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Scientific Article

Effect of growth regulator paclobutrazol on size fitting of basil as a potted plant

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Abstract

Basil (*Ocimum basilicum* L., Lamiaceae) is an herbal species cultivated primarily for culinary and aromatherapy. Basil plant height could reach more than 60 cm, and the plants tend to elongate, particularly in low-light environments. Our current study examined the potential uses of plant growth retardant paclobutrazol to control sweet basil height and improve potted basil's ornamental quality. The treatment tested was paclobutrazol concentration at 0, 5, 10, and 20 ppm, applied as 100 mL media drenching per pot five weeks after planting. The control plants were water-drenched using the same volume at the same time. Basil treated with PBZ at 10 ppm or 20 ppm had significantly shorter, smaller shoot canopy diameter, node and leaf number than the control, but had a similar number of branches to the control. Basil treated with PBZ at 10 ppm or 20 ppm showed a more compact and bushy pot plants with the height to pot ratio of 1.5. Higher leaf chlorophyll, indicated by a higher index value, was recorded only with the PBZ concentration of 20 ppm compared to the control and the other PBZ concentrations. Basil growth responses to PBZ at 10 ppm were not significantly different from those treated with PBZ at 20 ppm, therefore the use of PBZ at a lower concentration (10 ppm) is preferable. Further studies should examine whether repeated PBZ applications at lower concentration is more effective in producing shorter and more compact pot plants.

Keywords*:* Lamiaceae, plant growth retardant, *Ocimum basilicum* L., ornamental potted herb.

Resumo

Efeito do regulador de crescimento paclobutrazol no ajuste do tamanho do manjericão como planta de vaso

O manjericão (*Ocimum basilicum* L., Lamiaceae) é uma espécie herbácea cultivada principalmente para culinária e aromaterapia. A altura das plantas de manjericão pode chegar a mais de 60 cm e as plantas tendem a se alongar, principalmente em ambientes com baixa intensidade luminosa. Este estudo analisou os usos potenciais do paclobutrazol para controlar a altura do manjericão e melhorar sua qualidade ornamental em vasos. Os tratamentos testados foram as soluções de paclobutrazol a 0, 5, 10 e 20 ppm, aplicados via irrigação, 5 semanas após o plantio, na medida de 100 mL por vaso. As plantas controle foram molhadas com água em mesmo volume e período de aplicação. O manjericão tratado com PBZ a 10 ppm ou 20 ppm apresentou diâmetro de copa, número de nós e folhas significativamente menor do que o controle, mas teve um número de ramificações semelhante ao controle. O manjericão tratado com PBZ a 10 ppm ou 20 ppm apresentou plantas de vaso mais compactas e arbustivas com a relação altura para vaso de 1,5. A clorofila foliar mais elevada, indicada pelo índice maior, foi registrada apenas com a concentração de PBZ de 20 ppm em comparação com o controle e as outras concentrações de PBZ. Como as respostas de crescimento do manjericão ao PBZ a 10 ppm não foram significativamente diferentes daquelas tratadas com PBZ a 20 ppm, é indicado o uso de PBZ em uma concentração mais baixa (10 ppm). Estudos adicionais devem examinar se aplicações repetidas de PBZ em concentração mais baixa são mais eficazes na produção de plantas de vaso mais curtas e compactas

Palavras-chave: erva ornamental de vaso, Lamiaceae, *Ocimum basilicum* L., retardante de crescimento vegetal.

Introduction

Basil (*Ocimum basilicum* L.) is an herbal species belonging to the Lamiaceae family. Basil is one of the most important herbs, mainly used fresh and dried for culinary, and for essential oil extraction; in addition, basil leaves are a rich source of bioactive antioxidant compounds (Nazir et al., 2020; Dhama et al., 2021). The specific aroma of basil brings fragrance into homes; the main compounds responsible for basil aroma are eucalyptol 1,8-cineole,

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linalool, methyl chavicol, *α-trans*-bergamotene, methyl eugenol, and *epi-α*-cadinol (Rezaei-Chonayeh et al., 2021).

