

Exogenous Gibberellic Acid Stimulates Bulb Dormancy Breaking and the Role of Paclobutrazol in Maintaining the Size of Harvested Bulb of Lily (*Lilium* sp.) cv. Tisento

(Asid Giberellik Eksogen Merangsang Pemecahan Dorman Bebawang dan Peranan Paklobutrazol dalam Mengekalkan Saiz Bebawang Lili (*Lilium* sp.) kv. Tisento yang Dituai)

SITI NUR ANISAH¹, DIAH RATNADEWI^{2*} & ENCE DARMO JAYA SUPENA²

¹*Plant Biology Graduate Program, Faculty of Mathematics and Natural Sciences, IPB University, Jl. Agatis, Dramaga Campus. Bogor 16680, West Java, Indonesia*

²*Department of Biology, Faculty of Mathematics and Natural Sciences, IPB University, Jl. Agatis, Dramaga Campus. Bogor 16680, West Java, Indonesia*

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ABSTRACT

Lilies are increasingly demanded in Indonesia. However, the production of lily seedlings in Indonesia still needs to be improved, causing a strong dependence on imported bulbs as the planting material and low competitiveness in foreign flower markets. Insufficient lily production is due to the decreasing quality of the bulb as the planting material and the time required for vernalization to break the bulb dormancy. The study aimed to accelerate the time of bulb dormancy breaking and maintain the size of the lily bulb to get an efficient flower production with good quality. The research was conducted in a greenhouse during the rainy and dry seasons. Various exogenous gibberellic acid (GA3) concentrations with different soaking times were applied to lily bulbs to shorten the dormancy period. The most efficient treatment was soaking the bulbs in 100 mg/L of GA3 for 16 hours, from 19-20 weeks to 12-13 weeks. Further, paclobutrazol (PBZ) was sprayed on the plants to decelerate vegetative growth and grow bulb size. The results showed that GA3 could partly substitute vernalization to break bulb dormancy, and PBZ maintained the bulb size after plant harvesting. Additionally, the plant height was suppressed, and the stem diameter, leaf chlorophyll, and bulb carbohydrate content were significantly increased under 300 mg/L PBZ treatment, resulting in the bulbs' bigger size.

Keywords: Gibberellin; paclobutrazol; planting materials; plant quality; vernalization

ABSTRAK

Bunga lili semakin mendapat sambutan di Indonesia. Walau bagaimanapun, pengeluaran anak pokok lili di Indonesia masih perlu dipertingkatkan sehingga menyebabkan kebergantungan tinggi terhadap bebawang import sebagai bahan tanaman dan daya saing yang rendah di pasaran bunga luar negara. Pengeluaran bunga lili yang tidak mencukupi adalah disebabkan oleh penurunan kualiti bebawang sebagai bahan penanaman dan masa yang diperlukan untuk vernalisasi untuk memecahkan dorman bebawang. Kajian ini bertujuan untuk mempercepatkan masa pecah dorman bebawang dan mengekalkan saiz bebawang teratai untuk mendapatkan pengeluaran bunga yang cekap dengan kualiti yang baik. Kajian ini dijalankan di rumah hijau semasa musim hujan dan kemarau. Pelbagai kepekatan asid giberelik eksogen (GA3) dengan masa rendaman yang berbeza digunakan pada bebawang lili untuk memendekkan tempoh dorman. Rawatan yang paling berkesan ialah merendam bebawang dalam 100 mg/L GA3 selama 16 jam, dari 19-20 minggu hingga 12-13 minggu. Selanjutnya, paklobutrazol (PBZ) disemur pada tumbuhan untuk melambatkan pertumbuhan vegetatif dan membesar saiz bebawang. Keputusan menunjukkan bahawa GA3 sebahagiannya boleh menggantikan vernalisasi untuk memecahkan dorman bebawang dan PBZ mengekalkan saiz bebawang selepas penuaian tumbuhan. Selain itu, ketinggian tumbuhan telah ditindas dan diameter batang, klorofil daun dan kandungan karbohidrat bebawang telah meningkat dengan ketara di bawah rawatan PBZ 300 mg/L, menghasilkan saiz bebawang yang lebih besar.

