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## Research Article

# Effect of Paclobutrazol Growth Regulator on Tuber Production and Starch Quality of Cassava (*Manihot esculenta* Crantz)

[1]Sa-ngad Panyapruek, [2]Wantana Sinsiri, [2]Narit Sinsiri, [2]Panida Arimatsu and [3]Anan Polthanee

[1]Agricultural Development Research Center in Northeast Thailand, Faculty of Agriculture, Khon Kaen University, Thailand
[2]Division of Agricultural Technology, Faculty of Technology, Mahasarakham University, Thailand
[3]Department of Plant Science and Agricultural Resources, Faculty of Agriculture, Khon Kaen University, Thailand

## Abstract

Field experiment was conducted to investigate the effect of application paclobutrazol (PBZ) at different growth stages and concentration rates on growth, yield and starch quality of cassava grown under rainfed conditions. The PBZ application reduced plants height and leaf area index, but tend to increased total top dry weight, tuber fresh weight per plant and tuber yield of cassava as compared to untreated control. The tuber yield increased by 12, 35 and 67% over control of application PBZ at concentration rates 10, 20 and 30 ppm, respectively. Paclobutrazol applied at concentration 10, 20 and 30 ppm did not exhibit significantly different on the starch content in tuber as compared to control. Regardless of application at different growth stage, PBZ applied to plants at 210 DAP produced higher tuber yield and starch quality than those of application at 90 and 150 DAP.

Key words: Cassava, Paclobutrazol (PBZ), growth, yield, starch content

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Corresponding Author: Wantana Sinsiri, Division of Agricultural Technology, Faculty of Technology, Mahasarakham University, Thailand



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

## INTRODUCTION

Northeastern region of Thailand has been considered among the various regions of the country to be the largest producer of cassava (*Manihot esculenta* Crant). This crop has been recognized as one of the most important subsidiary cash crops apart from sugarcane. However, cassava yield produced by the farmers in northeastern is still low. This was mainly due to uneven of rainfall distribution as well as low fertility soil in the region. In general, yield components play an important role on cassava productivity are the tuber number and size (Aina *et al*., 2007). The tuber will be developed from the fibrous roots which cassava produced of more than 50 fine roots within one plant (Bunseng, 2008). The number of tuber developed from the fibrous roots more or less, depend upon ability of translocation of sugar and environment (Bunseng, 2008). Plant growth regulator triazole compound such as paclobutrazol, hexaconazole, triadimefon, etc., are widely used to modify canopy structure, yield, quality and stress tolerance in many crops (Kim *et al*., 2010; Tekalign and Hammes, 2004; Tsegaw *et al*., 2005; Gopi *et al*., 2009; Fletcher *et al*., 1999; Abdul Jaleel *et al*., 2007). Paclobutrazol (2RS, 3 RS)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1H,2,4-triaqzol-1-yl)-pentan-3-ol is a triazole plant growth regulator known to interfere with ent-kaurene oxidase activity in the ent-kaurene oxidation pathway (Rademacher, 1991), reduced gibberellins synthesis (Davis *et al*., 1991; Rademacher, 1991) and increase chlorophyll content (Fletcher and Hofstra, 1988). However, information of increasing growth, yield and quality using paclobutrazol (PBZ) in cassava crop is scanty. The objectives of this research, therefore, to investigate the effects of PBZ application at different growth stages and concentrations rates on growth, tuber yield and starch quality of cassava grown under rainfed conditions.

## MATERIALS AND METHODS

**Plant culture and paclobutrazol applications:** The land was prepared by ploughing twice to a depth of 30 cm and the soil was sandy loam (Typic Paleustults). The experimental site belong to the tropical monsoon climate with a dry season from November to April and a wet season from May to October. The crops were planted in July, 2009 and harvested for 280 Days After Planting (DAP).

The factorial in RCBD (Randomized Complete Block Design) with four replications was used in this experiment. The first factor consisted of PBZ application at three growth stages; 90, 150 and 210 DAP. The second factor included four PBZ concentration rates; 0, 10, 20 and 30 ppm. Before planting, a pit was created with size $50\times50\times30$ cm (wide$\times$long$\times$deep) with plant spacing between row and plant $100\times100$ cm. Cattle manure at rate of 19 t ha$^{-1}$ were filled into the pit and mixed with the soil at 7 days before planting. Then, each stem cutting (25 cm long) was planted vertically in a pit to a depth of 15 cm inside the soil. Hand weeding was done at 30 and 60 DAP. Pesticides were not used throughout the growing season in the present experiment.

