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Transformation of *Zinnia elegans* Jacq. as an ornamental potted plant by daminozide application

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Abstract

Zinnia elegans Jacq. is one of the ornamental plants potential to be used as a potted ornamental plants. The problem to be resolved is the size of the plant can reach 1 m, so it is necessary to modify the plant height into 20 cm to 25 cm using retardant (plant growth regulator), called daminozide. The purpose of this study was to determine the best concentration and soaking time using daminozide to inhibit the growth of zinnia. The research was conducted at Mangkuyudan 57, Yogyakarta. This research was arranged in a factorial design with 3 blocks as replication. Different concentrations of daminozide were used as first factor with three levels (1 $g.L^{-1}$, 2 $g.L^{-1}$, and 3 $g.L^{-1}$) and soaking times were used as the second factor (12 h, 24 h, and 36 h). The data were analyzed using analysis of variance and continued with HSD-Tukey at the α = 5 %. The results showed that there were an interaction between daminozide concentration and soaking time in the height of *Z. elegans.* There were also positive correlation between plant height, number of flower, and flowering period. The best combination of daminozide concentration and soaking times were 2 $g.L^{-1}$ and 12 h. This treatment gave the best height that fit to the criteria of a potted plant which was 20.08 cm. However, it reduced flower's diameter, number of flowers, and canopy's size.

INTRODUCTION

Ornamental plants have their own beauty and attractiveness value. One of the ornamental plants that is easily found in Indonesia is a *Zinnia elegans* Jacq. Many people cultivate *Z. elegans* due to its easiness in cultivation. *Z. elegans* has unique characteristics, varied colorful blooms, such as purple, red, white, yellow, and others, and also a variety of types of flower shapes such as single, double and pompom (Sardoei et al., 2014; Pallavi et al., 2016, Burlec et al., 2019)

In Indonesia, *Z. elegans* is used as a hedge plant. Basicaly, *Z. elegans* can also be used as flowering potted plant with wide variety of colors, shape and size, and latest innovation for the floriculture industry (Pinto et al., 2005). However, to make *Z. elegans* turn into potted flowers, the problem to be solved is the plant height of the *Z. elegans*. *Z. elegans* is able to grow up to 1.5 feet to 2.5 feet (Anonymous, 2008). Too high ornamental plants will reduce the aesthetic value when used as potted flowers. Therefore, modifying the height of *Z. elegans* to turn them as potted plant is highly needed.

One way that can be done is in using a growth regulator (retardant), called daminozide (Megersa, et al., 2018). Daminozide is a synthetic organic compound in the form of fine grains. Daminozide application with the right concentration level and proper time of disbudding will increase the quality of plants (Sitawati and Ni'mah, 2018). Saputra (2019) claimed that the application method of soaking seeds for 24 hours combined with 1,500 ppm of daminozide spraying is more effective at inhibiting

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the height of cosmos plants as opposed to applying only spraying treatment. The soaking method was able to suppress plant height by 76.16 %. The purpose of this study was to determine the best concentration and soaking time using daminozide to inhibit the plant height of *Z. elegans* in order to be used as ornamental-potted plant.

MATERIALS AND METHODS

The research was conducted in April–October 2020 at Jalan Mangkuyudan 57 Yogyakarta, Crop Ecology and Crop Science Laboratory in Faculty of Agriculture, Universitas Gadjah Mada. The tools used included lux meters, thermohigrometers, leaf area meters, pH meters, digital calipers, digital screw micrometers, spectrophotometry, and RHS color chart. The materials were manure, soil, water, NPK fertilizer, 80 % acetone, 97 % Alar daminozide, and red-purple *Z. elegans* seeds.

The design applied was a (3x3)+1 factorial design (control without daminozide application) with three blocks as replications arranged in a completely randomized block design (RCBD). The first factor was different concentration of daminozide (Alar 1 $g.L^{-1}$, 2 $g.L^{-1}$, dan 3 $g.L^{-1}$) and the second factor was the duration of soaking time in daminozide (12 hours, 24 hours, and 36 hours). The number of seeds used for each treatment was 140 seeds.