Kata kunci: Bahan penanaman; giberelin; kualiti tumbuhan; paklobutrazol; vernalisasi

INTRODUCTION

Floriculture commodities consist of potted flowers, cut flowers, and ornamental leaf plants. One of the floriculture commodities that have the potential to be developed is cut flowers because they are widely used for events, such as weddings, births, and funerals, as well as for decorations (Evi & Nur'aini 2017). Demand for cut flowers in Indonesia, including lilies, continues to increase along with income and community welfare (Handayati 2013). Lily flowers have diversely attractive colors and motifs (Sarvade, Ranpise & Thotar 2015), making them widely traded worldwide (Budiarto et al. 2020). Lilies occupy the 4th rank out of the top five cut flowers in the flowers auction in the Netherlands. International market demand for lilies increases yearly; for example, in 2020, a rise of 4.2% was recorded from the previous year (van Schilfgaarde & Mechelen 2020).

Lilies (*Lilium* sp.) are bulbous plants, members of the Liliaceae. Lilies originated from temperate regions in the Northern Hemisphere, such as Europe, Turkey, Japan, and North America (Sarvade, Ranpise & Thotar 2015). In Indonesia, lilies are widely cultivated in mountainous areas. The need for lily bulbs is vast and has yet to be met by domestic production, so the planting materials are still imported (Kurniati et al. 2012), particularly from the Netherlands. Dependence on imported sources increases the price of lily-cut flowers and reduces competitiveness in foreign marketplaces (Wahyurini 2010).

Lily is propagated conventionally by bulbs or their scales (Fauziah, Kusmiyat & Anwar 2019). The scale development to reach the desired size takes a long time, with a low propagation ratio, with only one to two daughter scales in each bulb (Mir et al. 2012). Lily bulbs also experience a period of dormancy (Fauziah, Kusmiyat & Anwar 2019), requiring cold temperatures to fulfill their physiological cycle (Wang et al. 2018). Plant growth regulators can alter the dormancy mechanism in various floricultural crops (Pal 2019). Application of exogenous gibberellic acid (GA3) in Asiatic lily shortened bulb dormancy period. This hormone was also responsible for internode elongation, cell enlargement, flower quality, and delayed senescence of flowers and leaves (Jayashree et al. 2020).

Bulb size affects the growth and flowering of lilies (Lazare & Zaccai 2016). Lily bulbs will shrink after the first harvest, thus affecting the quality of flower production in the next generation. In hybrid *Lilium*, Zheng, Wu and Xia (2012) reported that 300 mg/L paclobutrazol (PBZ) suppressed vegetative growth,

increased leaf chlorophyll content, inhibited gibberellins synthesis, and increased carbohydrate accumulation in bulbs. Therefore, PBZ treatment might increase the size of lily bulbs by increasing the photosynthetic process and transporting the assimilates from the source to the sink. This study aimed to determine the benefits of GA3 to shorten bulb dormancy time and PBZ in maintaining lily bulb size during plant growth to obtain efficient and conserved planting materials. Lily *Tisento* was selected since the market demand for the variety is among the most substantial in Indonesia, with its white flower, strong fragrance, and long vase life.

MATERIALS AND METHODS

This research was carried out from May 2021 to September 2022 on the hillside of Mount Halimun, Bogor Regency, West Java; 1400 m above sea level. The treatment consisted of two stages, namely breaking bulb dormancy and bulb enlargement, and each was carried out in two periods. Period I was the rainy season from September 2021 to February 2022 (22.6-29.3 °C, 14,9-17,3 mm/day rainfall, 6.000-25.000 lux light intensity). Period II was the dry season from March to September 2022 (22.9-29,7 °C, 9,3-15,1 mm/day rainfall, 6.000-36.000 lux light intensity). The bulbs were selected with a perimeter range of 13-15 cm. The perimeter is the circle's outer boundary or the bulb's circumference. They were harvested from the first cultivated plants by which the bulbs had been imported.

PLANTING PROCEDURE AND TREATMENTS

GA3 TREATMENTS FOR BREAKING BULB DORMANCY

In stage I, the selected bulb underwent a six-week cooling period (vernalization) at -1 °C. Then, the bulbs were washed to remove the remaining soil and dirt, followed by a seven-day pre-rooting period (put at 9-10 °C). Afterward, the bulb was soaked in GA3 solution (0, 50, 75, and 100 mg/L) for 8, 16, and 24 h at room temperature. The bulbs were then planted in a planting media consisting of cocopeat: perlite (85:15) in a 25×20 cm polybag. The media was enriched with the essential fertilizer NPK faster 25-7-7 (2 g/L) as much as 200 mL per polybag after one week of sprouting. Bulbs stored at -1 °C for six weeks, without GA3 treatment, were taken as treatment controls, and bulbs held at -1 °C for 16 weeks were taken as full vernalization controls. There were 17 bulbs in each treatment and control. Observations were carried out on the initial sprouting time, time range of initial sprouting, and percentage of sprouting bulbs.