Before PBZ application, cassava crops were irrigated throughout the field using sprinkler at soil moisture level close to the field capacity (FC. 12% by weight). Then, PBZ applied at rate of assigning in the experimental tested treatments. The PBZ concentration rate was calculated base on a given of paclobutrazol 5.29 gm a.i. diluted in water 500 cc to obtain the concentration at 10 ppm. Crops were treated with PBZ as soil drench by hand irrigation at 500 cc plant$^{-1}$ in order to increase the soil moisture content up to field capacity level.

**Growth parameters:** The plant height was measured randomly selected plants from the ground to the tip at 240 and 280 DAP. The leaf area was recorded randomly selected plants using automatic leaf area meter (AAC-400, Hayashi Denko Co., Ltd., Tokyo, Japan). The leaf area index was calculated by leaf area cover ground area. The total above ground biomass were cut randomly selected plants at ground level, and separate into stem and leaf. Then the material was dried in an oven at 60°C until constant dry weight was obtained, the total top dry weight was expressed in g plant$^{-1}$.

**Tuber yield and starch content:** Plants were harvested randomly selected five plants at 280 DAP. The tuber number per plant were recorded and tuber fresh weight per plant was measured. Tuber fresh weight was used for determining tuber yield per hectare and starch content. The starch content was measured using Reiman scale balance method.

**Statistical analysis:** The data was analyzed using the analysis of variance (ANOVA) by MSTATC software (Analytical Software Tallahassee, Florida, USA). Means were compared between treatments from the error mean square by LSD (Least Significant Difference) at the $p = 0.05$ and $p = 0.01$.

## RESULTS AND DISCUSSION

**Effect of PBZ application on shoot growth:** The PBZ application at different growth stages were significantly different in plant height of cassava at 240 and 280 DAP (Table 1). The PBZ applied at 90 DAP reduced plant height greater than those of PBZ application at 150 and 210 DAP in comparison with untreated control. Irrespectively of the concentration rates, PBZ significantly decreased in plant height all concentration rates as compared to untreated control (0 ppm) at 240 and 280 DAP (Table 1). Among the concentration rates, PBZ application at concentration 20 ppm inhibited plant height greater than those of concentration 10 ppm and 30 ppm. Plant height reduced 21.8-24.1% in treated plants as compared to untreated control at 280 DAP in the present experiment. This agreement with previous investigation by Zuo (2003), Yang and Cao (2011) and Medina *et al.* (2012). The plant height reduction was primarily due to internodes length shortening (Davis *et al.*, 1991; Pinto *et al.*, 2005).

For Leaf Area Index (LAI), PBZ application to the plants at different growth stages were significantly different on LAI at 240 DAP, but not significantly effect on LAI at 280 DAP (Table 2). Paclobutrazol applied at 150 DAP gave higher LAI than those of application at 90 and 210 DAP. Regardless of the concentration rates, PBZ application to the plants were significantly different among the concentration rates at 240 DAP, but not significantly effect at 280 DAP (Table 1). Paclobutrazol applied at concentration 10 ppm gave the lowest LAI at 240 DAP. However, PBZ applied at concentration

Table 1: Effect of paclobutrazol application at different growth stages and concentration rates on growth of cassava at 240 and 280 Days After Planting (DAP)

| | Plant height (cm) | | Leaf area index | | Total top dry weight (kg plant$^{-1}$) | |
|---|---|---|---|---|---|---|
| | 240 | 280 | 240 | 280 | 240 | 280 |
| Treatments | (DAP) | | | | | |
| **Growth stage (A)** | | | | | | |
| 90 DAP | 159.6$^{b}$ | 172.5$^{b}$ | 3.3a$^{b}$ | 3.7 | 1.8c | 2.2 |
| 150 DAP | 171.4$^{b}$ | 185.6a$^{b}$ | 2.9$^{b}$ | 3.3 | 2.1$^{b}$ | 2.4 |
| 210 DAP | 217.6a | 211.3a | 3.8a | 3.9 | 2.4a | 2.5 |
| **Concentration rate (B)** | | | | | | |
| 0 ppm | 216.2$^{a}$ | 229.2$^{a}$ | 3.4$^{a}$ | 3.8 | 1.9$^{b}$ | 2.2 |
| 10 ppm | 174.8$^{b}$ | 176.7$^{b}$ | 2.8$^{b}$ | 3.8 | 1.9$^{b}$ | 2.4 |
| 20 ppm | 164.6$^{b}$ | 174.2$^{b}$ | 3.2$^{ab}$ | 3.5 | 2.2$^{a}$ | 2.5 |
| 30 ppm | 175.9$^{b}$ | 179.2$^{b}$ | 3.1$^{ab}$ | 3.3 | 2.4$^{a}$ | 2.4 |
| **F-test** | | | | | | |
| A | ** | * | * | ns | ** | ns |
| B | ** | ** | * | ns | ** | ns |
| AxB | ns | ns | ns | * | ** | ns |

