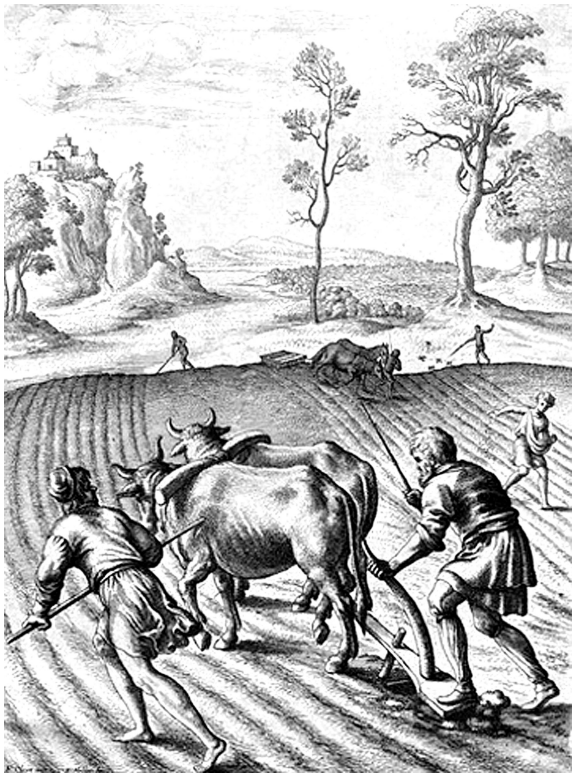
ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

# JOURNAL OF AGRONOMY



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OPEN ACCESS Journal of Agronomy

ISSN 1812-5379
DOI: 10.3923/ja.2018.169.173

# Research Article
# Effects of Application Time and Concentration of Paclobutrazol on the Growth and Yield of Potato Seed of G2 Cultivar Medians at Medium Altitude

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## Abstract

**Background and Objectives:** Potato production in Indonesia, at a medium altitude, can have a number of problems. Therefore, to increase potato productivity, there must be some alternative. One method is with the application of paclobutrazol. The objective of this study is to investigate the effects of application time and paclobutrazol concentration on the yield of potato seeds (G2 of cultivar medians) grown at a medium altitude. **Materials and Methods:** This experiment was conducted in the Research Station of Agriculture Faculty of Universitas Padjadjaran at an altitude of 685 m a.s.l. with a D3 rainfall rate and inceptisol soil. The experiment used a randomized plot design: The main plot factor was the application time of paclobutrazol at 30 DAP (days after planting) and 45 DAP, with the second factor being the concentration of paclobutrazol at 0, 50, 100 and 150 ppm. All parameters were tested by analysis of Variance (ANOVA), followed by Duncan's multiple range test at the 5% significance level. **Results:** Results showed there was no interaction between application time and paclobutrazol application on either the growth or yield of G2 potato seeds. However, application of paclobutrazolat45 DAP showed taller plants, with more and heavier tubers compared to application at 30 DAP. Paclobutrazol application reduced the plants' height, leaf area and dry weight of the plants. On the other hand, it increased chlorophyll content index, numbers of tubers and weight per plant. The use of50 ppm paclobutrazol resulted in the highest number of potato seeds of cultivar medians at 92.3%. **Conclusion:** In summary, the application of paclobutrazol at 50 ppm and 45 DAP is an optimal application for increased plant productivity of potatoes at medium altitude.

Key words: Concentration, medium altitude, paclobutrazol, potato, time application

Citation: Anne Nuraini, Sumadi, Syariful Mubarok and Jajang Sauman Hamdani, 2018. Effects of application time and concentration of paclobutrazol on the growth and yield of potato seed of G2 cultivar medians at medium altitude. J. Agron., 17: 169-173.

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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 horticultural crop containing carbohydrate content. Supporting food diversification as a carbohydrate product, potatoes have been the main industrial ingredient, as well as the main export commodity. In addition, potatoes are one of the most important foods in the world, besides wheat, corn, sorghum and rice. There has been an increase in consuming processed potato products, for example, frozen potatoes that are consumed as fried potatoes or French fries[1]. Potatoes cv. Atlantic and cv. Medians belongs to processed potatoes that mostly grown by Indonesian farmers. In 2014, average potato production in Indonesia was 17.74 t $ha^{-1}$. It was lower than the potato production of European countries that had reached 25 t $ha^{-1}$. The low production of potatoes in Indonesia is a function of the low quality seeds and the limited areas for growing potatoes at high altitudes.