PBZ TREATMENTS FOR MAINTAINING THE BULB SIZE

In stage II, all plants grown from the GA3 treatments were fully randomized and divided into four groups for the PBZ treatments. PBZ (0, 150, 300, 450 mg/L) was applied to the growing plants. PBZ solution was sprayed on the leaf's lower surface (abaxial), as much as 50 mL per plant in the period I (rainy season). In period II (dry season), PBZ was poured on the growing media to avoid leaf necrosis. The PBZ treatment was given twice, at the sixth and eighth weeks after sprouting (6th and 8th WAS), in the morning before sunrise. Controls were taken from full vernalized bulbs without PBZ. Depending on the number of the sprouting bulbs, 34 and 20 replicates were used in the period I and II, respectively. Any flower buds were removed when they appeared. The bulbs were harvested in the 16th week after sprouting, starting with cutting off the stem and leaving three leaves on the remaining limb. Two weeks later, the bulbs were dug out of the growing medium. Several measurements were taken, including morphological parameters (stem height, stem diameter, number of leaves, plant fresh and dry weight, and bulb perimeter) and physiological parameters, such as leaf chlorophyll content, starch, and sugar contents in bulbs after harvest. Leaf chlorophyll content was determined using spectrophotometry which referred to the method described by Quinet et al. (2012). Sugar and starch extractions were carried out using 80% ethanol. The aqueous extract was taken for sugar analysis, and the residue was used for starch analysis, following the method of McCready et al. (1950).

DATA ANALYSIS

This study was conducted in a one-factor completely randomized design (CDR). Quantitative data were analyzed using SPSS 25.0. The Shapiro-Wilk test was employed to examine the normality of the data. A one-way ANOVA was performed to test any different effects of the treatments, and if there was a difference, a further test was carried out with Duncan's Multiple Range Test (DMRT) 5%. Abnormally distributed data were tested with non-parametric Kruskal-Wallis and continued with Dunn's Post Hoc Test.

RESULTS AND DISCUSSION

BULB DORMANCY BREAKING

There was a significant ($P < 0.05$) effect of the combination of GA3 concentration and soaking time in determining

the initial time of bulb sprouting and the percentage of growing bulbs (Table 1). The G2L1 to G3L3 treatments generally gave better results than the other treatments, except when compared to the full vernalization control. However, the most efficient treatment for the time required to sprout was G3L2 (GA3 100 mg/L and 16 hours of soaking time); the fastest average time in periods I and II were 5.8 and 4.6 weeks, respectively. In 16 h of soaking time, the G3L2 treatment broke dormancy and reached 100% of sprouting bulbs, which was not significantly different from G3L3 with 24 h of soaking time. The difference in yield in the two seasons could be due to shorter photoperiodicity and lower daily temperature in the rainy season (period I) compared to the dry season (period II). According to Nyachiro et al. (2002), temperature is one of the critical environmental factors affecting seed dormancy induction during seed development and seed dormancy breaking during germination. Light and temperature can stimulate bud growth; low temperatures lower respiration rates and reduce the use of nutrients and energy, slowing down seed germination (Xu, Hu & Zhang 2012). Contrarily, Ma et al. (2016) suggested that high temperatures could increase the germination rate, vigor index, and sprout length.

The control's sprouting time was 1.1 weeks after experiencing 16 weeks of vernalization. The dormancy period of *Tisento* lily bulbs generally takes 19-20 weeks without GA3, consisting of 16 weeks of vernalization, two weeks of pre-rooting, and an average of 1-2 weeks of sprouting. The fastest time required to break bulb dormancy of GA3-treated bulb in this study was about 12-13 weeks, including six weeks of vernalization, one week of pre-rooting, and 5-6 weeks for sprouting. Even the G3L3-treated bulbs took only 10-11 weeks to grow. Bulbs treated with 50, 75, and 100 mg/L of GA3 developed earlier than those without GA3 (G0). There was no single bulb of treatment control grew.

