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RESEARCH ARTICLES

The effects of substrates on growth and green coverage of Blue daze (*Evolvulus glomeratus*) under rooftop condition

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Abstract

Establishment of the green space in urban environment has been regarded as one of the major strategies for the development of green cities. In this study, we provided experimental evidence for the uses of biochar-based substrates for the growth and development of blue daze (*Evolvulus glomeratus*) plants under the rooftop condition. We firstly analyzed the physical features of four common substrates, including 100% soil, soil + rice hull + coconut fiber (2:1:1), soil + coconut fiber + rice hull + coal slag (1:1:1:1) and soil + coconut fiber + rice hull + coal slag (1:2:2:1) to gain an advantages under the rooftop condition. Subsequently, the evaluation of the growth and development of the blue daze (*Evolvulus glomeratus*) in four formulas under the rooftop condition was investigated. Among them, the use of soil + coconut fiber + rice hull + coal slag (1:1:1:1) exhibited the highest values of growth dynamics and green coverage. Additionally, the effects of three thicknesses (5, 8, and 12 cm) of a selected formula were tested under the rooftop condition. The results revealed that the surface area of green coverage exhibited the highest value, by 1964.13 cm^2 at 90 days after planting in a depth layer of 8 cm. Taken together, our study could provide a solid foundation for further cultivation of blue daze plants under the rooftop condition.

Keywords Agronomy · Blue daze · Rooftop condition · Substrate · Thickness

Introduction

The fast economic development has been regarded as the main reason for the expanding urbanization, which has a large impact on the environment of these areas (Dennis et al. 2019). As the growth and development of the city, the natural scenery has been increasingly transformed into the urban landscapes, which was commonly described by the high buildings, crowded roads and high human density (Qianqian et al. 2019). The urbanization process initially prevent the natural habitat in the city (Dennis et al. 2019). Thus, it would be very significant to expand the green space in urban environments, which might improve water and air quality, decrease noise pollution, and reduce the heat-island effect.

Up till now, many efforts have been made to increase green space in urban landscapes. Among them, converting conventional roofs to green roofs has been reported as the most sustainable approach for the development of the green city (Klein and Coffman 2015; Aguiar et al. 2019). The concept of the green rooftop assist in developing vegetation in the urban areas and high rise buildings as defined earlier (Getter and Rowe 2006; Rowe 2011). Growing vegetation on rooftops is a nature-based solution to restore urban green spaces (Rogalla et al. 2008), increasing the aesthetics and heat resistant construction and reducing the radiation to the surface of the concrete (Susca et al. 2011). Earlier, green roofs were reported to contribute to the absorption of CO_2 and other harmful emissions that affect human health (Vijayaraghavan et al. 2017). Several plant species were used for the establishment of green roof such as *Silene vulgaris* and *Lagurus ovatus* (Ondono et al. 2016), *Portulaca grandiflora* (Vijayaraghavan et al. 2017), pansy (*Viola × wittrockiana*), Madagascar periwinkle (*Catharanthus roseus*) and Pavia lily (*Longiflorum × Asiatic lilies*) (A'saf et al. 2020).

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The popular substrates for growing plants under the rooftop condition are the clay soil, rice hull, coconut fiber and coal slag (Pandey et al. 2012) which proved to be the best formula for growing blue daze plants. The aim of this study was to evaluate the growth and development of blue daze (*Evolvulus glomeratus*), one of the major valuable ornamental plant species (Hooks and Niu 2019). The experiments were conducted to observe the growth of blue daze in various types of substrates. Finally, the formula and thickness of substrate for the cultivation of blue daze under the rooftop condition were determined.

Materials and methods

Materials

The blue daze plants stored in the Faculty of Agronomy, Vietnam National University of Agriculture (20° 59′ 50″ N and 105° 55′ 46″ W) were used as the materials in this study. Six-cm-stem tip was cut from a healthy blue daze plant, and was dripped in liquid rooting hormone. All cuttings were kept in moist sand for 2 weeks.

