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APPLICATION OF VOLCANIC ASH WITH PACLOBUTRAZOL (PBZ) ON GROWTH AND YIELD OF POTATO SEED

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ABSTRACT

Currently, production potato has been decreasing in North Sumatera, is caused by the insufficient availability of seeds quality. Paclobutrazol (PBZ) is a hormone that can increase the rate of assimilation and expand aggregation of acclimatization for tuber regulation. Volcanic ash which functions as an ameliorant in the soil is very useful for increasing nutrients in the soil. The aim of this research was to determine the effect of PBZ on vegetative growth of potato seeds with volcanic ash and the interaction between of them. The PBZ concentration (P0=0.00; P1=150; P2=300 and P3=450ppm) was the first factor in a Randomized Complete Block Design (RCBD). The volcanic ash dose (V0=0.00; V1=10.00 and V2=20.00 tonnes/Ha) was the second factor, this study with three replications. Parameter were measured plant height, stem diameter, chlorophyll content and yield. The results were showed the PBZ application accelerate of vegetative growth by decreasing plant height, increasing in stem diameter, chlorophyll content and yield as compared to the untreated plant, respectively. Unlike volcanic ash, no significantly in chlorophyll content and stem diameter but significantly different in plant height and yield as compared to control plant, respectively. Therefore, did not founded interaction between volcanic ash with PBZ for all parameters.

Key words; potato, vegetative, volcanic ash, PBZ

INTRODUCTION

Rice is the staple food for more than half the world's population, with approximately 90% in Asians consume of rice, particularly in Indonesia (Annisa, 2025). As food security becomes increasingly difficult to maintain, food diversification is necessary, not entirely replacing rice as a staple food, but rather changing and improving people's consumption patterns to provide a wider variety of foods with better nutritional quality (lende et al., 2020). One alternative is to consume tubers such as potatoes, cassava, sweet potatoes, taro, and yam.

Potatoes, the third most commonly consumed food crop after wheat and rice, are a major non-cereal food and contribute substantial daily energy. Some categorize potatoes as a horticultural vegetable. Potatoes are a high-carbohydrate agricultural commodity that can be used as a substitute for rice. This type of food also contributes significantly to food diversity and nutritional adequacy due to its content of vitamins, minerals, and fiber (Estiasih et al., 2017). Indonesian potato production was fluctuated from year to year, with total yield reaching 1.36 million tonnes in 2021 and 1.50 million tonnes in 2022, was increased of approximately 4.21%. However, potato yield for 2023 was projected to reach 1.25 million tons (BPS, 2024). In North Sumatra, potato seeds are still dependent on imports from outside the region, such as from Java Island, so yield is highly dependent on the seeds received. In general, the main problem in potato cultivation includes a lack of quality seeds, uncompetitive seed prices, and diseases. This decrease in yield can be caused by low-quality seeds or by potato cultivation techniques that have not changed in the use of fertilizers or other additives such as hormones. Therefore, planting potato to produce high-quality products has been using local sources such as volcanic ash and combined with plant growth regulators to stimulate, inhibit, or modify plant physiological processes to achieve high yields, one of the growth regulators is Paclobutrazol.

Although volcanic ash is a rich source of nutrients (Syamsiah and Rahina, 2017; Fiantis et al., 2021), it takes a long time for these nutrients to become available to plants. The weathering and mineralization mechanisms of volcanic ash are triggered by important factors that influence soil formation (Nurlaeny and Simarmata, 2014). To accelerate the weathering of volcanic ash, mixing it with organic matter or ameliorants can have a positive impact on soil fertility, crop yields, and help reduce soil and water pollution. Volcanic ash with 20 tonnes/Ha was gave better results in the parameters of plant height, stem diameter, number of leaves, and leaf area of corn crops (Koryati et al., 2025). The mineral composition of the volcanic ash can also be beneficial for the soil by increasing fertility but at the same time with contrasting effects

on plants due to the influence on soil characteristics such as pH, soil aeration, and biodiversity, which can detrimentally affect some crops (Mihai et al., 2023).

Paclobutrazol (PBZ) kind of plant growth retardants (PGR) are used to restrict plant growth and manipulate photosynthetic process without changing development pattern, being phytotoxic or having malformative effect. The use of chemical paclobutrazol to improve crop productivity has interested plant scientists for several years (Syahputra et al., 2018). The inhibitory effect of plant growth retardant is via inhibiting gibberellins biosynthesis in plants. Growth retardants do not reduce plant size, but reduce the plant's growth rate and should be applied just prior to rapid shoot growth and also can shorten plant stems, increase leaf chlorophyll content (Dewi, 2018; Sembiring et al., 2023).