Dormancy requires high temperatures or low temperatures to break (Wolkis, Baskin & Baskin 2018). The dormant period is necessary for certain plants for normal development (Shu et al. 2016). In certain species, if the cold period in a year is insufficient, plant growth will be slow, and flowers will be underdeveloped or deformed (Campoy et al. 2018; Chuine et al. 2016). Lily bulb undergoes dormancy after harvest, during which the bulbs gain sufficient energy to germinate and grow after breaking dormancy. Cold temperature induced metabolic activities in the lily scales, accelerated bulb

sprouting, and further plant development (Kim & Oh 2021; Shin, Chakrabarty & Paek 2002). Arisda and Mastuti (2021) reported that low temperatures affected potato tuber growth after dormancy, i.e., in the number of sprouting tubers and the initial sprouting time.

Storage of bulbs at -1 °C for six weeks, followed by the administration of GA3 concentration of 100 mg/L at soaking times of 8, 16, and 24 h, showed a 100% shoot growth. It indicated that the concentration of GA3 100 mg/L significantly accelerated the bulb dormancy breaking from 19-20 weeks to 12-13 weeks. Thus, the cold temperature requirement of *Tisento* lily bulbs was partially replaced by the GA3 treatment. Seed certification requires a minimum standard for bulb

germination in crops, such as garlic, potato, onion, and onion hybrids, which is 70-80% (Sadjad 1993; Trivedi & Gunasekaran 2013). Gibberellins (GAs) replaced the cooling function by activating 1,3-glucanase activity and promoting callose hydrolysis during bud dormancy release in *Populus* spp. (Rinne et al. 2011). It is suspected that the GA3 application met the need to form the α -amylase, which was quickly used for starch hydrolysis to produce energy for growing shoots (Taiz et al. 2015). In the treatment control, the bulbs entirely did not grow, presumably, because they did not achieve the driving force for the physiological process in those bulbs, i.e., the GA content was insufficient to meet the need for α -amylase enzyme activation.

TABLE 1. The initial time of bulb sprouting and the percentage of sprouting bulbs due to the treatment combination of GA3 concentrations and duration of soaking

Treatment	Initial sprouting time (weeks)		Time range of initial sprouting (weeks)		Percentage of sprouting bulbs (%)	
	Period I	Period II	Period I	Period II	Period I	Period II
Treatment control	-	-	-	-	0 ^a	0 ^a
Full vernalization control	1.1 ^a	1.1 ^a	1-2	1-2	100.0 ^d	100.0 ^e
G0L1	15.5 ^d	-	15-16	-	11.7 ^a	0.0 ^a
G0L2	13.3 ^d	15.5 ^f	9-16	15-16	17.6 ^a	11.7 ^a
G0L3	13.3 ^d	14.3 ^f	9-16	14-15	17.6 ^a	17.6 ^a
G1L1	7.6 ^c	7.7 ^c	6-9	6-9	64.7 ^b	64.7 ^b
G1L2	5.5 ^b	7.3 ^{de}	5-7	6-9	70.5 ^{bc}	64.7 ^b
G1L3	6.6 ^{bc}	7.1 ^d	5-8	6-9	82.3 ^{bcd}	70.5 ^b
G2L1	6.1 ^{bc}	6.7 ^{de}	4-9	6-8	88.2 ^{bcd}	76.4 ^{bc}
G2L2	6.8 ^{bc}	6.6 ^{de}	4-9	6-8	88.2 ^{bcd}	88.2 ^{bc}
G2L3	5.9 ^{bc}	6.2 ^{cd}	4-9	6-7	94.1 ^{cd}	88.2 ^{bc}
G3L1	5.7 ^b	5.7 ^c	3-9	5-6	100.0 ^d	100.0 ^e
G3L2	5.8 ^b	4.6 ^b	3-8	3-6	100.0 ^d	100.0 ^e
G3L3	5.2 ^b	3.9 ^b	3-7	3-5	100.0 ^d	100.0 ^e

Notes: numbers followed by different letters in the same column indicate significant differences based on Duncan's test ($\alpha = 5\%$). Period I = rainy season; period II = dry season; G0-G3 = GA3 concentration of 0, 50, 75, 100 mg/L; L1-L3 = soaking time of 8, 16, 24 hours; - indicates no sprouting at all

PLANT VEGETATIVE GROWTH AND BULB SIZE

Paclobutrazol demonstrated a significant effect ($p < 0.05$) on stem height, stem diameter, the number of leaves, plants' fresh and dry weights, and bulb perimeter. On average, the initial stem height before PBZ treatment was 41.4-53.4 cm. After PBZ treatment, the stems reached 52.7-66.6 cm, observed at 16 WAS. It was evident that PBZ shortened stem height, expressed by the narrower difference in stem height compared to the control, with the smallest growth in P3-treated plants in both planting periods (Table 2). PBZ has a significant effect on stem diameter growth. Unlike the stem height, increasing the concentration of PBZ gave more significant growth of stem diameter, and P3 resulted in maximal growth.