Based on these issues, to increase potato production in Indonesia can be resolved by increased seed production at a medium altitude of 300-700 m a.s.l., where many locations fit this description[2]. However, high temperatures at medium altitude (vs. a high altitude)would affect the plant's growth and development. Consequently, potato production is lower by 50% compared to the production in high altitudes[3]. Reduced production, due to increased gibberellin formation, triggers the growth of the shoot, but also inhibits the tuber's growth.

Temperature is an important factor in growing potatoes[4]. Low temperature may increase the tubers' initiation and the number of tubers formed. However, high temperatures increase the growth of a shoot, but inhibit its growth. To resolve this problem, the application of paclobutrazol is one alternative for plant treatment. Paclobutrazol application can be used in different ways, such as spraying it onto the plant crown, located at the surface of the soil (foliar application), watering the soil (soil drench) and stem injection (injection). Besides these application methods, the effect of paclobutrazol application is affected by its concentration, application time, including environmental and plant conditions. Mabvongwe[5] stated that early application of paclobutrazol at 49 DAP was more effective for increased tuber yield, starch content and reducing sugar content-compared to the latter aplication[5].

Paclobutrazol reduces the plants' height and leaf area index[6]. However, it also increased its assimilation, its application at 100 ppm decreased both $GA_3$ content on the leaf and related sugar content[7,8], but increased the starch content. Applying 50 and 100 ppm paclobutrazol reacting with N fertilizer affected the number of tubers per plot paclobutrazol worked effectively when applied on the plant's leaf and in the soil[9]. The substance was translocated through the xylem cell and reached the shoot. Moreover, applying 45 and 90 ppm showed reduced plant height and tuberization, along with the dry weight of roots and stems, however, it increased the dry weight of the leaf and number of tubers[10]. The objective of this experiment was to determine the effects of paclobutrazol and optimal application time and concentration on potato seed growth, plus yield of G2 of Cultivar Medians grown at a medium altitude.

## MATERIALS AND METHODS

The experiment was carried out at a research station located at the Agriculture Faculty of Universitas Padjadjaran of Jatinangor, in the Sumedang District, 685 m a.s.l. in inceptisol soil from October, 2016 to January, 2017. Randomized plot design was used for the research and consisted of 2 factors and 4 replications. An important factor was 2 different times of application: 30 and 45 DAP. The next factor was the use of paclobutrazol concentration at different levels: 0, 50, 100 and 150 ppm.

About 20 t $ha^{-1}$ of chicken manure was applied on both sides of the plants, 300 kg $ha^{-1}$ (46% N) urea fertilizer was given twice in the planting day and at 30 DAP. As such, 150 kg $ha^{-1}$ SP-36 (36% $P_2O_5$) and 100 kg $ha^{-1}$ KCl (60% $K_2O$) were given simultaneously on the first day. The first generation of cultivar medians potato seed of 10-20 g/tuber was planted at 5-7 cm in depth. This included 3% or 37.5 kg $ha^{-1}$ of carbofurant Insecticide spread around the seed to prevent bugs and other pest attacks. Paclobutrazol was sprayed onto the plant at 30 DAP with a volume of 15 mL per plant. The fungicides, 80% Mankozeb of 2 g $L^{-1}$ concentration and 25 g $L^{-1}$ deltamethrin of 2 cc $L^{-1}$, were sprayed to control pest attack and other diseases. Harvesting was carried out after the top part of the potato plant, the stem and its leaves turned yellow and withered, as the tuber skins were not peeling. Harvesting proceeded at 92 DAP.

Observation of plant growth (such as plant height, leaf area index, dry weight, chlorophyll content index and yield or number of tubers, their weight per plant, per hectare and the tubers seeds (<60 g) was conducted. Two ways ANOVA was conducted to assess the treatment difference. If the treatment changed significantly, Duncan's multiple test range would be conducted at a 5% significant level.