PBZ is capable of inhibiting gibberellin biosynthesis, vegetative growth is inhibited and assimilates will be transferred to the reproductive parts of the plant or the accumulation parts, such as tubers and stems (Desta and Amere, 2021). Others research with PBZ in tuber that was resulted comes about in delayed photosynthetic action, expanding acclimatize aggregation for tuber arrangement (Annisa, 2025). Paclobutrazol in "Crystal" guava was increased flower number and weight of harvested fruit (Yutamimah et al., 2023; Syahputra, 2019). The application of paclobutrazol can effectively reduce lodging occurrence and increase wheat yield under shading stress (Obaid et al., 2025). Some research of Paclobutrazol in another plant such as; PBZ in rice (Sinniah et al., 2012; Syahputra et al., 2016), PBZ in integrated rice-oil palm (Syahputra et al., 2020), and PBZ in sugar cane (Panti et al., 2018). Application of PBZ at an appropriate concentration during the period of power bud differentiation in rice promoted power bud growth after winter warming, thus promoting early powering and prolonging powering duration (Zhao et al., 2025). Therefore, the effects of Sinabung volcanic ash and its combination with the hormone paclobutrazol on potato plant growth and yield need to be investigated. The active ingredient in the hormone can be expected to modify potato plant growth and yield, as well as nutrient uptake.

MATERIALS AND METHODS

The research was conducted at the experimental field of the Horticultural Fondation Seed Centre, Kotagadung, Berastagi, Sumatera Utara, situated at Jl. Jamin Ginting KM 67, Raya Village, Berastagi District, Karo Regency. The altitude is ± 1500 above sea level, the average temperature is ± 19.50^{0}C, rainfall is ± 1,499 mm/year, and humidity is ± 83.5%, where the soil type is Andosol with a pH of 5-6.2. Materials utilized in the research included Granola variety

G2 potato seeds, volcanic ash from Sinabung montain, Paclobutrazol hormone. Various tools were employed, such as a meter, scissors, ruler, writing tools, oven, large bucket, ladle, hand sprayer, cutter knife, treatment labels, analytical balance, digital camera, and chlorophyll meter.

The research methodology involved a Factorial Randomized Complete Block Design (RCBD) with two factors under investigation. The first factor, volcanic ash (V) doses, had three levels: V_0: 0.00 tonnes/Ha, V_1: 10 tonnes/ha, V_2 and 20 tonnes/Ha. The second factor, Paclobutrazol concentration (P), consisted of four levels: P_0: Control, P_1: 150 ppm, P_2: 300 ppm and P_3:450 ppm. The study comprised three replications, with a planting distance of 50 cm x 50 cm, and row distance 30 cm x 30 cm resulting in 36 plots. The distance between plots was 50 cm, the distance between replications was 100 cm, and the plot size was 100 x 100 cm. Each plot accommodated 6 plants, totalling 216 plants, and 4 sample plants per plot, amounting to 144 sample plants.

Research Implementation

The research began with land preparation, clearing unwanted vegetation, and taking volcanic ash. For paclobutrazol was used "Cultar" with 30% W/V buy in market. Volcanic ash was taken from the village near Sinabung eruption with a thickness of 0-9 cm and air-dried for seven days, then sieved using a 2 mm sieve. Potato seed was used variety Granola (G) in generation "2" (G2) the weight of 7-10 g with diameter around 2-3 cm, and planting seed potato in the afternoon with 5-7 cm under the soil. Application of volcanic ash was done at making the plot experiment and defend on the treatment, while for the PBZ was applied at 35 days after planting with same dose 250 mL/plant. Regular watering and pest control were implemented, and gap filling replaced any dead or damaged plants. Harvesting occurred 95 days after planting based on visual criteria. The plant evaluation data process included plant heigh, stem diameter, chlorophyll content and yield. Determination of actual chlorophyll content was made at harvest. The leaf samples were soaked in 20 ml of 80% acetone in the dark for seven to ten days to ensure that all of the chlorophyll from the tissue was removed. A 3.5 ml of supernatant was then sampled to measure the absorbance using a Spectrophotometer at 664 and 647 nm for chlorophyll *a* and *b* respectively (Coombs *et al*., 1987). The chlorophyll content was calculated from the following formula:

Chlorophyll *a* $(mg/cm^2) = \{(3.5/3 \times (13.19\ A_{664} - 25.7\ A_{647})\}$

Chlorophyll *b* $(mg/cm^2) = \{(3.5/3 \times (22.10\ A_{647} - 52.6\ A_{664})\}$

Total chlorophyll (mg/cm^2) = Chlorophyll *a* + Chlorophyll *b*

The research data were analyzed using Factorial Randomized Complete Block Design (RCBD) with analysis of variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) in 5%. Linear regression analyses were used to investigate the relationship between the dosage of Volcanic Ash (V) and PBZ concentration (P).