Basil has vast morphological diversity in the size and color of the leaf, flower, and growth characteristics (Ciriello et al., 2021; Morales and Simon, 1996). The basil leaf color varies from green to dark purple with strong aroma, whereas the flower color can be white, red, lavender, or purple (Morales and Simon, 1996), so basil is popular as a potted ornamental herb. By presenting a growing interest in gardening during the pandemic, the indoor potted plants business has increased. Potted basils could be an attractive option for fragrant herbs as well as the aesthetic purpose for indoor environments.

There have been limited reports on the optimal growing culture of basil, particularly as potted plants. The ideal ornamental potted plants would have a good proportion of shoot to pot height ratio, and be healthy, besides have a long post-production life. Good-proportion potted plants are important to avoid plants tipping over, which occurred when the plants are too tall. The height of basil grown in pots could reach more than 60 cm, which is too tall for indoor decoration. Potted plants that are bushy and have short and compact postures would be more desirable. Paclobutrazol (PBZ) is a compound from the triazoles group that inhibits elongation of many plant species (Rademacher, 2016; Desta and Amore, 2021). When applied via the correct method at the optimal dose Paclobutrazol can increase leaf chlorophyll levels (Xia et al., 2018), and can extend the longevity of potted plants and potted flowers indoors. The responses of plant species to PGR application, however, vary with cultivars and season (Rademacher, 2016). For example, for herbaceous ornamental pepper and it was 25 ppm (Franca et al., 2017). Considering the herbaceous nature of basil, the concentrations of PBZ tested in this study is in the range of those tested in ornamental pepper.

Our study was conducted to determine how basil grown in pots responds to different dosages of paclobutrazol applied via soil drench, and whether paclobutrazol can effectively control basil plant height to make it more suitable as potted ornamental herbs. The experiments included the measurement of leaf chlorophyll level and morphological changes in the basil stem treated with the highest concentration of PBZ treatment.

Materials and Methods

Study Location

The study was conducted between October 2019 to June 2020 in greenhouse at the IPB University experimental station at Sukamantri, Bogor located 550 m above the sea level with a temperature range of 22.8 to 31.6 °C and relative humidity of 86.3%-89.2%.

Plant Material and Treatment

Sweet basil seeds were sown on the seedling tray; seedlings were transplanted into a pasteurized potting mix of cocopeat, compost and burnt rice hulls (v/v, 1:2:1) in 1 L pots having 15 cm diameter at 21 days after sowing. The treatment consisted of different concentrations of paclobutrazol (Patrol 250 SC (a.i. 250 mg L^{-1})) at 0, 5, 10 and 20 ppm applied as a single 100 mL media drenching per plant at 5 weeks after transplanting. Control plants were water drenched at the same volume (100 mL) at the same time. Each treatment had 8 blocks with 3 plants each. The plants were watered 3 times per week; pest and diseases were controlled manually by removing the infested leaves; NPK fertilizer (16-16-16) at 1 g per 1 L pot was applied every 4 weeks. Growth measurement was conducted weekly on plant height, shoot diameter, number of nodes, number of branches, and number of leaves per plant. Shoot height to pot height ratio was measured by dividing the average plant height by the pot height; the shoot diameter to pot diameter ratio was measured by dividing the average shoot diameter divided by the pot diameter.

Basil Stem Morphology

Samples of stem sections for histology analysis were taken from 8-week-old plants of the control and plants treated with the highest concentration of paclobutrazol (20 ppm) to get the clearer effects of the growth retardant on the stem tissues. Fresh stem sections were collected by cutting cross sections of the stem, which were immediately placed on glass slides, and added to a few drops of deionized water prior to covering with the cover slips. The histological sections were analyzed under an Olympus BX 52 microscope and photographs were taken with a digital camera (Olympus DP25) under 40x magnification.

Leaf Chlorophyll Determination

Leaf chlorophyll index was estimated using *At Leaf* handheld chlorophyll meter (FT Green LLC, Detroit, USA). Three mature and fully expanding leaves from the main branch of the control and plants treated with paclobutrazol were selected and measured.

Data Analysis

The experiment was set up as a completely randomized block design and treatments PBZ concentrations, with 8 blocks, each block consisting of 3 plants. Analysis of covariance (Anova) with SAS version 9.0 was used to analyze the plant growth data. The separation between means was conducted using Fisher Comparison Test. Regression analysis was conducted to establish the concentration response curves of paclobutrazol; control data was included in regression analysis. Leaf chlorophyll level and percentage of flowering plants are presented as average ± standard error.