Experimental design

Experiment 1: Evaluation of different substrate components

The experiment was carried out with four formulas (soil, rice hull, coconut fiber and coal slag at various ratios) as previously described (Pandey et al. 2012), in three replicates using a randomized completed block design (RCBD) (Hartung et al. 2019). Briefly, each of the experimental trays (610 mm × 420 mm × 200 mm) had six clusters (five blue daze plants were grouped in one cluster). A total of 90 healthy blue daze plants (5 plants/cluster × 6 clusters/tray × 1 tray/replicate × 3 replicates) prepared for this experiment. Four formulas were set as 100% soil (ST1), soil + rice hulls + coconut fiber (2:1:1; v:v:v) (ST2), soil + coconut fiber + rice hull + coal slag (1:1:1:1; v:v:v:v) (ST3) and soil + coconut fiber + rice hull + coal slag (1:2:2:1; v:v:v:v) (ST4). The thickness of the substrate in stray was 8 cm. Green roof modules were randomly located over the flat rooftop of the Department of Agronomy, Vietnam National University of Agriculture. During the study period (March–June 2018), average air temperatures and relative humidity were 22 ± 1 °C and 74 ± 7 % in March, 24 ± 2 °C and 75 ± 5 % in April and 24 ± 1 °C and 74 ± 5 % in May, and 27 ± 2 °C and 70 ± 5 % in June, respectively, with the total rainfall of 13 mm in (according to the local weather station of Hanoi, Vietnam). The humidity and temperature of the environment have been presented in Fig. 1. Six grams of combined nitrogen–phosphorus–potassium (16–16–16) fertilizer was used for a stray once a month, during the growing season. Using a soil moisture meter (TK100), freshwater was refilled up to 75% every 2 days during the experiment.

Experiment 2: Evaluation of thickness of the substrate

In this experiment, the substrate obtained in experiment 1 was subjected to evaluate the effects of substrate thickness on the growth and development of blue daze plants. The experiment was carried out with three formulas of three distinct substrate thicknesses of a selected substrate (TN1, 2 and 3), including 5, 8 and 12 cm, respectively. The experiment was performed with three replicates using an RCBD approach (Hartung et al. 2019), from August to November in 2018.

Measurements

The physical characteristics of substrates including air porosity (%), pH, and electrical conductivity (EC, mS/cm) were calculated by using various portable tools. The pH values

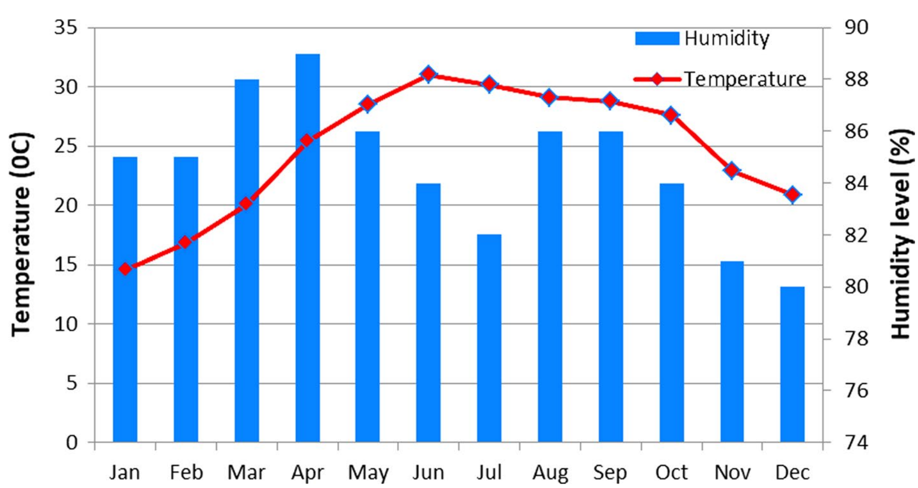

Fig. 1 The micro-climate data for temperature and humidity during the period from January 2018 to December 2018

in substrates were directly measured by the HI981030 GroLine Soil pH Tester (Hanna, Italia), while the soil EC was recorded by the pocket HI98331 Soil Test™ (Hanna, Italia). The air porosity was calculated as previously described (William 1990).