PBZ also significantly affected the number of leaves. P3-treated plants generated the least number of additional leaves from the initial state. The higher the concentration of PBZ, the less the number of new leaves. The growth of leaves was in line with the development of the stem length. The results conformed with the findings of Soumya, Kumar and Pal (2017) that PBZ played a significant role in reducing plant height and leaf count. Mabvongwe et al. (2016) reported that PBZ treatment prevented the synthesis of active gibberellins and reduced cell division/elongation and the stem length in *Solanum tuberosum*.

Hedden and Graebe (1985) previously stated that PBZ reduces gibberellic acid content in plant cells by inhibiting the oxidative step of gibberellin precursor ent-kauren to ent-kaurenic acid in the biosynthesis pathway. PBZ application at an earlier time will inhibit the activity of gibberellic acid in plant cells and hamper stem elongation by detaining the growth of stem internodes. Cell elongation is inhibited when gibberellin production is inhibited, but cells are still actively dividing. Consequently, the new cells do not

elongate. This evidence causes a decrease in leaf number and internode length (Desta & Amare 2021). Malik, Wani and Nazki (2021) reported in Asiatic lily that the application of PBZ caused the leaf segments to be shorter, reducing the plant height without affecting the number of flowers. Paclobutrazol increased stem diameter by enlarging the thickness of the cortex, vascular bundles, and pith (Mabvongwe et al. 2016; Tsegaw, Hammes & Robbertse 2005).

There were vegetative growth differences in periods I and II. Plant growth was generally less in period I than in period II regarding stem height, diameter, and leaf number (Table 2). It happened presumably because of the difference in light intensity, photoperiod, and temperature in periods I (rainy season) and II (dry season). Yang et al. (2017, 2014) stated that in low light conditions, the dry matter of roots, stems, and leaves was lower, and the photosynthetic rate, transpiration, stomatal conductance, and stem diameter decreased. Meanwhile, Fernandes et al. (2013) stated that high light radiation could increase the number of leaves while the leaf area decreased. The higher light intensity and temperature in period II might explain the more robust plant compared to period I.

The fresh and dry weights of the shoot in periods I and II were opposite to the increase in PBZ concentrations (Figure 1). The control demonstrated the highest weight compared to the treated plants (P1-P3). The fresh and dry weights of the root (root and bulb) (Figure 2) showed contrast patterns from those of the shoots, with P2 giving the most significant root weight. The control and P0 presented the lowest weight, while the treatment P2 gave the most extensive root biomass. In period I, the shoot weight was more suppressed by PBZ than in period II, but the root weight was larger than in the other period.

TABLE 2. Effects of PBZ on the stem height, stem diameter, and number of leaves of *Tisento* lily, differences from the initial state before and after PBZ treatment*

Treatment	Stem height growth (cm)		Diameter growth of the stem (cm)		Additional number of leaves	
	Period I	Period II	Period I	Period II	Period I	Period II
Control	18.8 ^c	13.4 ^c	0.0 ^a	0.1 ^a	7.4 ^d	7.5 ^d
P0	10.1 ^d	13.8 ^c	0.0 ^a	0.1 ^a	3.3 ^c	3.4 ^c
P1	5.6 ^c	6.8 ^b	0.1 ^b	0.2 ^b	2.2 ^b	2.5 ^b
P2	2.7 ^b	3.6 ^a	0.3 ^c	1.0 ^c	1.3 ^{ab}	1.7 ^b
P3	0.6 ^a	1.8 ^a	0.4 ^c	1.1 ^c	0.7 ^a	0.8 ^a

Notes: *observation at the 16th weeks after spraying (WAS). Numbers followed by different letters in the same column show a significant difference based on Dunn's Post Hoc Test ($\alpha = 5\%$). P0-P3 = PBZ concentration of 0, 150, 300, 450 mg/L; Period I = rainy season and PBZ sprayed on the lower surface (abaxial) of leaves, period II = dry season and PBZ was poured on the growing media; control = plant derived from full vernalized bulbs