Results and Discussion

Basil Vegetative Growth

Application of PBZ significantly reduced plant height but did not affect branch number (Table 1). Plant height showed a negative linear response to increasing concentration of paclobutrazol (Figure 1A). There was no significant difference between PBZ at 10 and 20 ppm in affecting plant height (Table 1).

Table 1. Basil plant height, branch number, shoot canopy diameter, node number, leaf number, plant/pot height ratio, shoot canopy/pot diameter with and without paclobutrazol treatment at 8 weeks after transplanting

Paclobutrazol (ppm)	Plant height (cm)	Branch number	Shoot canopy diameter (mm)	Node number	Leaf number	Plant/pot height ratio	Shoot canopy/ pot diameter ratio
0	36.90 a	20.10	275.91a	12.45a	160.55a	3.69	1.84
5	30.62 b	17.70	259.08ab	11.16ab	123.58b	3.06	1.73
10	24.90 c	16.00	229.13b	11.12b	110.75b	2.49	1.54
20	24.70 c	17.70	230.88b	10.50b	124.13b	2.47	1.53
	<0.001**	ns	0.03*	0.02*	0.04*	ns	ns

Note: Means with the same letter are not significantly different at P <0.05 using Fisher test; ns = not significant

PBZ at all concentrations reduced the number of leaf (p = 0.04, Table 1), and at 10 or 20 ppm reduced shoot canopy diameter (P = 0.03; Table 1) and number of nodes compared to the control (p = 0.02, Table 1). Shoot canopy diameter, number of nodes and number of leaf showed a negative linear response to increasing concentration of paclobutrazol (Figure 1 B, 1 C, and 1 D). There were no significant differences between 5, 10 and 20 ppm PBZ in affecting these variables (Table 1).

