to previous measured variables, there was an insignificant effect of the interaction of both preharvest factors on shoot length; however, the single factor effect of N and paclobutrazol led to significant emergent shoot length variation (Table 4). The dose of 100% N fertilizer produced a higher shoot length and was significantly different compared to other treatments at 56 and 74 DAS. 100% N fertilizer dose meets the potato plants' nitrogen requirements at optimal levels. It was supported by a previous study that concluded the urgency of N to support potato plant growth (Mubarok et al., 2024). N fertilizer contains ammonium ion compounds with a more stable nitrogen supply and low evaporation, so that it is easily absorbed by plants (Khalil, 2014).

At 70 DAS, a concentration of 150 ppm paclobutrazol produced a higher shoot length compared to a concentration of 50 ppm. The administration of paclobutrazol inhibits vegetative growth, so that assimilation is focused on tuber growth (Azima et al., 2017). With higher concentrations, the accumulation of photosynthate in tubers is greater, encouraging shoot growth. This accumulation can be converted into energy for shoot formation and increase food reserves in tubers. Tuber with larger food reserves produces stronger and more shoots than small tubers.

Table 4. Emergent shoot length from potato seed tuber in response to different preharvest nitrogen and paclobutrazol applications

Treatment	Shoot Length (mm) 56 DAS	74 DAS
Preharvest Nitrogen (N)		
N_1 : 50%	2.34 a	2.42 a
N_2 : 100%	2.37 b	3.27 b
N_3 : 150%	2.19 a	2.99 b
Preharvest Paclobutrazol (P)		
P_1 : 50 ppm	2.17 a	2.07 a
P_2 : 100 ppm	2.29 a	3.04 ab
P_3 : 150 ppm	2.24 a	3.32 b

Means followed by the same letter within the same column and factor are not significantly different, based on Duncan's test at 0.05 significance. DAS – days after storage.

Emergent shoot biomass. There was an insignificant interaction effect between preharvest N and paclobutrazol on emergent shoot biomass. However, a single factor of paclobutrazol resulted in a significant impact. Paclobutrazol 150 ppm (P_3) significantly increased shoot dry weight by 0.517 g compared to treatments of 50 ppm (P_1) and 100 ppm (P_2). The provision of a higher concentration of paclobutrazol caused the resulting seeds to have more food reserves, which is in line with the results of the shoot length at the end of the 70-day storage period, with the highest results in the treatment of paclobutrazol concentration 150 ppm (P_3). This is also supported by the germination power of seeds in the 150 ppm treatment (P_3), producing the highest results to support seed growth. Plant dry weight is the result of photosynthate assimilation, which is distributed to the roots and all parts of the plant.

Table 5. Emergent shoot biomass from potato seed tuber in response to different preharvest nitrogen and paclobutrazol applications

Treatment	Emergent Shoot Biomass at 74 DAS (g)
Preharvest Nitrogen (n)	
n_1 : 50%	0.263 a
n_2 : 100%	0.321 a
n_3 : 150%	0.271 a
Preharvest Paclobutrazol (p)	
p_1 : 50 ppm	0.243 a
p_2 : 100 ppm	0.424 b
p_3 : 150 ppm	0.517 c

Means followed by the same letter within the same column and factor are not significantly different, based on Duncan's test at 0.05 significance.

Conclusion

There was an insignificant interaction effect between the effect of preharvest N fertilizer and paclobutrazol application on all observed parameters. However, the dose of N fertilizer affected the shoot length, implying the urgency of preharvest N in improving sprouting performance. For instance, N 100% (10 g/plant) significantly produced the highest shoot length, indicating a seedling growth booster after storage. Additionally, 150 ppm paclobutrazol is recommended to significantly increase shoot length, seedling growth rate, and shoot biomass of G_0 potato seed tubers.

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