The agronomical traits of blue daze plants were observed at six indicating times, including 15, 30, 45, 60, 75 and 90 days after planting (DAT). Three typical growth indicators namely plant height (cm), canopy diameter (cm) and the average numbers of branches level 1 per plant were calculated as done earlier (Ketjarun et al. 2016). Particularly, the plant height was measured from the ground to the top of the leaves, while the canopy diameter was calculated as the average value of two directions perpendicular to each other. The average numbers of branches level 1 per plant (shoots/leaves) and length of 1st branches were calculated directly in the blue daze plants every seven days. Trays were photographed twice a month by a digital camera as previous procedures with some minor adjustments (Easlon and Bloom 2014) to calculate the surface area of green coverage: The image analysis was performed by using the ImageJ software (Schneider et al. 2012) as reported earlier (Rueden et al. 2017).

Statistical analysis

We used a one-way analysis of variance (ANOVA) to compare the average values among treatments. LSD (Least significant difference) test was used to find the means that were significantly different from each other (Assaad et al. 2014). Data were analyzed using the IRRISTAT 5.0 software.

Results and discussion

Analysis of basic physical properties of the substrates in rooftop condition

In order to evaluate the effects of the substrates on the growth and development of blue daze plants in rooftop conditions, we firstly assessed three typical features of four formulas, like air porosity, pH and soil EC values. We hypothesized that the formula contains more biochar materials, like rice hulls, coconut fibers and coal slag may cause a higher value of these characteristics. As expected, the air porosity ranged from 20.50 (ST1) to 52.12% (ST4), while the pH and EC scores varied from 6.36 (ST1) to 8.25 (ST4) and 120 (ST1) to 304 mS/cm (ST4), respectively (Table 1).

The incorporation of rice hulls can improve the physical features of soil, like reducing soil bulk density and increasing soil pH and EC values (Milla et al. 2013). Furthermore, the use of these biochar materials as a major substrate can improve crop productivity (Milla et al. 2013). Therefore, it is important to know that the formula of soil mixed with biochar materials may enhance the growth and development of blue daze plants or not?

Table 1 The basic physical properties of substrates

Formulation	Air porosity (%)	pH	EC (mS/cm)
ST1	20.50	6.36	120
ST2	31.43	6.90	185
ST3	37.14	7.20	271
ST4	52.12	8.25	304

Evaluation of growth and development of blue daze under the influence of different substrates in rooftop condition

In order to evaluate the growth of blue daze plants under four formulas of substrates, two major characteristics, including plant height and branches at the various indicating times were calculated. The data observed at 15, 30, 45, 60, 75 and 90 DAT was presented in Table 2. As a results, we found that the ST3 and ST2 formulas exhibited the highest growth dynamics (the plant height has reached 27.8 and 27.6 cm at 90 DAT, respectively), followed by ST4 (23.3 cm) and ST1 (21.3 cm) (Table 2). Similar to plant height, we found that two formulas, ST3 and ST2, again shared the highest number of branches, by 9.9 and 7.2 branches, respectively (Table 3). Our results could explain that the use of biochar materials, particularly rice hulls, coconut fibers and coal slag enhance the physical properties of substrates (Table 1), consequently promote the growth and development of blue daze plants. Our findings showed interesting information for further studies to explore the soil-environmental conditions for blue daze cultivation. The number of branches calculated in the ST1 and ST4 formulas was found as 6.6 and 4.9 branches, respectively (Table 3). Additionally, the length of 1st branches was recorded to be the highest value at 90 DAT, by 18.6 (ST3), 17.7 (ST2), 13.0 (ST4) and 12.3 cm (ST1).

We also observed the different changes of green coverage traits including canopy diameter and surface area of blue daze plants at four substrates (ST1, ST2, ST3 and ST4). The results of the canopy diameter monitoring in the experiment are shown in Table 2; Fig. 2. As expected, the ST3 formula has exhibited the fastest canopy growth, by 21.3 cm at 90 DAT, followed by the ST2 (16.7 cm), ST4 (13.0) and ST1 formulas (10.9 cm) (Table 2). Previously, nondestructive measurements of blue daze plant, the attributes like canopy diameter have been commonly used to estimate the mass, area, or volume of plants (Ansley et al. 2012). The canopy diameter is a critical characteristic of blue daze plants in order to provide green coverage on rooftops. Taken together, the incorporation of materials