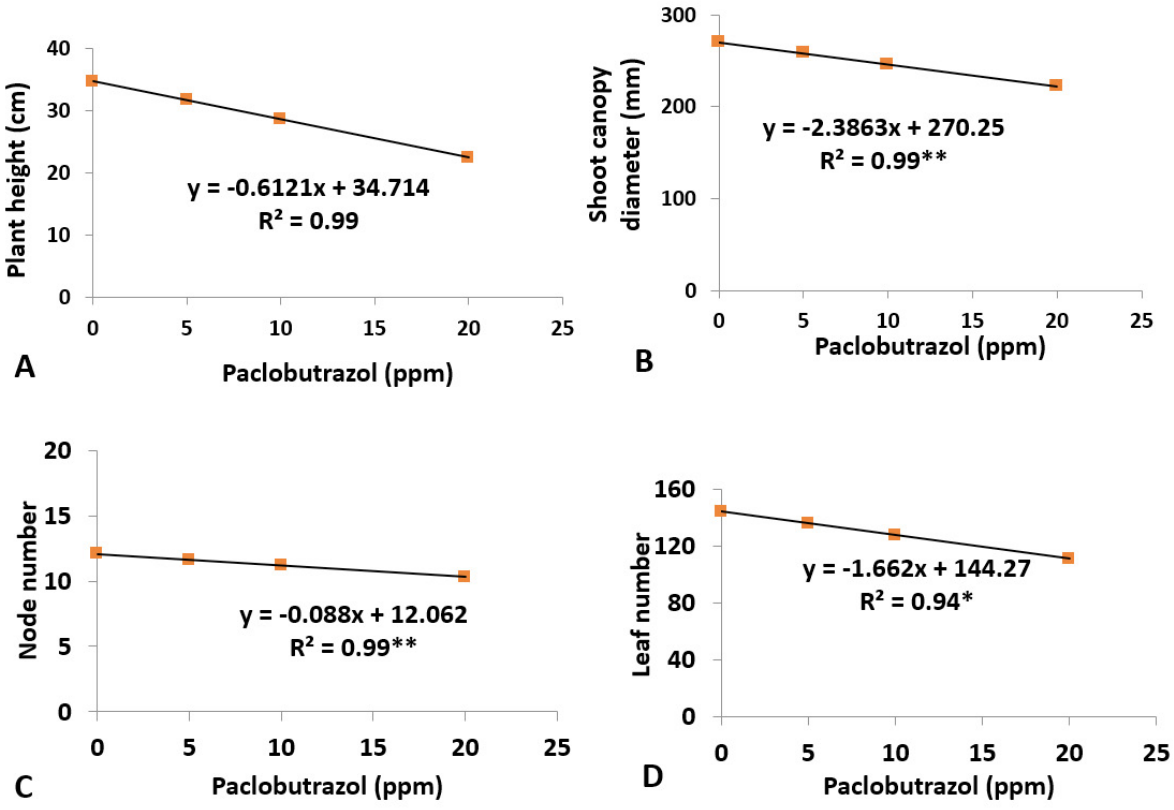

Figure 1. Regression models of paclobutrazol effects on plant height (A), shoot canopy diameter (B), node number (C) and leaf number (D) of basil at 8 weeks after transplanting. *significant difference at (P < 0.05); **significant difference at (P < 0.01).

Paclobutrazol has been used to control the height of various ornamental species, both annuals and perennials, but the effective dosages can vary with plant species, stages of plant development, and method of application (Rademacher, 2016), for example, 25 ppm of PBZ was required to control plant height of capsicum (Ribeiro et al., 2019). The reduced plant height is a consequence of the inhibition of gibberellin synthesis, a class of phytohormones that promote cell elongation, resulting in longer internodes (Rademacher, 2016; Nagar et al., 2021). Plants treated with paclobutrazol that was applied at the optimal dose and the correct method of application had elevated leaf chlorophyll levels (Franca et al., 2017); this trait can potentially extend the longevity of potted plants and potted flowers indoors.

Paclobutrazol in this study was applied to the medium as drenching, as paclobutrazol translocation in plants is mostly acropetal, i.e. via the xylem, and medium drenched-paclobutrazol provide uniform plant responses (Franca et al., 2017).

Stem Morphology

Our study demonstrated an increase in the basil stem diameter and enlarged stele with 20 ppm PBZ treatment compared to the control plants (Figure 2).