*,**Significant at $p \leq 0.05$, 0.01, ns: Not significant, Means in a column followed by a common letter are not significantly different at the 0.05 level by LSD, DAP: Days after planting

Table 2: Effect of paclobutrazol application at different growth stages and concentration rates on tuber number, tuber fresh weight, tuber fresh yield, harvest index and starch content of cassava at 280 Days After Planting (DAP)

| Treatments | Tuber number (no. plant$^{-1}$) | Tuber fresh weight (kg plant$^{-1}$) | Tuber fresh yield (t ha$^{-1}$) | Starch content (%) | Harvest index (HI) |
|---|---|---|---|---|---|
| **Growth stage (A)** | | | | | |
| 90 DAP | 10.0 | 4.57 | 45.8 | 18.9$^{b}$ | 0.69 |
| 150 DAP | 12.0 | 3.84 | 38.4 | 20.1$^{ab}$ | 0.73 |
| 210 DAP | 11.0 | 4.96 | 49.6 | 21.1$^{a}$ | 0.70 |
| **Concentration (B)** | | | | | |
| 0 ppm | 9.0$^{b}$ | 3.48$^{b}$ | 34.8$^{b}$ | 20.4 | 0.68 |
| 10 ppm | 10.0$^{ab}$ | 3.88$^{b}$ | 38.8$^{b}$ | 20.0 | 0.70 |
| 20 ppm | 11.0$^{ab}$ | 4.68$^{ab}$ | 46.8$^{ab}$ | 20.5 | 0.69 |
| 30 ppm | 13.0$^{a}$ | 5.79$^{a}$ | 58.0$^{a}$ | 19.2 | 0.76 |
| **F-test** | | | | | |
| A | ns | ns | ns | * | ns |
| B | * | * | * | ns | ns |
| AxB | ns | ns | ns | ns | ns |

*,**Significant at $p \leq 0.05$, 0.01, ns: Not significant, Means in a column followed by a common letter are not significantly different at the 0.05 level by LSD, DAP: Days after planting

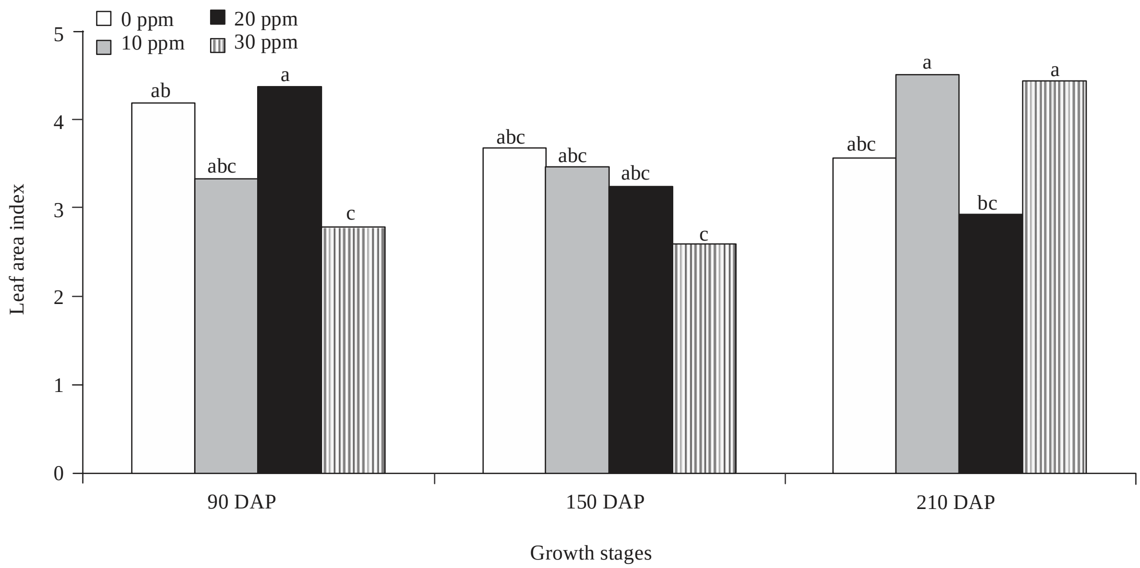


Fig. 1: Interaction between paclobutrazol application at different growth stages and concentration rates on leaf area index at 280 days after planting

30 ppm tend to reduced the greatest LAI value at 280 DAP in the present experiment. This confirms the results reported in previous experiments with cassava (Gomathinayagam *et al*., 2007), potato (Tekalign and Hammes, 2004) and tomato (Berova and Slatev, 2000). The reduction of leaf area in treated plant was probably due to increase ABA content and reduces GA biosynthesis (Asami *et al*., 2000).

