Effects of paclobutrazol and mepiquat chloride on root yield and starch quality of cassava at different harvesting dates

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ABSTRACT: The investigation was conducted to determine the effects of paclobutrazol and mepiquate chloride on growth, yield and starch content of cassava at different harvesting dates. The experiment was conducted at Land Development Department Experimental Field, Khon Kaen, Thailand in 2009 under rainfed condition. A factorial in randomized complete block design was employed in this study. Factor one was plant growth regulator application included sole application of paclobutrazol (PBZ) or mapiquat chloride (MC), PBZ combining with MC and no application of growth regulator as control. The second factor consisted of four harvesting dates at 8, 9, 10 and 11 months after planting. The results found that sole application of PBZ or MC or PBZ combining with MC application adversely decreased plant height significantly, but significantly increased leaf area index as compared to control across all harvesting dates. Sole application of PBZ produced significantly higher storage root yield than those of sole application MC, but not significant difference with PBZ combining with MC and no application control across all harvesting dates. Cassava harvested for 9 months and 10 months were significantly higher storage root yield than those of harvesting at 8 and 11 months across all growth regulators application. The PBZ and MC application had no significant effect on the starch content in storage root of cassava across all harvesting dates. Cassava harvested for 8 months gave the highest starch content in the present study.
Keywords: cassava, paclobutrazol, mepiquat chloride, yield, starch content.

Introduction

Cassava (*Manihot esculenta* Crantz) has been recognized as one of the most important subsidiary cash crops in northeastern Thailand. Total production of 31 million tons in Thailand, mainly in the northeastern part accounts for 40% of total cultivated areas in the country (OAE, 2015). However, the current production of cassava could not meet the demand of raw material for related industries. Improvement of cassava yield to provide higher economic benefits can play an important role in developing enthusiasm for smallholder farmers in northeastern Thailand. This is due to cassava yield in Thailand is rather low about 18 tons per hectare when compared to 36 tons per hectare in India (FAO, 2014). Therefore, increasing yield per unit of land areas is an important policy of the Thai government.

Plant growth regulator such as paclobutrazol (PBZ) and mepiquat chloride (MC) used in crop field management with many purposes often have a beneficial effect on quantity and quality of harvestable products in potato (Tekalign and Hammes, 2004; Tsegaw et al., 2005) and tomato (Berova and Zlatev, 2000). PBZ reportedly improved the tuber yield and starch content of cassava (Qing-song and Xiao-hui, 2011). In similar trend, MC that increased the tuber yield and starch content in cassava was also reported by Lima de Souza et al. (2010). However, information of PBZ and MC application on growth, storage root yield and starch quality of cassava at different harvesting dates is scarce. The objectives of this research were, therefore, to investigate the effects of PBZ or MC applied solely and together on growth, yield and starch content of cassava at different harvesting dates

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under rainfed condition.

Materials and Methods

Experimental site and climate data

The experiment was conducted at Land Development Department Experimental Field, Khon Kaen, Thailand. The soil had sandy loam in texture and there are classify as Typic Paleustults (Buol et al., 1980). The experimental site is under tropical climate, having 6 months of dry season (November to April) with wet season starting from May to October. Weather data during crop growth period was shown in **Table 1**.

Experimental design and treatments

A factorial 4 x 4 in Randomized Complete Block Design (RCBD) with four replications was employed in this experiment. Factor one was plant regulator application consisted of sole application of PBZ and MC at the rate of 10 ppm, PBZ combining with MC, each at the rate of 10 ppm and no application of growth regulator as the control. The second factor included four harvesting dates: 8, 9, 10 and 11 months after planting. The PBZ and MC concentration rate was calculated basing on a given of PBZ and MC 5.29 gm a.i. diluted in water 500 cc to obtain the concentration at 10 ppm. Cassava plants were treated with sole application of PBZ or MC or PBZ + MC at 90, 110, 130 and 150 days after planting (DAP) as soil drench recommended by Gomathinayagam et al. (2007).

Plant culture

The land was prepared by ploughing twice to a depth of 30 cm. Cassava was planted in July 2009 and harvested at 8, 9, 10 and 11 months after planting. After the last ploughing, a pit was created with size 50 x 50 x 30 cm (wide x long x deep) with plant spacing between row and plant 100 x 100 cm for intensive crop culture. Cattle manure at rate of 6.25 t ha^{-1} were filled into the pit and mixed with the soil at 7 days before planting. Then, stem cutting of 25 cm long were inserted vertically into the soil.