The research began with soaking the seeds based on the predetermined concentration and soaking time treatment. Furthermore, the treated seeds were sown on a tray containing a mixture of soil and manure with a ratio of 1:1. The nursery process lasted for three weeks. At the age of 3 weeks after planting (WAP), the plants were moved into polybags 20 cm x 20 cm that contained a mixture of soil and manure with a ratio of 1:1. When a plant died or was contaminated with some disease, it would be replaced by a new plant. At the age of 5 WAP, 2 g of NPK fertilizer were added into each polybags. Further treatment was carried out by spraying daminozide based on with predetermined concentrations when the plants were 5 WAP–7 WAP. The preservation carried out included watering, weeding, controlling pests and diseases. At the age of 16 WAP, the seeds were harvested.

The variable observed were plant height (cm), flower's diameter (mm), number of flower, canopy's size (cm), the bud's emerging time (days), bud to flower period (days), flowering period (days), and total dry weight (gram). Plant height was measured once a week from 3 WAP–16 WAP starting from base of the plant to the apical. The diameter of the flower was measured when the buds appeared until it was fully bloomed. The number of flowers for 16 weeks was calculated from the number of flowers produced from 3 WAP–16 WAP. The canopy's size was measured from the end of the canopy to the widest canopy for each plant at 10 WAP. The bud emerging time was observed when the first buds appeared. Bud to flower period was observed when the bud appeared until the flower bloomed perfectly. Observation of the flowering period started from the first bloom until all the flowers on the plant dried. The measurement of total dry weight was done at 16 WAP.

The data obtained were analyzed using Analysis of Variance (ANOVA) followed by HSD-Tukey at the 0.05 probability level. Moreover, the correlation test was used to determine the relationship between variables. It is important to note that all the statistical analyses were conducted using RStudio 1.0.153.

RESULTS AND DISCUSSION

Potted ornamental plants have their own criteria to be called a quality ornamental plants. Some of the criteria that determine the quality of potted plants, especially potted table is plant height at the range of 20 cm to 25 cm with canopy's size of more than 20 cm, brightly colored flowers, unfaded, and having a normal-shaped leaves free from pests and pathogens disease (Herdiani, 2017).

In this research, daminozide or succinic acid-2,2-dimethylhydrazide was one of retardants (part of plant growth regulator) used because it is easy to find and relatively affordable (Kurnia, 2015). Daminozide is very easily translocated to all plant tissues, such as roots, stems and leaves. In Table 1, it can be seen that the treatment plants had significantly lower plant height compared to control plants. The two treatments also showed an interaction. It means the combination of treatments had an influence to the height of *Z. elegans*. Pinto et al. (2005) claimed that at the end of plant growth, the treatment plants were shorter than the control plants. The decrease in plant height was associated with shorter internodesbut did not decrease the number of plant internodes.

Table 1. Plant height of *Z. elegans* at 10 weeks after planting with daminozide application on several daminozide concentrations and soaking time

Treatments	Daminozide concentrations			Mean (cm)
	1 g.L^{-1}	2 g.L^{-1}	3 g.L^{-1}	
Control				63.42 a
Soaking time 12 hours	30.63 b	20.08 c	11.32 c	20.68
Soaking time 24 hours	17.42 c	14.33 c	13.00 c	14.92
Soaking time 36 hours	16.60 c	11.47 c	10.98 c	13.02
Mean (cm)	21.55	15.29	11.77	(+)
CV (%)	24.54			

Remarks: Means followed by the same letters are not significantly different according to HSD-Tukey (α = 5 %). (+) signifies an interaction.

Table 2. Flower's diameter with daminozide application on some concentrations and soaking time

Treatments	Daminozide concentrations			Mean (mm)
	1 g.L^{-1}	2 g.L^{-1}	3 g.L^{-1}	
Control				55.9 ap
Soaking time 12 hours	45.75	41.30	31.50	39.5 b
Soaking time 24 hours	42.00	44.10	33.50	39.9 b
Soaking time 36 hours	40.90	35.00	29.50	35.1 b
Mean (mm)	42.90 q	40.10 q	31.50 r	(-)
CV (%)	19.12			

Remarks: Means followed by the same letters are not significantly different according to HSD-Tukey (α = 5 %). (-) shows no interaction.