A significant interaction was observed between PBZ application at different growth stage and concentration rates on LAI at 280 DAP. With PBZ application at 90 DAP, LAI significantly decreased at 30 ppm as compared to untreated control and treated plants at 20 ppm. On the other hand, PBZ applied to the plants at 210 DAP, LAI significantly reduced at 20 ppm in comparison with application at 10 ppm and 30 ppm (Fig. 1). Again, PBZ applied to the plants at 150 DAP, LAI did not significantly reduced at 30 ppm as compared to application at 10 ppm and 20 ppm as well as untreated control (Fig. 1).

In case of total Top Dry Weight (TDW), PBZ application at different growth stages were significantly different on TDW of cassava at 240 DAP, but did not show significantly effect at 280 DAP (Table 1). Paclobutrazol application to the plants at 90 DAP gave significantly lower TDW than those of application at 150 and 210 DAP. In this experiment, PBZ application at 90 DAP tend to inhibited TDW greater than those of application at 150 and 210 DAP when cassava harvested at 280 DAP. Irrespectively of the concentration rates, PBZ application to the plants were significantly different on TDW among the concentration rates at 240 DAP, but did not significant effect on 280 DAP (Table 1). Paclobutrazol application at concentration 20 ppm and 30 ppm significantly increased TDW over untreated control at 240 DAP. In the present experiment, PBZ application at all concentration rates tend to produced higher TDW than those of untreated control.

The PBZ treated plants produced higher TDW than those of untreated control, although, treated plants appearance shorter in plant height and lower leaf area index than those of untreated control. This response could be attributed to wider stem and thicker dark green leaves in this study. Paclobutrazol application to the plants reduced in height was accompanied by significant stem thickening (Berova and Zlatev, 2000). In wheat, PBZ application increased thickness of the leaves by inducing additional layers of palisade mesophyll cells (Gao *et al*., 1987). In potato, PBZ application increased stem diameter due to induction of thicker cortex, larger vascular bundle and wider pith diameter (Tsegaw *et al*., 2005).

A significant interaction was observed between PBZ application at different growth stage and concentration rates on TDW at 240 DAP. Paclobutrazol applied at 210 DAP significantly increased TDW at concentration 20 ppm as compared to untreated control and application rate at 10 ppm and 30 ppm. Paclobutrazol applied to the plants at 90 and

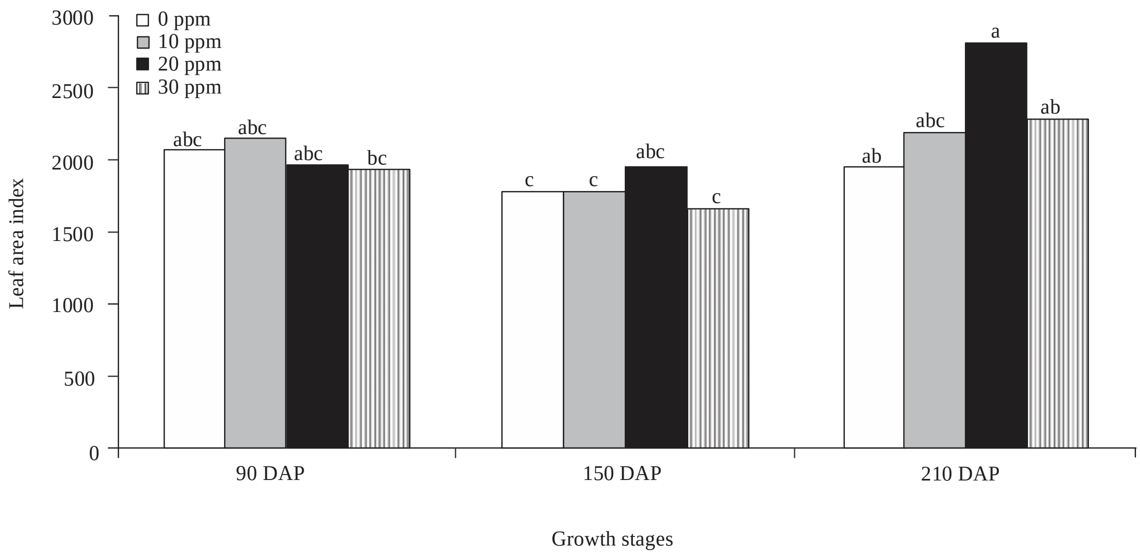


Fig. 2: Interaction between paclobutrazol application at different growth stages and concentration rates total top dry weight at 240 days after planting

