Effect of Paclobutrazol Application Time on Growth, Yield and Starch Content of Two Cassava Cultivars under Rainfed Conditions of Northeastern, Thailand

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ABSTRACT
The purpose of the present study was to investigate the effect of paclobutrazol (PBZ) application time on growth, yield and starch content of cassava under rainfed conditions. A split-plots design was set up with four replications. The main-plot consists of two cassava cultivars (CMR and RY-7) and three PBZ application times (90, 135 DAP and two combined 90 and 135 DAP) in comparison with no paclobutrazol application (control) assigned as sub-plots. The study showed that all PBZ application times reduced plant height. PBZ single application at 135 DAP or two combined application at 90 and 135 DAP increased leaf number per plant and leaf area index. The maximum storage root yield was obtained when PBZ applied at 135 DAP over without PBZ application (control) by 46% in the present study. PBZ application at 90 DAP combined with 135 DAP produced the highest starch content of the storage roots. In the present experiment, two cassava cultivars did not show a significant difference on growth, yield and starch content in storage root.

Key words: Cassava, Growth, Paclobutrazol, Starch content, Yield.

INTRODUCTION
Northeastern Thailand has a semi-humid tropical climate which is characterized by rainy (May-October) and dry (November-April) season (Goto et al. 2008). Cassava is a cash crop of smallholder farmers in northeastern Thailand. It planted over 8-months period that contained both dry and rainy season. Cassava planting time takes place both at early of rainy season (May-June) and at late of the rainy season (October-November). However, highest yields were obtained with planting in May, at the start of the rainy season (Tongglum et al. 2001).

In recent years, there has been a tremendous increase in the research effort to improve the production through breeding program such as drought tolerant and acidic soil (Oguntunde, 2005; Chemonges et al. 2013) nutrients management (Subandi and Suyanto, 2015) improvement quality of planting materials (Khanthavong et al; 2012; Polthanee and Manuta, 2016) and supplemental irrigation (Polthanee and Srisutham, 2017). It was also noticed that the possibility of increasing the production per unit land area under cultivation using plant growth regulator paclobutrazol (Yang and Cao, 2011; Panyapruek et al., 2016). However, there is limited information on the appropriate time of paclobutrazol application for current recommendation cultivars (early and late maturity) to maximize yield and quality of tubers when cassava grown in the rainy season of northeastern Thailand.

MATERIALS AND METHODS

Description of the study area: The experimental site belong to the tropical monsoon climate with a dry season from November to April and wet season from May to October. The cassava planted in July, 2015 and harvested for 8 months after planting. The soil is classified as Typic Paleustults, on well-drained soil with sandy loam in the texture. The total amount of rainfall was about 702.6 mm during the growing period with the maximum amount of 302 mm in August (Table 1). The crop initial subjected to drought at the late week of October 2015 until harvest in January 2016. The average maximum (36°C) and minimum (15°C) temperature observed in June 2015 and January 2016, respectively (Table 1).

Experimental design and plant culture: The split plot design with four replications was used in this experiment. The two cassava cultivars (early maturity, CMR and late maturity, RY-7) assigned as main-plots. Paclobutrazol (PBZ) application time; single application at 90 days after planting (DAP), single application at 135 DAP and two combined application at 90 and 135 DAP in comparison with water treated plant (control) assigned as sub-plots.

The land was prepared by ploughing twice to a depth of 30 cm, ridging was made after the last ploughing by four wheels tractor. Each stem cutting was vertically planted on the top of the ridges with plant spacing 1.0x1.0 m. Chemical fertilizer grade 15-13-18 at rate of 188 kg/ha was applied at 1 month after planting. Hand weeding was
undertaken at 30 and 60 DAP. Paclobutrazol concentration 10 gm dissolved in one litre of water and applied to one plant around the root zone by making small ring.

**Growth parameters measurement**: The plant height was measured from the randomly selected five plants at harvest from the tip, number of nodes of main stem, leaf number and leaf area were determined in similar plants. Leaf area was recorded using automatic leaf area meter (AAC-400, Hayashi Denko Co., Ltd., Tokyo, Japan). Then the leaves were dried in an oven at 60°C until constant dry weight. The leaf area index (LAI) was calculated by leaf area cover ground area.

**Storage root parameters measurement**: Twenty plants in the harvesting area (10x10 m) were determined for the number of storage roots, fresh and dry storage roots yield, as well as the starch content. The starch content was measured using Riemarne balance method (Bainbridge et al. 1996).

### RESULTS AND DISCUSSION

**Plant height**: Plant growth regulator PBZ of all application times significantly reduced (P≤0.05) plant height of cassava across cultivars as compared to treatments where PBZ was not applied (Table 2). In the present study, number of nodes per main stem did not show a significant difference with no PBZ control treatment (Table 2). This indicate that plant height reduction was primarily due to internodes length shortening. A reduction in plant height has also been observed in tomato plants treated with PBZ (Berova and Zlatev, 2000) and olive (Kumar and Sharma, 2016). The growth retarding effect of triazole is caused by the inhibition of gibberellic acid biosynthesis and increased abscisic acid content (Bachenauer and Grossmann, 1977).