Table 2 Influence of substrate composition to the plant height and canopy diameter of blue daze plants under the rooftop condition

Traits formulas	Plant height (cm)						Canopy diameter (cm)					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
ST1	9.7	13.0	16.9	20.5	21.2	21.3	4.4	6.6	7.6	10.2	10.7	10.9
ST2	11.5	17.3	21.8	26.4	27.4	27.6	4.8	9.1	12.2	15.9	16.4	16.7
ST3	12.7	22.7	24.8	27.3	27.7	27.8	5.0	11.0	13.9	20.1	20.9	21.3
ST4	10.2	14.7	17.9	22.2	23.4	23.3	4.3	6.7	8.4	12.2	12.8	13.0
$LSD_{5\%}$	0.9	1.4	3.0	4.1	4.7	4.7	0.8	1.1	1.4	2.815	4.9	5.4

Table 3 Influence of substrate composition to the characteristics related to the branch of blue daze plants under the rooftop condition

Traits formulas	Number of 1st branches (branches)						Length of branches (cm)					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
ST1	1.9	4.1	5.3	6.2	6.4	6.6	4.6	7.0	9.9	11.6	12.0	12.3
ST2	2.1	5.5	6.8	6.8	6.8	7.2	4.7	9.5	13.5	16.8	17.4	17.7
ST3	2.6	5.9	7.6	9.4	9.5	9.9	5.4	11.1	14.5	17.9	18.4	18.6
ST4	1.7	3.9	4.3	4.6	4.6	4.9	4.2	7.3	9.9	12.3	12.7	13.0
$LSD_{5\%}$	0.9	1.0	1.0	0.9	1.2	1.4	0.8	1.2	1.7	2.3	2.6	2.9