Linear models by Agresti (2015):

$$Y_{ijk} = \mu + \alpha_i + V_j + P_k + V\,P_{jk} + \varepsilon_{ijk}$$

where: Y_{ijk} = response value of the variable for unit j and k in block i, μ = overall average of the dependent variable. α_i = block effect of the unobserved factor in block i (i = 1, 2, ..., b). V_j = treatment effect of the V factor at the level j (j = 1, 2, ..., t). P_k = treatment effect of the P factor at level k (k = 1, 2, ..., t). $V_j P_k$ = Interaction effect of V and P factor at level j (j = 1, 2, ..., t) and k (k = 1, 2, ..., t). E_{ijk} = measurement error or noise that the factors in the model cannot explain.

RESULTS AND DISCUSSIONS

Plant Height

The outcomes of the factorial RCBD ANOVA highlight a significant influence of volcanic ash and PBZ treatments on the plant height, while the interaction between these treatments was considered noteworthy. The results of the DMRT mean difference test are outlined in Table 1. Measurement on plant height before application showed that the field was uniform as no significant differences were detected among the concentration of PBZ and volcanic ash doses for both treatments. Treatment with paclobutrazol had a considerable influence on plant height for two months after planting and at harvest, depending on the concentration of paclobutrazol. Reduction in plant height was observed with increase in paclobutrazol concentration both at 1 month after application and also at harvest (Table.1). There was no significant difference between control and the plants treated with 150 ppm PBZ at one month after application in plant height. Reduction in plant height was observed upon application with a concentration of 300 ppm onwards with 450 ppm giving the highest retardation effect, even though this was insignificant as compared to 300 ppm. When plant height was measured at harvest, the trend in effect of concentration of PBZ was similar to that observed at 2 months after planting.

Table.1 : The effect of different concentrations of PBZ applied at 35 DAP and doses of

volcanic ash on plant height.

treatments	Plant height (cm)		
	1 month	2 months	at harvest
P0 (control)	17,65	32,59 a	49,77 a
P1 (150ppm)	18,21	29,43 ab	45,07 ab
P2 (300ppm)	17,91	25,65 bc	41,48 bc
P3 (450 ppm)	18,16	23,34 c	37,88 c
V0 (control)	17,85	30,59 b	46,78 b
V1 (10 tonnes/Ha)	17,92	32, 41 ab	47, 77 ab
V2 (20 tonnes/Ha)	18,31	33,89 a	50, 29 a

Note; Means followed by the same letter(s) in the same column are not significantly different using DMRT test at p=0.05

It has been reported that reduction in plant height is a consequence of increase of PBZ concentration in rice plant (Syahputra et al., 2016). Similarly, research on potato plants was showed that plant height decreased with increasing PBZ concentration. Unlike in volcanic ash, increase in dose of volcanic ash was followed increase in plant heigh. Plant height was significantly different as compare among them, but the best result was achieved at a dose of 10 tonnes/Ha. This was consistent with research by Koryati (2024), which was founded that increasing the dose of volcanic ash as resulted higher in plant height of corn. It can be shown that both treatments Paclobutrazol hormone and volcanic ash was showed better results on plant height, but no interaction was founded between the two treatments on plant height.

Stem Diameter

Stem diameter was enhanced by application of higher concentration of PBZ (Table .2) and also higher doses of volcanic ash for both sampling times at two months and harvesting, with 300 mg/L being optimal as the effect did not differ with plant treated with 450 ppm. Stem diameter had much lower values as compared to that obtained at harvest indicating an increase in stem diameter with plant still growth until harvest. However, as only two sampling dates were chosen for this study, it is not possible to know if stem diameter was highest at harvest or at an earlier stage before it declined at harvest. The reason for increase in stem diameter with plant maturity could be related to the deposition of plant height. These results indicated one important finding, namely that high concentration of PBZ contributes to the improvement of the physical of plant, thus increased stem diameter due to growth of potato stem. The different of doses volcanic ash did not gave significant on stem diameter. Whether was measured at one month, two months and harvest time with the same result insignificantly among them.

Table.2 : The effect of different concentrations of PBZ applied at 35 DAP and doses of volcanic ash on stem diameter.

treatments	stem diameter (mm)		
	1 month	2 months	at harvest
P0 (control)	2,78	5,52 c	9,27 c
P1 (150ppm)	3,02	6,6 bc	10,13 bc
P2 (300ppm)	2,81	7,74 ab	10,82 ab
P3 (450 ppm)	2,92	8.17 a	11,67 a
V0 (control)	2,94	6,97	10,35
V1 (10 tonnes/Ha)	3,03	7,53	10,72
V2 (20 tonnes/Ha)	3,01	7,82	10,94

Note; Means followed by the same letter(s) in the same column are not significantly different using DMRT test at p=0.05

In this study, stem diameter was measured at a fixed 5 cm height from the ground; this method would mainly assess the physical strength of the basal part. Among the concentration of PBZ, stem diameter showed that there was significant difference at concentrations of 150, 300 and 450 ppm both for two months and at harvest, but insignificantly at one month measured, where stem diameter was increased following the increase in PBZ concentration.