In the present study, early application of PBZ at 90 DAP did not show a significant difference in plant height when compared to PBZ application at 135 DAP. This is in contrast with the finding of Malvongwe et al. (2016) studying potato treated with PBZ, early application at 28 DAP significantly increased the stem length and plant height when compared to PBZ application at 35 DAP or 42 DAP. In present experiment, cassava cultivars had no significant effect on plant height and number of nodes across PBZ application times (Table 2).

**Leaf growth**: PBZ application treatments significant increased (P≤0.05) leaf number per plant and leaf area index across cultivars when PBZ applied at 135 DAP or 90 DAP combined with 135 DAP as compared to no PBZ control treatments (Table 2). This was attributed to PBZ application

### Table 1: Weather data of the experimental site during cropping season.

| Month | Rainfall (mm) | Temperature (℃) | ET (mm.day⁻¹) | Relative Sunlight (h day⁻¹) |
|-------|--------------|-----------------|---------------|---------------------------|
|       |              | Maximum         | Minimum       |                           |
| Year 2015 |              |                 |               |                           |
| June  | 112.8        | 36.04           | 25.15         | 5.94                      | 85 | 7.21 |
| July  | 131.8        | 33.62           | 25.11         | 5.52                      | 89 | 3.61 |
| August| 301.7        | 32.58           | 24.20         | 4.14                      | 91 | 5.44 |
| September | 80.2        | 32.78           | 24.60         | 3.52                      | 92 | 5.16 |
| October| 46.9         | 31.74           | 23.17         | 3.83                      | 89 | 6.87 |
| November| 0.0          | 33.72           | 22.70         | 5.19                      | 86 | 8.36 |
| December| 0.0          | 32.56           | 20.32         | 4.69                      | 87 | 7.96 |
| Year 2016 |              |                 |               |                           |
| January| 29.2         | 29.99           | 15.22         | 4.69                      | 83 | 7.54 |

### Table 2: Plant height (PH), number of nodes per main stem (NNS), leaf dry weight per plant (LDW), leaf number per plant (LN) and leaf area index (LAI) of cassava as affected by timing of PBZ application.

| Treatment                      | PH(cm) | NNS(no.node) | LDW(gm pl⁻¹) | LN(gm pl⁻¹) | LAI |
|--------------------------------|--------|--------------|--------------|-------------|-----|
| Cassava cultivar (C)           |        |              |              |             |     |
| Early maturity (CMR)           | 172.3  | 74.7         | 117.1        | 209.3       | 6.6 |
| Late maturity (RY-7)           | 155.5  | 155.5        | 135.1        | 172.4       | 6.3 |
| Time of PBZ application (T)    |        |              |              |             |     |
| 90 DAP                         | 161.5 b| 68.2         | 112.3        | 177.3 ab    | 6.2 ab |
| 135 DAP                        | 154.7 b| 66.3         | 118.8        | 194.8 a     | 6.8 a |
| 90+135 DAP                     | 149.3 b| 73.8         | 175.5        | 221.1 a     | 7.4 a |
| No PBZ (control)               | 190.5 a| 72.5         | 97.5         | 170.2 b     | 5.5 b |
| F-test                         |        |              |              |             |     |
| C                              | ns     | ns           | ns           | ns          | ns  |
| T                              | *      | *            | ns           | *           | *   |
| CxT                            | ns     | ns           | ns           | ns          | ns  |
treatments delayed leaves senescence during drought period in dry season. This is in agreement with the finding of Abdul Jaleel et al. (2007) in cassava. Leaf number and leaf weight increased in low concentration PBZ application to citrus plantlets was reported by Hazarika et al. (2002). In contrast, PBZ applied to bottle gourd at all concentration significantly decreased leaf size was reported by Rai et al. (2003). In this study cassava cultivars did not show a significant difference on the leaf number and LAI across PBZ application times (Table 2). 

In the present experiment, cassava experienced drought at five months after planting for three months prior to harvest. Jugklang and Saengnil (2012) reported that PBZ application to the crops increased drought tolerance by inducing a number of physiological and biochemical adaptation such as maintaining relative water content in leaves, decreasing electrolyte leakage and proline content, increasing the vitamin C and vitamin E levels and the activities of catalase and superoxide dismutase (Jungklang et al. 2017). Based on these results, PBZ might delay leaves senescence during drought period and finally allow that plant to maintain its leaf number per plant and leaf area index in the present experiment. Previous study revealed that the onset of senescence leaves in several plant species is considerably delayed by triazoles treatments (Davis and Curry, 1991; Binns, 1994) and treated plant retained photosynthetically active longer than the untreated plant (Hunt and Proctor, 1992).

In the present study, LAI did not show a significant difference between early PBZ application at 90 DAP and late application at 135 DAP at 8 months after planting. This result is similar to the findings of Panyapruek et al. (2016) who reported that PBZ application to the cassava at 90 and 150 DAP had no significant effect on LAI at 8 months after planting.