150 DAP with concentration 20 ppm did not show significantly different among untreated control, as well as application at rates of 10 and 30 ppm (Fig. 2).

**Effect of PBZ application on yield and yield components:** Paclobutrazol application at different growth stages were significantly different on tuber number per plant, tuber fresh weight per plant and tuber fresh yield of cassava at 280 DAP (Table 2). However, PBZ applied to the plants at 210 DAP tend to produced higher tuber fresh yield than those of application at 90 and 150 DAP treatments. Irrespectively of the concentration rates, PBZ application at different concentration rates were significantly effect on tuber number per plant, tuber fresh weight per plant and tuber fresh yield of cassava at 280 DAP (Table 2). Paclobutrazol applied at concentration 30 ppm significantly higher tuber number, tuber fresh weight and tuber fresh yield than those of untreated control. In the present experiment, tuber yield increased 12, 35 and 67% over control when PBZ applied at 10, 20 and 30 ppm, respectively. In this study, tuber yield of PBZ treatments increased over control, mainly due to the production of larger tubers size. This agreement with previous investigation reported by Yang and Cao (2011). The application of others plant growth retardants such as triazole increased invertase activity enzyme and involved in kinetin and auxin (Gomathinayagam *et al*., 2007). Kinetin act as mainly on tuber initiation where auxin predominantly intensified tuber growth, resulting in the production of larger tuber (Romanov *et al*., 2000; Tekalign and Hammes, 2005). The PBZ treatment increased the root diameter by about 52% over control in potato plant (Tsegaw *et al*., 2005). The PBZ treatments considerably boosted tuber yield and this may be due to increased chlorophyll content and enhanced rate of net photosynthesis in potato plants (Tekalign and Hammes, 2004). Previous study revealed that the onset of senescence leaves in several plant species is considerably delayed by triazoles treatments (Davis *et al*., 1991; Binns, 1994) and treated plant retained photosynthetically actives longer than the untreated plant (Hunter and Proctor, 1992).

**Effect of PBZ application on starch content and harvest index:** The PBZ application to the plants at different growth stages were significantly different on the Starch Content (SC) and Harvest Index (HI) at 280 DAP (Table 2). The maximum SC and HI were obtained when PBZ applied at 210 DAP. Regardless of the concentration rates, SC was not significantly effect among concentration rates, but shows significantly different on HI in this experiment (Table 2). The PBZ application at all concentration rates gave higher HI than those of untreated control. This indicates that PBZ application increased assimilate partitioning to the tubers. Enhancing translocation of photosynthates to rapid tuber growth in PBZ treated plants was reported in potato (Tekalign and Hammes, 2004). In this study, PBZ application to the plants did not significantly effect on the starch content as compared to untreated control. This probably due to PBZ application only once, it is not enough to alter the carbohydrate status in plants. In previous experiment, PBZ applied to the plants four times at 90, 110, 130 and 150 DAP, significantly increased the starch content in tuber. The PBZ application to cassava plant significantly increased SC was reported by Yang and Cao (2011); Medina *et al.* (2012). In this study, PBZ application at late growth stage at 210 DAP significant higher the starch content than those of application at early growth stage on 90 DAP. This was probably due to early PBZ application may be loss into the soil before the tuber uptake, resulting a longer level of retardant in tuber during the late growth stage (tuber maturation phase). The PBZ application improved harvest index in cassava production was also reported by Medina *et al.* (2012).

## CONCLUSION

PBZ applications to cassava plants significantly inhibited plant height, and tend to reduce the LAI of cassava at 280 DAP. In the present experiment, PBZ application at 90 DAP showed shorter plants than those of PBZ application at 150, 210 DAP and at harvest (280 DAP). The PBZ application at concentration 10, 20 and 30 ppm increased the tuber yield by 12, 35 and 67% over untreated control. The PBZ application at 210 DAP significantly increased the starch content in tuber as compared to PBZ application at 90 and 150 DAP.

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