## RESULTS

**Plant height, leaf area index, dry weight and chlorophyll content index:** The statistical analysis showed there was no interaction effect between paclobutrazol application time and

Table 1: Effect of application time and paclobutrazol concentration on plant height, leaf area index, dry weight and chlorophyll content index

| Treatments | Plant height (cm) | Leaf area index | Dry weight of each plant (g) | Chlorophyl content index |
|---|---|---|---|---|
| **Time application (DAP** | | | | |
| 30 | 30.33[a] | 2.33[a] | 37.70[a] | 35.07[a] |
| 45 | 35.70[b] | 2.27[a] | 35.36[a] | 34.05[a] |
| **Paclobutrazol concentration (ppm)** | | | | |
| 0 | 45.98[b] | 2.69[b] | 40.78[b] | 25.41[a] |
| 50 | 35.63[a] | 2.29[a] | 34.89[a] | 36.64[b] |
| 100 | 32.93[a] | 2.32[a] | 37.21[a] | 38.28[b] |
| 150 | 26.90[a] | 1.41[a] | 33.24[a] | 34.52[ab] |

Average numbers followed by same letters are significantly different based on Duncan's multiple range test on 5%

Table 2: Effect of application time and paclobutrazol concentration on the tubers quantity per plant, tubers weight per plant, tubers weight per hectare and G2 potato seed percentage

| Treatments | Tubers quantity per plant (knol) | Tubers weight per plant (g) | Tubers weight per ha (ton) | G2 tubers seed percentage (%) |
|---|---|---|---|---|
| **Application time (DAP)** | | | | |
| 30 | 6.21[a] | 298.50[a] | 11.98[a] | 89.00[a] |
| 45 | 8.98[b] | 328.92[b] | 13.15[b] | 86.00[a] |
| **Paclobutrazol concentration (ppm)** | | | | |
| 0 | 5.08[a] | 234.85[a] | 9.39[a] | 85.00[a] |
| 50 | 7.04[b] | 340.88[b] | 13.63[b] | 92.30[b] |
| 100 | 8.54[b] | 359.60[b] | 14.38[b] | 88.50[a] |
| 150 | 7.71[b] | 336.53[b] | 13.46[b] | 85.00[a] |

Average numbers followed by same letters are significantly different based on Duncan's multiple range test on 5%

its concentration on plant height, leaf area index, dry weight and chlorophyll content index. Individually, application time of paclobutrazol affected only the plant height, while its concentration affected the height and the leaf area index, given its dry weight and chlorophyll content index (Table 1). Paclobutrazol applied at 45 DAP resulted in taller plants compared to application at 30 DAP. Finally, paclobutrazol applied at 30 DAP inhibited plant growth and caused plants to remain shorter. Application time at 30 DAP and 45 DAP did not show any effects on the leaf area index, dry weight or chlorophyll content index. Table 1 showed that paclobutrazol at levels 50, 100 and 150 ppm could reduce the plants' height, leaf area index and dry weight. However, it increased the chlorophyll content index compared to controls.

**Number of tubers, tuber weight per plant, tuber weight per hectare and percentage of seeds:** The interaction between application time and paclobutrazol concentration did not significantly affect the numbers of tubers, weight per plant, weight per ton per ha or percentage of the seed. However, it significantly affected the number of tubers per plant, the tubers' weight per hectare and the G2 seed percentage (Table 2). The paclobutrazol application at 45 DAP resulted in a greater number of tubers, along with the tubers' weight per plant and weight per ton per ha, compared to application at 30 DAP, with an average number of 8.98 knol, 328.92 g and 13.15 t $ha^{-1}$, respectively. The concentration of paclobutrazol at 50, 100 and 150 ppm significantly increased the number of tubers per plant, tubers' weight per plant and tubers weight per ha was compared to no paclobutrazol application-while only the application of paclobutrazol at 50 ppm significantly increased the percentage of G2 seed with an average value of 92.30% (Table 2).