Crops were treated by hand irrigation at 500 cc $plant^{-1}$. Hand weeding was undertaken at 30 and 60 DAP. Pesticides were not used entire the growing season in the present experiment.

Data recording and statistical analysis

The plant height was measured randomly selected four plants from the ground to the tip of each plot at 8, 9, 10 and 11 months after planting. The leaf area was recorded randomly selected plants using automatic leaf area meter (AAC-400, Hayashi Denco., Ltd., Tokyo, Japan) at 8, 9, 10 and 11 months after planting. The leaf area index (LAI) was calculated by leaf area cover ground area. The above ground biomass was determined randomly selected four plants at 8, 9, 10 and 11 months after planting. Crops were cut at ground level. Then, the material was fresh weight and dried in an oven at 80 °C until dry weight are constant. The above ground fresh weight and dry weight were expressed in gm $plant^{-1}$. The storage fresh root weight per plant was recorded from the same plants with above ground biomass samples.

At harvesting dates of 8, 9, 10 and 11 months after planting, five plants were randomly selected for determining the storage root yield and starch content. The starch content was measured using Reiman scale balance method (Bainbridge et al., 1996).

The data was analyzed using the analysis of variance (ANOVA) by MSTATC software (Analytical solfware 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

Plant height

PBZ and MC growth regulators application significantly decreased in plant height as compared to no application control (Table 2). The plant height was reduced by application of PBZ were reported in tomato (Berova and Zlatev, 2000) and in cassava (Zhou, 2003; Gomathinayagam et al., 2007; Medina et al., 2012). Similar trend of application MC to reduce in plant height was reported in cassava (Lina de Souza et al., 2010). This was due to PBZ and MC inhibited internode growth (Davis et al., 1991; Pinto et al., 2005; Gomathinayagam et al., 2007). The growth redarding effect of PBZ and MC is caused by the inhibition of gibberellic acid (GA) biosynthesis (Izumi et al., 1987) reduced the cell number, length and width of the xylem cells (Fletcher et al., 2000). Irrespective of harvesting dates, plant height was significantly affected by harvesting dates across two growth regulators application. The tallest plants were observed for 11 months harvesting.

Above ground biomass

Across all harvesting dates, PBZ and MC application had significant effect on above ground fresh weight and dry weight (Table 2). The highest above ground fresh weight and dry weight were obtained in sole PBZ treated plants, and it was significantly higher than those of sole MC treated plants. However, above ground fresh weight and dry weight had no significant effect among sole application PBZ, PBZ combining with MC and no application control treatments. Medina et al. (2012) reported that PBZ application in cassava significantly decreased above ground biomass as compared to no application control. Further, Lima de Souza (2010) reported that MC application in cassava significantly increased above ground biomass in comparison with no application control.

Regardless of harvesting dates, above ground biomass was significantly affected by harvesting dates across two growth regulators application. The highest above ground biomass was observed for 9 months after planting, and decreasing with age both in the control and treated plants (Table 2). This was mainly associated with leaves senescence that caused by water stress during the rainless period in dry season (Table 1).

Leaf area index (LAI)

Across all harvesting dates, sole application of PBZ or MC or PBZ combining with MC application significantly increased LAI as compared to no application control (Table 2). However, LAI was not significantly affected by all PBZ and MC application treatments. The highest LAI was attained in PBZ combining with MC treated plants. This contrast with the previous works resulted that PBZ application inhibited the growth of stems and leaves in cassava (Gomathinayagam et al., 2007; Tang, 2008). Similar trend was observed in tomato (Berova and Zlatev, 2000) and potato (Tekalign and Hammes, 2004). The results of this work also show that all

PBZ and MC application treatments produced significantly higher LAI than those of no application control. This was due to LAI of application PBZ and MC plants associated with less number of leaves senescence than those of no application control during the dry season. This agree with the previous studies as reported by David and Curry (1991).

Irrespective of harvesting dates, PBZ and MC application had significant effect on LAI across all harvesting dates (**Table 2**). The highest LAI was obtained for 9 months after planting, but not significant difference with 10 months after planting in the present experiment. It also observed that LAI continued decreasing at 10 and 11 months after planting. This was attributed to the leaves senescence that caused by water stress during the rainless period in dry season **(Table 1)**.