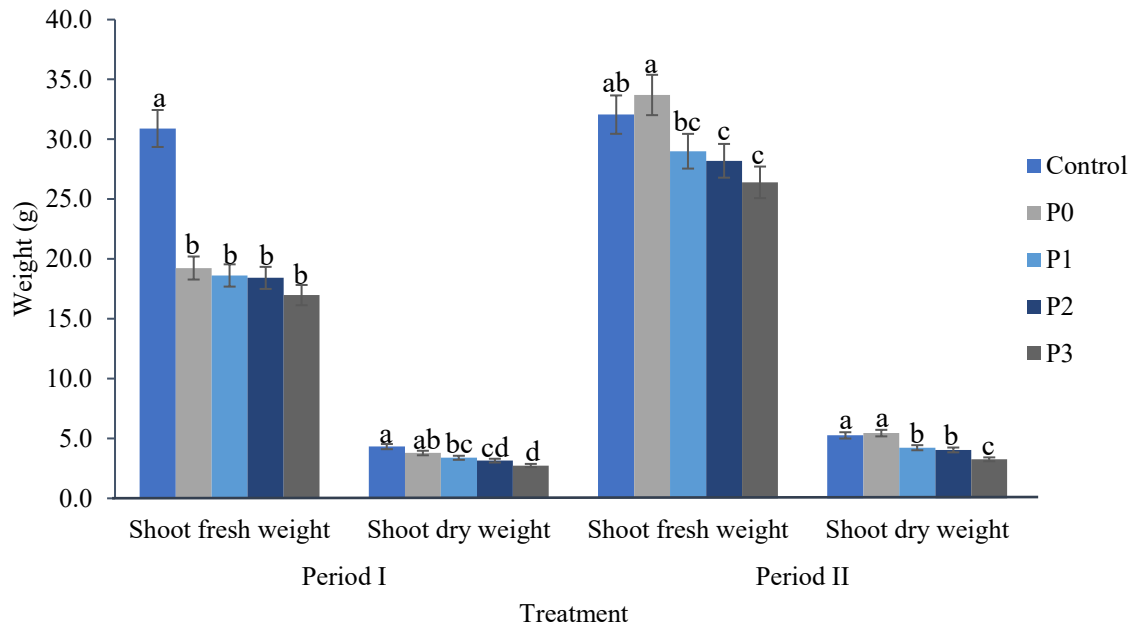


FIGURE 1. Effects of different PBZ concentrations on the fresh and dry weights of the plant's shoot. Period I = rainy season and PBZ sprayed on the lower surface (abaxial) of leaves, period II = dry season and PBZ was poured on the growing media; P0-P1 = PBZ concentration of 0, 150, 300, 450 mg/L; control = plant derived from fully vernalized bulbs