Good quality potted ornamental plants has plant height criteria of 20 cm to 25 cm. In this research, the concentration of 2 g.L^{-1} and soaking time for 12 hours had a plant height of 20.08 cm, so it could fit with the criteria. Pasian and Bennet (2001) argued that seed of marigolds soaked using retardant (paclobutrazol) for 24 hours would decrease the percentage of usable transplant. When seeds were imbibed for 6 hours, 16 hours or 24 hours, seedling heights were also reduced by 30 %, 38 %, and 41 % for marigold. The seeds should be soaked before sowing inhibits plant growth since the early emergence of plant cotyledons (Saputra, 2019). Retardants are known to have an effect on gibberellin levels, where gibberellin induces elongation, while retardants will reduce gibberellin levels and cause a decrease in stem growth (Shin et al., 2009). Application of retardant inhibited the formation of gibberellins, in which giberrellins are reponsible for cell elongation. Nevertheless, when cell elongation was inhibited, thereby, internode length was reduced (Jain, 2016).

Based on Table 2, daminozide significantly reduced flower's diameter in *Z. elegans* when compared to control plants. However, the treatment combination did not show any interaction. Further test results showed that the treatment with the concentration of daminozide 3 g.L^{-1} had the smallest flower diameter (31.5 mm) in comparison to the concentration of 2 g.L^{-1} and 1 g.L^{-1}. The higher the application of daminozide concentration, the lower the flower's diameter. Sharaf-Eldien et al. (2017) stated that retardant (paclobutrazol) at different rates will decrease flower diameter in *Z. elegans*. The concentration of paclobutrazol at 150 ppm will decrease by 8.34 % and 7.12 % in the first and second seasons respectively than control ones.

A linear decrease of plant height and flower diameter was observed with paclobutrazol and daminozide application (Carvalho-Zanao et al., 2017). The higher the concentration and application frequency, the lower the flower's diameter. This is caused by retardants that inhibit the hormone gibberellin which plays a role in cell division. When the gibberellin hormone is inhibited, growth and

Table 3. Number of flowers for 16 weeks with daminozide application on some concentrations and soaking

Treatments	Daminozide concentrations			Mean (flower)
	1 g.L^{-1}	2 g.L^{-1}	3 g.L^{-1}	
Control				9.33 ap
Soaking time 12 hours	2.83	2.00	1.67	2.78 b
Soaking time 24 hours	2.50	2.17	1.50	2.06 b
Soaking time 36 hours	3.00	1.50	2.17	2.22 b
Mean (flower)	2.78 q	1.89 q	1.78 q	(-)
CV (%)		27.98		

Remarks: Means followed by the same letters are not significantly different according to HSD-Tukey (α = 5 %). (-) shows no interaction. Data on the number of flowers for 16 weeks were transformed into √x.

Table 4. The canopy's size with daminozide application on some concentrations and soaking

Treatments	Daminozide concentrations			Mean (cm)
	1 g.L^{-1}	2 g.L^{-1}	3 g.L^{-1}	
Control				25.00 ap
Soaking time 12 hours	17.88	15.75	11.50	15.12 b
Soaking time 24 hours	14.13	16.88	12.43	15.29 b
Soaking time 36 hours	13.35	13.25	11.58	11.83 c
Mean (cm)	15.04 q	14.48 q	12.73 q	(-)
CV (%)		16.56		

Remarks: Means followed by the same letters are not significantly different according to HSD-Tukey (α = 5 %). (-) shows no interaction.

development in plants can't be optimal (Nugroho and Elonard, 2019).

From Table 3, it can be seen that the application of daminozide was able to significantly reduce the number of flowers for 16 weeks on *Z. elegans* when compared to control plants (9.33 flowers). The treatment combination did not show any interaction on the number of flowers. Widyawati (2019) claimed that plant growth regulators can be used to manipulate plants, one of which is in the flowering process.

Providing retardants results in inhibition of flower formation so it will reduce the number of flowers. The decline in the number of flowers is related to the ability of daminozide to decrease the number of buds. When higher concentration was given, the number of buds would get smaller and reduce the number of flower.