Storage root weight per plant

Across all harvesting dates, PBZ and MC application had significant effect on fresh storage root weight (FSRW) per plant of cassava **(Table 3)**. The sole application of PBZ or PBZ combining with MC was significantly higher FSRW than those of sole application of MC, but not significant difference on FSRW with no application control. This contrast with previous studies by Medina et al. (2012) reported that PBZ application significantly decreased tuberous roots fresh mass per plant in cassava. In the present study, sole application of PBZ or PBZ combining with MC significantly increased FSRW when compared to sole application MC.

Irrespective of harvesting dates, PBZ and MC application had significant effect on FSRW (**Table 3**). Crop harvested for 9 months after planting significantly higher FSRW than those of harvesting at 8 and 11 months, but not significant difference on FSRW with 10 months after planting. In the present experiment, FSRW decreased with increasing age due to low water content in storage root that caused by low soil moisture during the rainless period in dry season.

Storage root yield

Across all harvesting dates, PBZ and MC application had significant effect on fresh storage root yield of cassava **(Table 3)**. Sole application of PBZ was significantly higher root yield than those of sole MC, but not significant difference with PBZ combining with MC application and no application control. This was due to sole PBZ application associated with higher leaf area index (**Table 2**) and storage root weight per plant (**Table 3**) in the present experiment. These findings are accordance with the previous studies (Zhou et al., 2004; Li et al., 2008; Yuan et al., 2010; Qing-song and Xiao-hai, 2011). PBZ application increased chlorophyll a and b content of the leaf tissue, increased tuber fresh mass and dry matter content in potato was reported by Tekalign and Hammes (2004). Triazole (triadimefon, hexaconazole, paclobutrazol and etc.) 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 tubers (Romanov et al., 2000).

Regardless of harvesting dates, PBZ and MC application had significant effect on fresh storage root yield across all plant growth regulator applications **(Table 3)**. The highest storage root yield was obtained for 9 months after planting, but not significant difference with 10 months after planting. This was associated with the crop harvesting at 9 months after planting produced higher leaf area index and fresh root weight per plant than those of the other harvesting dates in the present study.

Starch content

Across all harvesting dates, two growth regulators application had significant effect on the starch content in storage roots of cassava (**Table 3**). The PBZ combining with MC application was significantly higher the starch content than those of sole application PBZ treatment, but not significant difference with sole application MC and no application control. In previous experiments with cassava plants, Quing-Song and Xiao-Hui (2001) reported that PBZ application significantly increased the starch content in tuber roots. Similar results were observed with MC application in cassava (Lima de Souza, 2010). The starch content increased in storage roots due to decrease starch hydrolysis (Upadhyaya et al., 1986) and alters the carbohydrate status in plants (Vu and Yelenosky, 1992).

Regardless of harvesting dates, starch content was significantly affected by harvesting dates across all growth regulators application. The highest accumulation of starch content in root was obtained for 8 months after planting. This confirms the results reported in previous experiment with cassava plants (Santisopasri et al., 1998). Cassava gave the highest accumulation of starch content for 8 months after planting associated with low amount of biochemical like lipid, protein, cyanide, phenolic compounds and fiber (Santisopasri et al., 1998).

A significant interaction was observed between growth regulators application and harvesting dates of the starch content in storage roots of cassava (**Figure 1**). The PBZ combining with MC application significantly increased the starch content for 8 months after planting as compared to sole application of PBZ or MC application and no application control. Whilst PBZ combining with MC application had no significant effect on the starch content in storage roots of cassava for 9, 10 and 11 months after planting.

Table 1 Weather data of experimental site during cropping season in 2009-2010

Month	Temperature (°C)		Rainfall	Evaporation	Relative
	Maximum	Minimum	(mm)	(mm/day)	humidity (%)
<u>Year 2009</u>					
May	33.5	25.5	388.5	5.33	83
June	33.8	26.0	474.3	5.93	82
July	32.3	25.7	655.4	5.03	85
August	32.8	25.6	815.0	4.50	87
September	32.6	25.2	999.9	4.02	89
October	33.2	24.7	0.00	5.60	89
November	32.5	20.2	0.00	5.59	78
December	31.7	18.4	0.00	4.77	81
<u>Year 2010</u>					
January	30.9	17.6	61.6	5.19	88
February	34.3	18.5	21.0	6.23	90
March	35.8	18.6	0.00	5.18	86
April	38.7	24.7	39.0	6.78	88

Table 2 Effect of paclobutrazol (PBZ) and mepiquat chloride (MC) application on growth of cassava at different harvesting dates under rainfed condition.