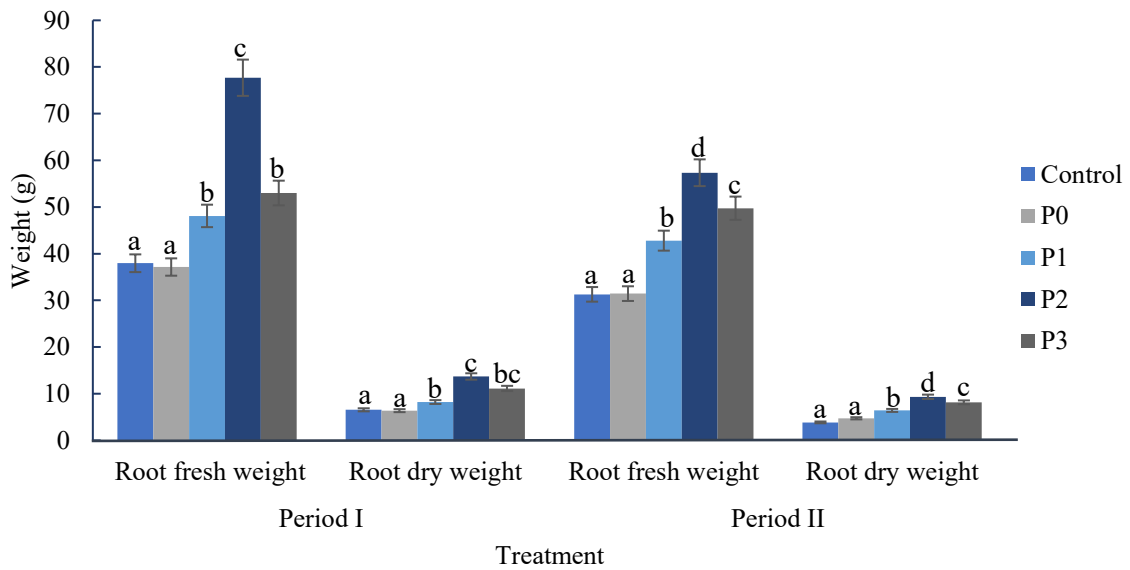


FIGURE 2. Effects of different PBZ concentrations on the fresh and dry weights of the plant's root. Period I = rainy season and PBZ sprayed on the lower surface (abaxial) of leaves, period II = dry season and PBZ was poured on the growing media; P0-P3 = PBZ concentration of 0, 150, 300, 450 mg/L; control = plant derived from fully vernalized bulbs

The weight of P3 roots was lower than P2's because the P3 plants partially experienced leaf necrosis that might damage leaf components, thereby reducing photosynthesis. PBZ suppressed the shoot growth but increased the photosynthetic products and translocated them to the bulb. The increase in the root weight proved this. The result was supported by Desta and Amare (2021), and Lazare and Zaccai (2016) who stated that PBZ reduced vegetative growth but increased the accumulation of photoassimilates to lower organs, such as bulbs. Higher photo-assimilation increased plant weight, at the same time, also increased carbohydrate reserves by increasing the bulb perimeter.

Perimeter is a general measure of the size of a lily bulb. A significant difference was influenced by PBZ concentration on the perimeter size after being harvested (Table 3). There was an increase in the perimeter, especially from treatment P2 (300 mg/L PBZ) in periods I and II. Lily bulbs are divided into two groups according to their perimeter size: 5-8 cm (S = small) and 12-16 cm (L = large) (Lazare & Zaccai 2016). In the control, P0, and P1- treated plants, the size of the bulb shrank at the end of the planting time, indicated by a negative value (-) in average size different. Meanwhile, the bulbs obtained from the P2 treatment were categorized as large (12.1-15.3 cm). PBZ at 300 mg/L (P2) and 450 mg/L (P3) maintained and tended to increase bulb perimeter. The slight decrease in bulb size at P3 was possibly due to the increase in daughter bulbs. PBZ in shallot plants increased bulb formation: bulb number, size, and weight were superior (Elizani & Sulistyarningsih 2019). Paclobutrazol increased shallot bulb yield by maintaining shoot biomass production and chlorophyll content, resulting in a more extended photosynthesis period and higher accumulation of assimilates. Bandara and Tanino (1995) stated that PBZ doubled the number of potato tubers compared to the control but had no effect on tuber weight. It was suggested that PBZ increase the number of tubers at the expense of the size of the mother tubers. PBZ applied through leaf spray might be absorbed by the petiole and stem and be translocated through the xylem to the growing tip, inflicting to-shoot growth inhibition (Desta & Amare 2021).

The highest chlorophyll content was in P2-treated plants, which in the period I was not significantly different from the control plants (Table 4). In period II, P3-treated plants resulted in the most abundant

chlorophyll than the other treatments. The chlorophyll content increased parallelly with the PBZ concentration, particularly in the dry season (period II). The leaves chlorophyll in period II was 2 to 4-fold higher than in period I and to its control. According to Budiono et al. (2016), chlorophyll content is influenced by environmental factors, such as light intensity, temperature, and air humidity. More precisely, Gao et al. (2021) stated that the higher the light intensity, the higher the chlorophyll level will be in plants. Xia et al. (2018) reported that PBZ increased the leaf chlorophyll content, which increased photosynthesis. The high chlorophyll content and slow degradation rate cause the photosynthesis activity goes well for a longer duration.

Leaves on P3 of the period I suffered necrosis. In the period I, PBZ was sprayed over the leaf's lower surface (abaxial). Two weeks later, P3 plants showed symptoms of chlorosis accompanied by brownish spots on the leaf surface that became necrosis. We suspected that it was due to the high concentration (450 mg/L) of PBZ. Therefore, in period II, PBZ was poured on the surface of the planting media to avoid necrotic symptoms. The PBZ application on the media surface did not generate leaf necrosis.