Daminozide did not only reduce the number of flowers but also the canopy's size on *Z. Elegans* when comparing to control plants (Table 4). The treatment combination did not show any interaction on the width of the *Z. elegans*'s canopy. The decrease of the canopy's size was caused by inhibition of gibberellin synthesis, which gave an effect reducing the number of leaves and leaf area of *Z. elegans*. The canopy's size can be obtained from the measurement of the outer leaf width between one side and the other. On the other words, the leaf area will affect the canopy's size.

Widyawati (2019) claimed that giving retardants caused the canopy's size to be narrower than the control plant. The canopy will develop by the growth on the stems, branches, leaves or flower stalks of the plant. Providing retardants is presumed to be able to inhibit the growth of elongation in various plant organs, so that the canopy's size becomes narrower. The effect of giving retardants causes plants to look more proportional to the height and width of the canopy. Retardants can cause plant growth to be more compact. The performance of *Z. elegans*

after daminozide applications shown in Figure 1.

Daminozide application is also known to give an effect of prolonging the appearance of flower buds significantly on *Z. elegans* compared to control plants (Table 5). However, the treatment combinations did not show any interaction. The longer time the buds appear is related to the retardant effect that inhibits gibberellin biosynthesis. Gibberellin is a hormone that can accelerate growth and flowering.

The gibberellin has been implicated in the control of flowering in several plant's species. Reduction of endogenous gibberellin delays flowering in long days and prevents flowering in short days for some plants (Blazquez et al., 1998). When the biosynthesis of gibberellin is inhibited, it'll reduce the accumulation of gibberellin in plants. This will affect the flowering of the plant, one of which is the bud's emerging time. Rajiv et al. (2018) stated that retardant application would delay days to flowering of Nerium. This delay could happen because retardants reduced the

Figure 1. Performance of *Z. elegans* with daminozide application on some concentrations and soaking time at 13 weeks after planting.

Table 5. The bud's emerging time (days) with daminozide application on some concentration and soaking time

Treatments	Daminozide concentrations			Mean (days)
	1 g.L^{-1}	2 g.L^{-1}	3 g.L^{-1}	
Control				25.50 bq
Soaking time 12 hours	33.17	33.50	33.00	33.22 a
Soaking time 24 hours	32.00	29.83	32.17	31.33 a
Soaking time 36 hours	31.83	33.17	29.83	31.61 a
Mean (days)	32.33 p	32.17 p	31.67 p	(-)
CV (%)		9.08		

Remarks: Means followed by the same letters are not significantly different according to HSD-Tukey (α = 5%). (-) shows no interaction.

Table 6. Bud to flower (days) with daminozide application on some concentrations and soaking time

Treatments	Daminozide concentrations			Mean (days)
	1 g.L^{-1}	2 g.L^{-1}	3 g.L^{-1}	
Control				16.83bq
Soaking time 12 hours	21.83	21.17	20.17	21.06 a
Soaking time 24 hours	20.25	20.67	20.00	20.31 a
Soaking time 36 hours	21.33	22.83	20.67	21.61 a
Mean (days)	21.14 p	21.56 p	20.28 p	(-)

Remarks: Means followed by the same letters are not significantly different according to HSD-Tukey (α = 5%). (-) shows no interaction.

indigenous level of gibberellin to a permissible concentration required for flowering. Retardant application will prolong vegetative phase. Moreover, giving daminozide also significantly prolongs the period of buds to be flower compared to control plants (Table 6). The period from buds to flower getting longer is presumed due to the insufficient concentration of daminozide used in stimulating the flowering. Basically, every plant has a different sensitivity to retardants.

Menhennet (1979) highlighted that the use of retardant application not in the right time and the concentration can delay flowering. It would inhibite the formation of several substances needed by

Table 7. Flowering period (days) with daminozide application on some concentrations and soaking time

Treatments	Daminozide concentrations			Mean (days)
	1 g.L^{-1}	2 g.L^{-1}	3 g.L^{-1}	
Control				57.33 ap
Soaking time 12 hours	41.50	37.33	30.67	36.50 b
Soaking time 24 hours	30.17	32.67	27.00	29.94 c
Soaking time 36 hours	37.33	40.83	29.33	35.83 bc
Mean (days)	36.33 q	36.94 q	29.00 r	(-)
CV (%)		19.2		

Remarks: Means followed by the same letters are not significantly different according to HSD-Tukey (α = 5%). (-) shows no interaction.