**Number and storage roots weight per plant:** In the present study, PBZ treated plants did not show a significant difference in the number of storage roots per plant when compared to no PBZ control treatment (Table 3). Panyapruek et al. (2016) reported that PBZ application to the cassava at rate of 10 and 20 ppm had no effect on the number of storage roots, but it was significantly increased the number of storage roots at rate of 30 ppm. PBZ application time at 90 and 150 DAP did not show a significant difference in the number of storage root per plant in the present study. This result agreed with the finding by Panyapruek et al. (2016) who reported that PBZ application at 90 and 150 DAP had no significant effect on the number of storage root.

Regardless of fresh storage root weight per plant, PBZ application at 135 DAP significantly increased (P≤0.05) fresh storage root weight per plant across cultivars (Table 3). Panyapruek et al. (2016) stated that PBZ application to cassava at rate of 10 and 20 ppm did not show a significant difference on the fresh storage root weight per plant, but significant effect when PBZ applied at rate of 30 ppm. Cassava cultivars had no significant effect on the number and storage root weight across PBZ application times in this study (Table 3). 

**Storage root yield and starch content:** PBZ application at 135 DAP significantly increased (P≤0.05) fresh storage root yield of cassava across cultivars when compared to no PBZ control treatment (Table 3). This was attributed to higher in LAI and fresh storage root weight per plant resulting to greater storage root yield when cassava harvested at 8 months after planting. Yield increased by 46% of application at 135 DAP treatment when compared to no PBZ control treatment. This was mainly due to larger in sizes of storage roots. This agreement with previous investigation by Yang and Cao (2007) in cassava. Leaf number and leaf weight significantly increased over the control in all the cassava varieties. This was mainly due to larger in sizes of storage roots. The variety SC 8 attained the highest average yield when compared to the other three varieties. In the present experiment, yield did not show a significant difference between the two cultivars CMR and RY-7 (Table 3). Early

| Table 3: Number of storage roots per plant (NSR), fresh storage roots weight per plant (FSRW), fresh storage root yield (FSRY), storage roots starch content (SRSC) and harvest index (HI) of cassava as affected by timing of PBZ application at harvest. |
|-------------------------------------------------|--|--|--|--|--|
| Treatment | NSR(no. pl$^4$) | FSRW(kg pl$^4$) | FSRY(t ha$^4$) | SRSC(%) | HI |
|---|---|---|---|---|---|
| **Cassava cultivar (C)** | | | | | |
| Early maturity (CMR) | 12.8 | 3.4 | 33.1 | 27.8 | 0.61 |
| Late maturity (RY-7) | 15.4 | 2.9 | 27.5 | 28.4 | 0.64 |
| **Time of PBZ application (T)** | | | | | |
| 90 DAP | 16.2 | 3.0 ab | 29.4 ab | 26.6 c | 0.65 a |
| 135 DAP | 13.2 | 3.9 a | 35.6 a | 28.8 b | 0.67 a |
| 90+135 DAP | 14.6 | 3.1 ab | 30.6 ab | 30.6 a | 0.58 b |
| No PBZ (control) | 12.4 | 2.4 b | 24.4 b | 26.4 c | 0.61 b |
| **F-test** | | | | | |
| C | ns | ns | ns | ns | ns |
| T | ns | * | * | * | * |
| CxT | ns | ns | ns | ns | ns |
cultivars (CMR) tend to give higher the storage root yield than those of late cultivars (RY-7) when the crop harvested for 8 months (normally harvest 12 months).

For starch content, PBZ application at 135 DAP or double application at 90 DAP and 135 DAP significantly increased (P≤ 0.05) the starch content of root at harvest. This result was similar to those of the studies by Yang and Cao (2011) who reported that PBZ application to cassava significantly increased the starch content of all cassava varieties. Nanzhi 199 variety gave the highest starch content when compared to the other three varieties. PBZ applied to mungbean increasing the starch content under flooding stress both tolerant and susceptible genotypes as compared to untreated control (Yadav and Hemantaranjan, 2017). In the present experiment, the cultivar CMR and RY-7 did not show a significant difference on the starch content in the storage root (Table 3).

**Harvest index:** PBZ application at 90 DAP or 135 DAP significantly increased (P≤0.05) harvest index (HI) across cultivars when compared with without PBZ control treatment (Table 3). This indicates that PBZ application increased assimilate partitioning to the storage roots. Enhancing translocation of photosynthates to rapid storage roots growth in PBZ treated plants. This agree with the finding by Medina et al. (2012) and Panyapruck et al. (2016). Cassava did not show a significant difference on the HI across PBZ application times in the present study (Table 3).

**CONCLUSION**

All PBZ application times significantly reduced plant height, but had no effect on the number of nodes per main stem. PBZ application at 135 DAP or double application at 90 and 135 DAP increased leaf number per plant and LAI. PBZ application at 135 DAP significantly increased the storage root yield by 46% over control. Whereas, PBZ application at 90 DAP or double application at 90 and 135 DAP increased the storage root yield by 21% and 23%, respectively. PBZ application at 135 DAP or double application at 90 and 135 DAP significantly increased the starch content in the storage roots of cassava at harvest.

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