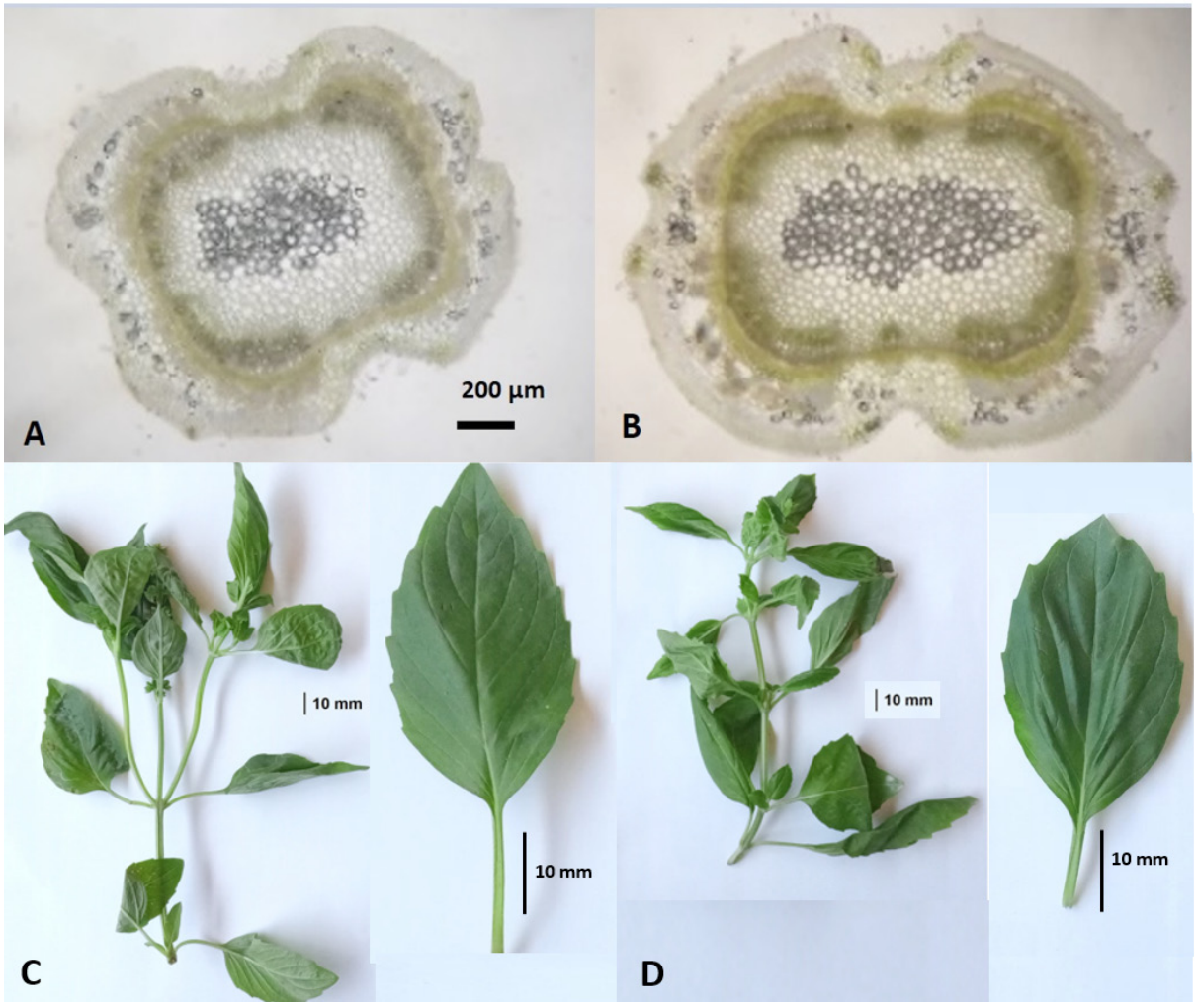

Figure 2. Morphology of 8-week-old basil stem: control (A) and with paclobutrazol treatment at 20 ppm (B). Stem was wider, and chlorophylls were more densely packed with paclobutrazol treatment (B) than control (A). Morphology of branch and leaf without paclobutrazol (C) and with paclobutrazol treatment at 20 ppm (D). Internodes are shorter and leaves are darker green with paclobutrazol treatment (D) compared to control (C). Horizontal bar = 200 µm; vertical bar = 10 mm.

These results concur with Tsegaw et al. (2005), which observed that paclobutrazol increased stem diameter in potatoes, larger vascular bundles, thicker cortex and larger pith cells, as well as with Burrows et al. (1992), which reported a greater proportion of xylem ring in PBZ-treated *Chrysanthemum*. Enlarged stele from PBZ treatment could result in stronger stems, which is an important characteristic of indoor plants. Figure 2 also shows more densely packed chlorophylls in the PBZ-treated stem, which indicate a higher photosynthetic potential compared to the control plants.

Based on the ratio of the shoot-to-pot height, and shoot canopy-to-pot diameter, PBZ application at all concentrations produced basil pot plants with a visually better plant-to-pot height proportion than the control, even though these values were not significantly different (Table 1). The ratio of plant height to pot height had decreased from 3.69 to 2.47, whereas the ratio of canopy diameter to pot diameter from 1.84 to 1.53. The highest paclobutrazol application (20 ppm) had the lowest ratio plant to pot height and canopy-to-pot diameter; Barroso et al. (2012) proposed a ratio of plant height to pot height of 1.5 to be balanced and attractive. The pot diameter that we used in this study is 150 mm whereas the plant height is about 300 mm with 5 ppm of PBZ, 248 mm with 10 ppm or 20 ppm of PBZ treatment. Therefore, the ratio of plant height to pot height of 1.5, which is considered to be balanced and well-proportion (Barroso et al., 2012), has been obtained with the PBZ at 10 or 20 ppm (Table 1). The plant appearance, indicated by the maintained size and shape in proportion to the pot sizes is one of the important preferences for ornamental pot buyers (Behe et al., 2013). The ratio of the canopy to pot diameter indicates the density of the plants, and is an important characteristic of potted plants. Customers prefer bushy pot plants which is indicated by smaller proportions of the canopy to pot diameter.