Unlike with volcanic ash application, whereas for all measured, one month, two months and at harvest time was no significant different. Application volcanic ash at different doses in corn plant was increase in stem diameter but statically no significant different (Koryati et al., 2024). Stem diameter occurs at lower of plant (around 5 cm from the bottom) in response to higher up the concentration of PBZ at tomato (Basooriya and Kumarasinghe, 2025) and in rice (Syahputra, 2021).

Chlorophyll Content and Yield

Increasing level of paclobutrazol concentration resulted in a take up in the chlorophyll content in the leaves, and the whole treatment was significantly different as compared to control plant (Table.3). Chlorophyll content was increased with increasing PBZ concentration and was significantly different. Result of volcanic ash in chlorophyll content and interaction between two treatments PBZ and volcanic ash was showed that no significant different among them of doses and concentration.

Table.3 : The effect of different concentrations of PBZ applied at 35 DAP and doses of volcanic ash on chlorophyll content and yield.

treatments	chlorophyll content (mg/cm2)	yield (g)

P0 (control)	5.68 c	500,26 c
P1 (150ppm)	6.76 b	574,34 bc
P2 (300ppm)	7.29 ab	660,85 ab
P3 (450 ppm)	7.91 a	692,17 a
V0 (control)	6,73	524,12 b
V1 (10 tonnes/Ha)	7,05	591,36 ab
V2 (20 tonnes/Ha)	6,96	665,51 a

Note; Means followed by the same letter(s) in the same column are not significantly different using DMRT test at p=0.05

In line with yield, the different paclobutrazol rates in this experiment was a significant increase in yield with the application of 150, 300 and 450 ppm of PBZ, which would translate to an increase of 7-14% in total yield per hectare. Lower concentration of PBZ (150 ppm) did not how a significant increase in yield, but PBZ at 300 and 450 ppm had significantly higher yields compared to control with no significant (at $p<0.05$) difference among the two treatments. Unlike in volcanic ash, with the different of doses was shown in significant in chlorophyll content but significantly different with yield, whereas high dose (20 tonnes/Ha) significant as compare to untreated plant but insignificantly with dose 10 tonnes/Ha.

Several researchers were shown that application PBZ at different concentrations can increase crop yields at rice (Syahputra et al., 2018), tuber (Annisa, 2025), guajava (Hasanah et al., 2022) and tomato ((Basooriya and Kumarasinghe, 2025). At harvest, increasing rate of PBZ application brought forward the attainment of increase in fresh weight. Treatment differences between the control plants and those that received 300 and 450 ppm were particularly large for most of this fresh weight. As well as with volcanic ash result was showed that significant differently, in general similarly were mentioned in corn (Nurlaeny and Simarmata, 2014; Koryati et al., 2025).

Data on chlorophyll content in Table.3 indicate that PBZ treatment significantly affected chlorophyll concentration in leaves, and significant effect for all PBZ concentration. At concentrations 150, 300 and 450 ppm, values for yield significantly increased compared with control treatment, except at 150 ppm. Chlorophyll content increased with the increase in PBZ concentration, resulting in high at photosynthetic rate and could be increase in yield. Data on this characteristic indicated that PBZ led to a linear increase in chlorophyll concentration and yield with a greater effect being observed at increasing concentrations.

CONCLUSION

Based on the results of this study, after application of PBZ with several concentrations and volcanic ash with different doses, it was found that application of paclobutrazol resulted in decline in plant height and also increased stem diameter, chlorophyll content and yield. Lower concentration of PBZ did not give sufficient increase in plant height, stem diameter and yield as compared to control. Higher concentration of PBZ did not give increased efficiency compared to that with 300 ppm. Therefore, improved chlorophyll and yield due to application of PBZ is expected to change the general morphology of potato plants and provide it with better mechanical strength. The different results with volcanic ash, where the stem diameter and chlorophyll were not significantly different, but the plant height and yield were showed a significant difference. Based on the dose in volcanic ash was showed 10 tonnes/Ha insignificantly with untreated plant and 20 tonnes/Ha. Lower dose of volcanic ash gives sufficient increase in plant height and yield, thus, was ideal for achieving a balance between having a realistic increased in growth and yield.

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