## DISCUSSION

The concentration of paclobutrazol significantly affected the reduction of the plants' height, leaf area index and dry weight of the plants, but increased the chlorophyll content index (Table 1). In a previous study, it was shown that paclobutrazol reduces plants' growth caused by shortening of the node of the stem[2,7,11,12]. Paclobutrazol was a growth inhibitor and in turn caused stem shortening. It also increased the chlorophyll content to improve photosynthetic activity[13]. The increased photosynthesis activity increased production of gibberellins' synthesis. The increased level of photosynthesis was affected by a diverted reaction in certain gibberellins' synthesis like phytol, which was a chlorophyll-transforming precursor[14].

The timing of paclobutrazol application did affect plant growth or development. Our results coincide with those of Lengkong *et al.*[15], as the application of paclobutrazol significantly inhibited plant height[15]. Applying paclobutrazol at an earlier stage would inhibit the plants' height more obviously[8]. The inhibited plants' height was a function of assimilated remobilitation in tuberization, which resulted in their weight gain. Paclobutrazol application time did not

significantly affect the leaf area index, dry weight, or chlorophyll content[16]. Pinto *et al.*[17] found that the retardant substance impeded stem elongation by inhibiting its physiological activity[17]. However, it did not affect production or translocation to other parts of the plant.

The function of paclobutrazol as a plant inhibitor was obvious if it was applied in the beginning of plant growth (30 DAP), but showed a small effect if applied at 45 DAP. Application at 45 DAP was entering the end phase of extension growth[18], thus the growth and extension of leaf areas served as a source of ready-used photosynthesis material for tuberization, so they were not greatly impeded. The increase of photosynthetic translocation from the leaves to the tubers was triggered by paclobutrazol application[11].

High temperature created greater amount of gibberellins in potatoes, thus it triggered stolon elongation and induced it to grow into tubers instead. However, paclobutrazol applied as an inhibitory substance, thus impeding gibberellins' reaction, proved to yield an increased percentage of stolon from the tubers. As a result, tuber quantity per plant of G2 cultivar medians with paclobutrazol application was increased at 7.4-8.5 knol/plant. Increased potato tubers planted at a medium altitude was closely related to gibberellins' concentration at the end of a stolon, which paclobutrazol application inhibited. Langille and Hepler[19] stated that plants grown in a suitable environment for promoting potato growth (along with low temperature and a low concentration of gibberellins), also showed increased numbers of tubers per plant[19]. In addition, the plants given retardant compounds from triazole-like paclobutrazol showed increased numbers of tubers per plant, although they were grown in a less suitable environment due to high temperatures and high concentrations of gibberellins. Hormonal gibberellin impedibility could speed up the tubers' initiation and process, supported by increased assimilation and translocation towards the tubers, so that tuber size would be maximized[11]. High yield due to paclobutrazol application was related to the high stolon percentage, which formed the tubers, resulting in higher numbers of tubers per plant[20]. Several studies with deciduous trees and paclobutrazol were observed to increase the accumulation of storage compounds[9].

## CONCLUSION

It was conclude that the interaction effect of application time and paclobutrazol concentration on the growth and yield of potatoes has not been confirmed. Application time at 45 DAP showed taller plants, a higher numbers of tubers and a heavier weight of the tubers compared to 30 DAP. Paclobutrazol inhibited plant height, leaf area and dry weight, but increased chlorophyll content index and the tubers' quantity and weight per plant. Application can increase the degree of seed size, such that the optimal size was approximately 92.30% at a50 ppm concentration level.

## SIGNIFICANCE STATEMENT

In Indonesia, potato is grown in the high altitude that has a low temperature. Introducing potato production to medium land with high temperature is needed a modification of plant growth condition such as by the application of paclobutrazol. In this study, it was identify the effect of the time application and concentration of paclobutrazol. There showed that the time application and concentration significantly effect on the increasing yield of potato tuber in the medium land.

## ACKNOWLEDGMENT

I would like to thank the Rector of Universitas Padjadjaran for facilitating this research through the ALG (Academic Leadership Grant) Program in 2018. Many thanks to Mr. Imam Zakarya, Hadi and Hila Aulia Rachman for his support and his assistance throughout the research in the station.

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