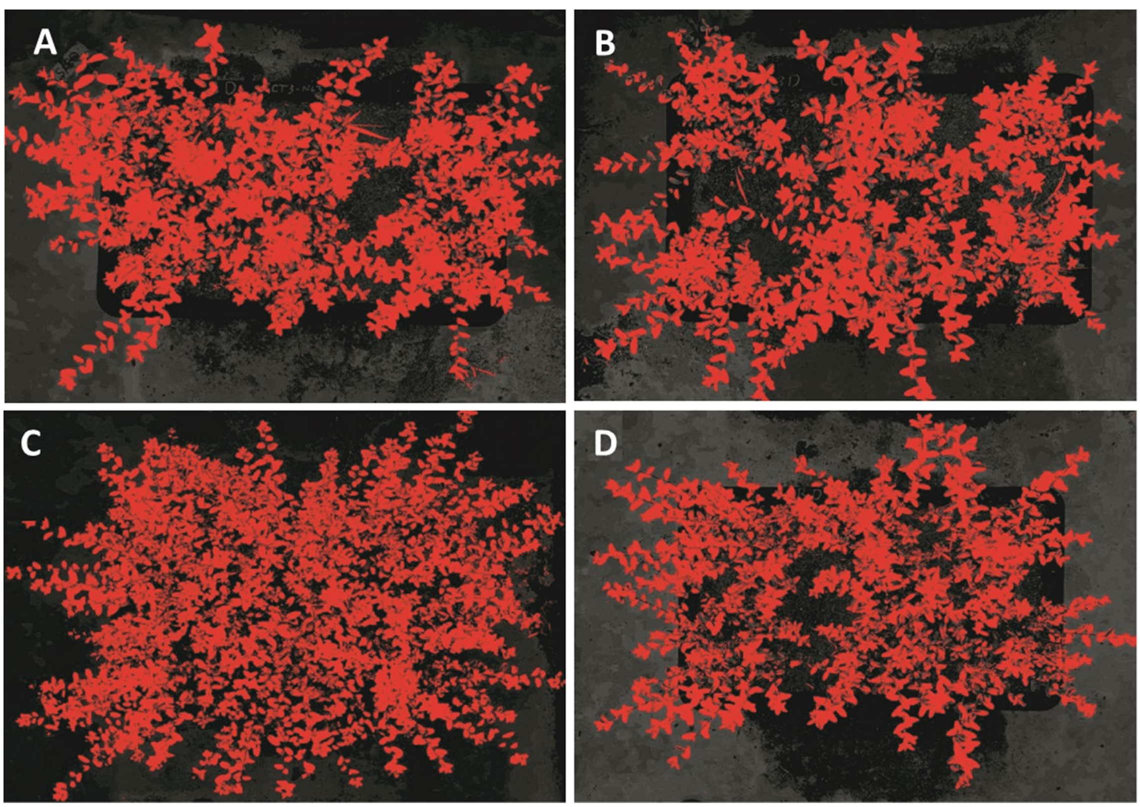

Fig. 2 The coverage areas of blue daze plants in four formulas under the rooftop condition. The blue daze plants were planted in **A** 100% soil, **B** soil + rice hulls + coconut fiber (2:1:1), **C** soil + coconut fiber + rice hull + coal slag (1:1:1:1), **D** soil + coconut fiber + rice hull + coal slag (1:2:2:1)

in ST3 was suitable for the development of canopy diameter in blue daze plants. In this study, the surface areas of blue daze plants under four substrates (ST1, ST2, ST3 and ST4) have been investigated as the green surface was reported to reduce the damage of the radiation and ultraviolet light in crowded urban areas (Aguiar et al. 2019). The blue daze plants at these indicating DAT were scanned and calculated by the ImageJ (Rueden et al. 2017). As the result, we found that the coverage areas of blue daze plants were expanded slowly from 15 to 45 DAT. At this stage, the ST3 has shown the highest value of the green area, by 1412.41 cm^2, whereas the ST4 was noted as the lowest value of the surface area, by 941.76 cm^2. From the 60 days onwards, the blue daze plants in all four formulas were observed to grow faster than in the previous stage. Particularly, the ST3 had the highest surface area of green coverage, by 2545.39 cm^2 at 90 DAT, followed by ST1 (2348.28 cm^2), ST2 (2093.09 cm^2) and ST4 (1852.60 cm^2) formulas (Table 4). We also demonstrated that the substrates of soil incorporated with biochar materials (ST3) were suitable for the growth and development of blue daze plants under the rooftop condition.

Evaluation of growth and development of blue daze under the influence of different thicknesses of the substrate in rooftop condition

It has been confirmed that the thickness of substrates tend to affect plant growth (Dusza et al. 2017; Liu et al. 2019). Briefly, the depth layer of substrates may increase substrate C and N content but is likely to lead to high water retention. In this study, three formulas of the thickness of the substrate layer, including 5 (TN1), 8 (TN2) and 12 cm (TN3) were proposed. The results of monitoring the influence of substrate thickness on the green coverage of plants on the rooftop are shown in Table 5 and Fig. 3.We found that the

Table 4 Calculation of the surface area of green coverage of blue daze plants in different formulas under the rooftop condition

Traits formulas	The surface area of green coverage (cm^2)					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
ST1	795.13	936.29	1179.96	2005.90	2333.50	2348.28
ST2	798.82	957.92	1221.78	1750.16	1972.21	2093.09
ST3	867.05	1079.81	1412.41	1846.42	2430.60	2545.39
ST4	731.11	817.92	941.76	1405.17	1711.49	1852.60
$LSD_{5\%}$	25.75	159.09	369.04	711.36	559.48	412.18