Treatment	Plant height (cm)	Above ground fresh weight (gm plant)	Above ground dry weight (gm plant)	Leaf area index
Growth regulator (G)				
PBZ	183.3c	2,569.4a	955.9a	1.168a
MC	180.4c	1,921.3b	688.8b	1.112a
PBZ + MC	196.6b	2,216.3ab	818.5ab	1.226a
Control	210.2a	2,299.4ab	810.5ab	0.792b
Age (A)				
8 months	192.8b	1,965.6b	713.9b	0.81c
9 months	181.8b	2,603.1a	942.5a	1.34a
10 months	189.6b	2,468.7a	806.3ab	1.14ab
11 months	206.3a	1,968.8b	890.4ab	1.00bc
F-test				
G	**	**	*	**
A	**	*	*	**
G x A	ns	ns	ns	ns

Means followed by different letter within columns are significantly different at 5% level (*), at 1% level (**) and ns = not significant.

Table 3 Effect of paclobutrazol (PBZ) and mepiquat chloride (MC) application on fresh root weight per plant, storage root yield and starch content of cassava at different harvesting dates under rainfed conditions

Treatment	Fresh storage root weight/plant (kg)	Fresh storage root yield (t ha^{-1})	Starch content (%)
Growth regulator (G)			
PBZ	3.69a	25.68a	24.63b
MC	2.89b	19.19b	26.19ab
PBZ + MC	3.55a	23.12ab	27.73a
Control	3.47ab	22.18ab	26.43ab
Age (A)			
8 months	2.91c	19.63b	31.40a
9 months	3.84a	26.06a	26.83b
10 months	3.71ab	24.69a	20.30c
11 months	3.16bc	19.68b	26.45b
F-test			
G	*	*	*
A	*	*	**
G x A	ns	ns	**

Means followed by different letter within columns are significantly different at 5% level (*), at 1% level (**) and ns = not significant.

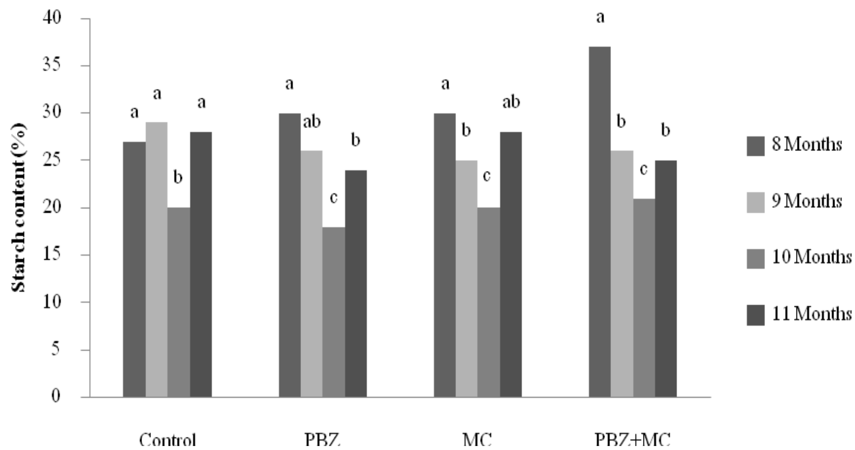

Figure 1 Interaction between plant growth regulators and harvesting dates on starch content (%) in storage root of cassava (PBZ = paclobutrazol, MC = mepiquat chloride).

Conclusion

Across all harvesting dates, sole application of PBZ or MC or PBZ combining with MC application had no significant effect on storage root yield and starch content as compared to no application control. However, sole PBZ application or PBZ combining with MC increased the storage root yield by 15.8% and 3.7%, respectively. Sole application of MC produced significantly lower the storage root yield than those of sole application of PBZ. Cassava harvested for 9 months after planting gave the maximum storage root yield, but not significant difference with 10 months after planting across all growth regulators application. The sole application of PBZ or MC or PBZ combining with MC application had no significant effect on the starch content in root of cassava across all growth regulators application. Cassava harvested for 8 months after planting gave the highest starch content across all growth regulators application.

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