We obtained the highest starch and sugar contents in the bulb of P2 in periods I and II (Table 4). The increasing concentration of PBZ enhanced the starch and sugar content, with the maximum at 300 mg/L (P2), indicated by the decreased contents in P3. PBZ at 300 mg/L (P2) also maintained the bulb at least at the initial size. This result was supported by Zheng, Wu and Xia (2012), who stated that the PBZ application in *Lilium* Oriental hybrids 'Sorbonne' increased the bulbs' weight and starch content. Through secondary effects, PBZ caused leaves to postpone senescence in some plants. Xia et al. (2018) stated that plants use photosynthesis to produce carbohydrates and store them as starch, as shown by the change in the morphology and quantity of starch granules in leaf mesophyll cells. When we referred to the bulb size (Table 3), and the leaf chlorophyll content (Table 4), P2 and P3-treated plants with higher chlorophyll were also richer in starch and sugar in their bulb. Additionally, according to Wu et al. (2018), PBZ increased the activity of the sucrose transporter enzyme from the source to the sink. Therefore, PBZ has the potential to maintain lily bulb size.

TABLE 3. Effects of PBZ on the bulb perimeter after harvest

Treatment	The bulb perimeter in period I (cm)			The bulb perimeter in period II (cm)		
	Before	After	Difference	Before	After	Difference
Control	14.0	12.0	-1.9 ^a	15.1	10.1	-4.9 ^a
P0	13.0	11.1	-1.9 ^a	15.2	11.7	-3.5 ^b
P1	13.3	12.1	-1.2 ^b	14.7	13.3	-1.1 ^c
P2	13.8	15.3	+1.4 ^d	14.2	15.3	+1.1 ^d
P3	13.0	13.4	+0.3 ^c	13.8	14.3	+0.4 ^d

Notes: Numbers followed by different letters in the same column indicate significant differences based on Duncan's test ($\alpha = 5\%$). P0-P3= PBZ concentration of 0, 150, 300, 450 mg/L; Period I = rainy season and PBZ sprayed on the lower surface (abaxial) of leaves, period II = dry season and PBZ was poured on the growing media; control = plant derived from full vernalized bulbs

TABLE 4. Leaf chlorophyll content, starch, and sugar content in bulbs*

Treatment	Period I			Period II		
	Chlorophyll (mg/g)	Starch content (%)	Sugar content (%)	Chlorophyll (mg/g)	Starch content (%)	Sugar content (%)
Control	8.6 ^c	22.5 ^a	16.3 ^a	4.9 ^a	15.9 ^a	10.1 ^a
P0	1.9 ^a	22.6 ^a	16.1 ^a	9.7 ^b	20.7 ^a	13.0 ^b
P1	5.2 ^b	41.9 ^b	26.0 ^b	13.2 ^c	39.1 ^b	18.4 ^c
P2	7.5 ^{bc}	59.2 ^d	37.2 ^d	14.9 ^c	63.4 ^d	37.3 ^c
P3	5.6 ^b	46.2 ^c	29.1 ^c	16.5 ^d	46.9 ^c	25.6 ^d

Notes: *Analyzed at the 2nd day for leaf chlorophyll content and the 9th day of starch and sugar content in bulbs after the plant harvest. Numbers followed by different letters in the same column show a significant difference based on Duncan's test ($\alpha = 5\%$). P0-P3 = PBZ concentration of four levels (0, 150, 300, 450 mg/L); Period I = rainy season and PBZ sprayed on the lower surface (abaxial) of leaves, period II = dry season and PBZ was poured on the growing media; control = plant derived from full vernalized bulbs

CONCLUSIONS

Gibberellin (GA3) effectively accelerated the release of bulb dormancy of *Tisento* lily and therefore served as a partial substitution of vernalization, from usually 19-20 weeks to 12-13 weeks. Regarding efficiency, with the consistently shortest bulb germination time in both seasons and 100% shoot-growing buds, the 100 mg/L GA3 treatment in 16 h of soaking time (G3L2) was the optimal treatment. The dormancy breaking was faster

in the dry season rather than in the rainy season. PBZ increased lily bulb size by suppressing shoot growth but increasing rooting section and leaf chlorophyll content. PBZ at 300 mg/L (P2) induced the accumulation of carbohydrates in the form of sugar and starch in the bulb and maintained the bulb size after harvest. Thus, GA3 can be manipulated to shorten the bulb dormancy period, and PBZ maintains the bulb size of the lily in tropical climates.

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*Corresponding author; email: dratnadewi@apps.ipb.ac.id