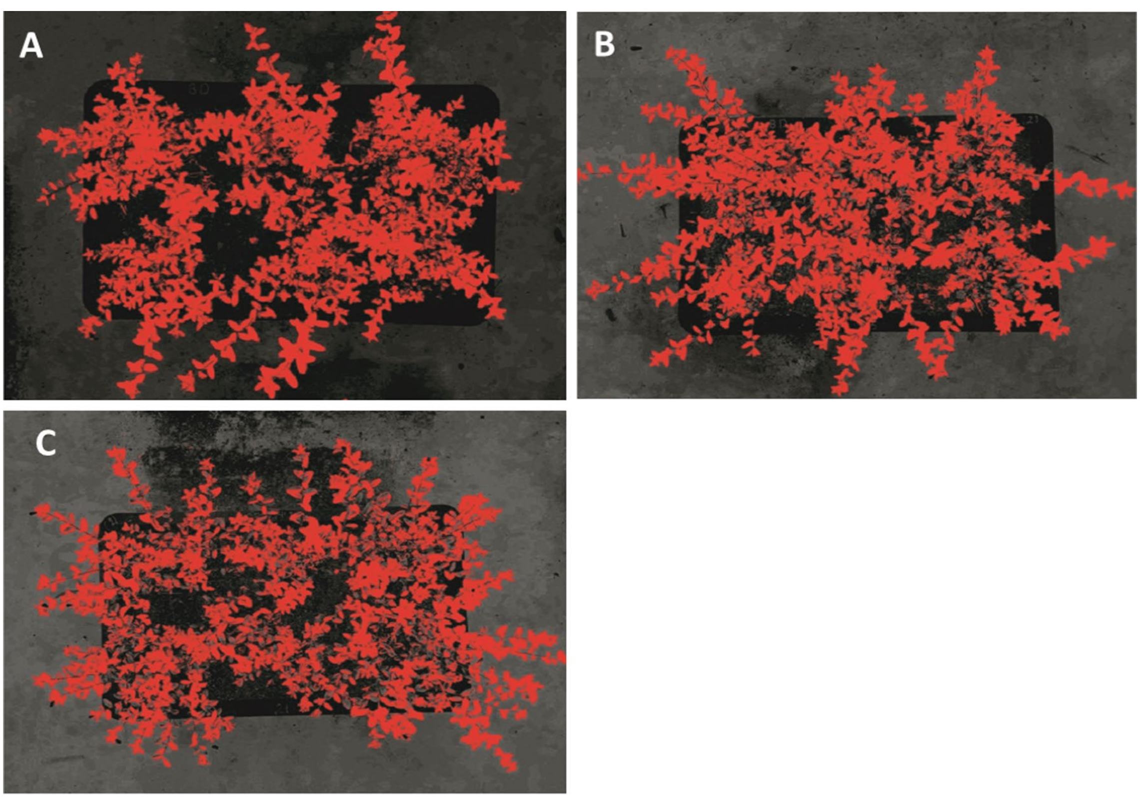

Fig. 3 The coverage areas of blue daze plants in threethicknesses of substrates under the rooftop condition: 5 cm (**A**), 8 cm (**B**), and12 cm (**C**)

Table 5 Influence of substrate thickness to the surface area of green coverage of blue daze plants

Traits formulas	The surface area of green coverage (cm^2)					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
TN1	802.75	904.05	1000.49	1388.09	1661.35	1757.83
TN2	760.40	867.34	1017.62	1430.41	1685.67	1964.13
TN3	827.03	888.69	1009.84	1373.27	1607.49	1899.67
$LSD_{5\%}$	112.87	125.98	148.52	256.09	161.01	167.40

TN2 formula had the highest surface area of green coverage, by 1964.13 cm^2 at 90 DAT, followed by TN3 (1899.67 cm^2) and TN1 (1757.83 cm^2). It could be explained that the TN1 formula was designed with the smallest volume of media, therefore less water and nutrients for the development of blue daze plants, whereas a depth layer of 12 cm reduced the air porosity, which might prevent the nutrient uptake of root sytems. Previously, a compost-soil-bricks (1:1:3; v:v:v) mixture, with a depth of 10 cm was highly recommended for the growth and development of *Silene vulgaris* and *Lagurus ovatus* plants under the rooftop condition (Ondono et al. 2016). Here, with four material components (soil, coconut fiber, rice hull and coal slag) in the substrate, a depth layer of 8 cm was highly recommended for the growth and development of blue daze plants under the rooftop condition.

In summary, the blue daze plants were initially grown in various types of substrates under the rooftop condition. We demonstrated that the substrates of soil + coconut fiber + rice hull + coal slag (1:1:1:1) were suitable for the growth and development of the blue daze plants under the rooftop condition. The thickness of 8 cm was demonstrated to boost the growth and development of blue daze plants as compared with other formulas. The informations in this research could provide a solid foundation for further cultivation of blue daze plants under the rooftop condition in big cities.

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