The leaves of PBZ-treated plants (20 ppm) are visually smaller and had darker green compared to the control (Figure 2 C and D). The darker green color in the PBZ-treated plants was confirmed with higher *At Leaf* values of the 20 ppm PBZ-treated (47.04 ± 2.08) over the control (40.65 ± 4.26). The *At Leaf* values of the basil treated with 5 and 10 ppm PBZ were not significantly different from the control (Table 2).

Table 2. Chlorophyll index value (*At Leaf*) and percentage of flowering plants with and without paclobutrazol application

Paclobutrazol concentration (ppm)	Chlorophyll index value (*At Leaf*)	Percentage of flowering plants at		
	42	28	35	42
		(days after transplanting)		
0	40.65 ± 4.26 a	18.0 ± 0 a	25 ± 5 a	25± 5 a
5	39.87 ± 6.77 a	40 ± 3.5 b	65 ± 3.8 b	65 ± 3.8 b
10	40.65 ± 3.73 a	65 ± 5.0 c	70 ± 0 b	70 ± 2.0 b
20	47.04 ± 2.08 b	70 ± 3.5 c	75± 0 b	75 ± 0 b

Note: Means with the same letter are not significantly different at P <0.05 using Fisher test. Values are means ± standard error.

In this study, *At Leaf* was used to estimate the basil leaf chlorophyll content. *At Leaf* has been used as a tool for a non-destructive estimate of the leaf chlorophyll content, and the measurement values correlate with those measured using a spectrophotometer (Novichonok et al., 2016). Elevated levels of leaf chlorophyll after PBZ application have been reported in rose (Carvalho-Zanão et al., 2018) and peonies (Xia et al., 2018). In addition, an increased photosynthetic rate was recorded in the PBZ-treated peony (Xia et al., 2018). Paclobutrazol can also prevent the degradation of chlorophyll in leaves (Franca, 2017); this characteristic is important for ornamental plants because plants with darker leaf colors make the plants look more attractive, and higher chlorophyll content in the leaves can potentially make the plants last longer indoor.

Basil Generative Growth

Paclobutrazol treatment resulted in the basil plants being treated with PBZ to flower earlier; > 40% of the paclobutrazol treated had flowered 28 days as opposed to 18% in control (Table 2). There were no significant differences in the percentage of flowering plants between PBZ concentrations at 35 and 42 days after transplanting (Table 2).

For culinary uses, the leaves from mature plants that had entered a generative stage would have their leaf taste changed, therefore flowering basil is likely not preferable for consumption purposes. However, for indoor decoration uses, plants with flowers could be an additional value. Basil flowers are terminal in the form of inflorescence with a striking white colour, which is a contrast to the green colour of the leaves so flowering basils could be an additional value as potted ornamental herbal. Promoted flowering with the paclobutrazol application has been reported in *Celosia cristata* (Tawila, 2018), and this effect is related to the increase in carbohydrates in the shoots (Desta and Amare, 2021). In addition to promoting flowering, PBZ application can make plants more resilient and able to cope better under adverse environmental condition including low light, drought, and heat stress (Soumya et al., 2017). For potted basil, adaptability to low light can potentially make the postproduction shelf life longer indoor and in retail outlets.

Conclusions

PBasil treated with PBZ at 10 ppm or 20 ppm had significantly shorter, smaller shoot canopy diameter, node and leaf number than the control, but had a similar number of branches to the control, resulting in a generally smaller and bushier plants. As the plant responses to PBZ at 10 ppm were not significantly different from those treated with PBZ at 20 ppm, the use of PBZ at 10 ppm is preferable. Shorter plants with good proportion to pot size are preferred by customers, and are easier to pack and transport. Future studies could be directed to include the postproduction aspects of the potted basil to examine if the paclobutrazol treatment can make the plants last longer at the indoor environment.

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Author Contribution

AK research orientation, suggestions, monitoring the experiment, preparation of the manuscript. **KK:** creation of idea, research orientation, sample preparation and laboratory measurement, monitoring the entire experiment, statistical analysis, preparation of the manuscript. **NF:** installation of the greenhouse experiment, conduction, documentation. **KS:** monitoring the experiment, suggestions on manuscript preparation.

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