Table 8. Total dry weight of plants at the age of 16 weeks after planting with the application of daminozide on some concentrations and soaking time

Treatments	Daminozide concentrations			Mean (g)
	1 g.L^{-1}	2 g.L^{-1}	3 g.L^{-1}	
Control				25.65 ap
Soaking time 12 hours	6.60	3.78	2.73	4.37 b
Soaking time 24 hours	3.52	3.46	2.14	3.04 b
Soaking time 36 hours	3.69	2.84	2.53	3.02 b
Mean (g)	4.60 b	3.36 bc	2.47 c	(-)
CV (%)		18.85		

Remarks: Means followed by the same letters are not significantly different according to HSD-Tukey (α = 5%). (-) shows no interaction.

Table 9. Correlation analysis between variables

Variables	PH	FD	NF	CS	BET	BFP	FP	TDW
PH (Plant height)	1.00							
FD (Flower's diameter	0.79	1.00						
NF (Number of flowers)	0.92	0.74	1.00					
CS (Canopy's size)	0.89	0.83	0.81	1.00				
BET (The bud's emerging time)	-0.65	-0.39	-0.77	-0.55	1.00			
BFP (Bud to flower period)	-0.64	-0.41	-0.68	-0.51	0.60	1.00		
FP (Flowering period)	0.88	0.75	0.83	0.80	-0.49	-0.36	1.00	
TDW (Total dry weight)	0.95	0.86	0.88	0.94	-0.56	-0.65	0.83	1.00

Remarks: 0 to 0.30= negligible correlation; 0.30 to 0.50= weak correlation; 0.50 to 0.70= moderate correlation; 0.70 to 0.90= strong correlation; 0.90 to 1.00= very strong correlation (Mukaka, 2012).

plants for the formation of flower primordia. It is also supported by the statement of Salacha and Zawadzińska (2017) that Eucomis autumnalis will begin flowering 3 days longer than control when being applied drenched with flurpimidol or sprayed with daminozide. Retardant slightly delays flowering.

Table 7 showed that daminozide application reduced the flowering period. It is supported by the statement of Carvalho-Zanao et al. (2018) that the use of retardants in general could reduce the flowering period of plants, but it depends on the dosage, species, and retardants used. Retardants are usually used to prolong the flowering period in plants but this does not happen too often (Pobudkiewicz, 2008). Nazarudin (2012) claimed that PGRs (plant growth regulators) inhibit the formation of gibberellin on plants. Gibberrellin is responsible for the stimulation of cell division and elongation. When gibberellin biosynthesis is inhibited, it affects the plant's growth.

Application of daminozide significantly reduced the total dry weight of *Z. elegans* plants as opposed to control plants (Table 8). Control plants had the highest mean total dry weight of 25.65 g. The combination did not show an interaction. The further-test here was no significant between treatments plants.

Reduction in plant dry weight indicates decreased assimilates in the plant. Rezazadeh et al. (2016) claimed that spray applications at ≥ 30 ppm uniconazole, 60 ppm or 100 ppm paclobutrazol, or 80 ppm flurprimidol can reduce total plant dry weight of potted red firespike. This reduction in dry weight is due to inactive gibberellin activity. When the activity of gibberellin is inhibited by daminozide application, the plant cells will continue to divide, but not lengthen the cells so it will affect the dry weight of the plant.

Table 9 indicates that plant height, number of flower, and flowering period had high positive correlation. It means that when plant is getting higher, it is followed by increase number of flowers and also longer flowering period. Khan et al. (2012) stated that plant height correlated with number of flowers. The larger the plant, the greater the number of flowers would be. The higher the plant's size, the bigger the size of the canopy, and it will further increase total dry weight of plant. But, when plant is getting higher, the bud emerging time and bud to flowering period is getting shorter. It's shown by correlation analysis between the bud emerges time, bud to flowering period and plant height in negative correlation.

CONCLUSIONS

The combination of application daminozide concentration 2 $g.L^{-1}$ and soaking time for 12 h gave the best height that fit the criteria of a potted plant which was 20.08 cm. However, it would reduce flower's diameter, number of flowers, and size of canopy.

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