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Indoor Green Curtains

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Abstract

Green curtains were placed on an indoor window frame to observe the growth of plants from spring to late summer in 2019. For photosynthesis of plants, sunlight uniformly scattered through a non-woven cloth was used. In this study, easily available herbaceous plants of five families and seven species were examined for making indoor green curtains. As a result, among the plants tested, the vine plants were well grown. For example, the morning glory blossomed several flowers every day and produced many seeds (over 100 seeds). In addition, two cucumbers and two mini tomatoes were also obtained from the indoor green curtain. However, the leaf color based on chloroplasts was lighter than common colors grown outdoors. On the other hand, ornamental foliage plants grown as a comparative experiment grew lushly and well. In conclusion, morning glory as the fast-growing and odorless plant was well suitable for the indoor green curtain in the plants examined. Thus, the indoor green curtain can be expected to have ecological and economical effects to maintain indoor environment and also healing effect of residents.

Introduction

As a method for maintaining low room temperature in summer, there is placed a green curtain outdoor [1]. As a result, sunlight that enters the room can be shielded to some extent. In general, vine plants are often employed for the green curtains. Compared to cloth curtains, the green curtains can be cooled the surroundings efficiently and enable not only absorb the energy of sunlight on the surface of plants, but also circulate or evaporate water which has a large specific heat capacity. Therefore, the green curtains can be said to be a water membrane for efficiently cooling the surroundings.

However, in warm regions where the green curtains are needed, the wind forces of hurricanes, typhoons, and tornadoes are increasing year after year due to global warming [2]. If the green curtain collapses due to such a strong wind, not only will the house be damaged, but also the flying green curtain may cause damage to people and other buildings. In addition, to place the green curtain in the outdoor, the space for that is required. In houses where such space cannot be secured, especially in high-rise condominiums, the room exposed to the sunlight directly tends to be hot because there is nothing to block the sunlight around. Further, when the green curtain is placed outdoors, insects and the like settle in there, and mosquitoes and centipedes may enter the room when a window is opened. Such concerns can also be raised by covering vine plants with walls and planting moss and plants on the outer walls. On the other hand, recently there have been cases where moss is planted on indoor walls [3]. However, such way cannot effectively block and utilize sunlight that enters the room.

In this study, the possibility of the indoor green curtain to avoid the above-mentioned problems was examined. As the plants forming the indoor green curtains, herbaceous plants of five families and seven species were employed. In the ex-

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periment, a white non-woven cloth was applied to the inside of the window glass so that the incident sunlight was scattered throughout the room. Then, the difference in growth between the plants to be tested and the ornamental foliage plants was compared. Finally, the possibilities of the indoor green curtain as the ecological and economical methods to maintain indoor environment and also healing effect of residents were discussed.

Materials and methods

All plant species used in the study were purchased from Daiso-Sangyo Ltd. (Hiroshima, Japan). Plant cultivation used different planters before and after germination. As germination planters, two 2-liter PET bottles were used by vertically dividing them into two, and each container on each of them was provided with several through holes for drainage. Tissue paper was spread on each of these two planters, and then commercially available vegetable culture soil (DCM Holdings Co., Ltd. Tokyo, Japan) was spread. Seeding was performed with 3 to 4 kinds of seeds per planter. The planter was placed on the table in front of the window and water was sprayed to provide sufficient moisture to the culture soil every day. A non-woven cloth (46 x 240 cm, Daiso-Sangyo Ltd.) was attached to the glass surface inside the window.

For cultivation of the plants to form the green curtains, two size of polypropylene planter equipped water-supply tray (DCM Holdings Co., Ltd.) were used. The size of one planter was 500 x 290 x 315 mm with a 20-liter soil volume and a 5-litter water tray volume, and the size of another planter was 650 x 320 x 320 mm with a 30-liter soil volume and a 7.5-litter water tray volume. In each planter, soft pumice (ca 2 cmφ, Kanuma soil mined in Japan), water moss (sphagnum moss), and rice husk charcoal were spread in layers in this order, and then chemical fertilizer (0.5 cmφ, N:P:K = 1:1:1 in weight; Daiso-Sangyo Ltd.) was scattered in an appropriate amount, and a mixed soil of vegetable culture soil and chemical fertilizer was spread thereon. Plant shoots were planted in 20 L and 30 L planters, respectively, and placed on the window side for observation.

Results

Until a year before starting on this study, several kinds of ornamental foliage plants were grown on the window side of a room on a 19th floor of a 20th floor building on another campus. There were no tall buildings around the building. The room faced the north side, so it was not exposed to direct sunlight, but the brightness of the sky penetrated through the mirror glass with low reflectance. The cultivation of these plants started from June 2015 and continued until now (Supplementary Figure 1a). In March 2018, these plants moved to a current room of Hachioji campus and then have grown several times larger than when they started growing (Supplementary Figure 1b). Since the moving, these plants grew lushly in just one year due to that the current room is very well suited for plant growth (Supplementary Figure 1c). Then, the author considered the possibility to an indoor green curtain employing normal herbaceous plants including vines and vegetables.

By the information obtained from the website of Geospatial Information Authority of Japan, the location of the building where the current room is altitude 175 m, latitude 35.6253, and longitude 139.3423. The current room is on the 9th floor of the building on the northeast side of the arc-shaped 12-story twin tower, and the room faces the southwest building. This tower was designed referring to the City Hall of Toronto in Canada. The exterior wall of this building is made of mirror glass with low reflectance. During the season when the culmination altitude is high, strong sunlight enters to the room before and after noon. The size of the window frame is 160 cm in height, 275 cm in width, 35 cm in the table in front of the window, and 90 cm in height from the floor, and the planters wereplaced on the table. The window frame into which sunlight enters is divided by four glasses, of which the lower left glass has a structure in which the lower side opens slightly outward. The non-woven cloth was stuck on the entire glass surface inside the window. As a result, the sunlight that enters through the window reaches the interior of the room, allowing sunlight to reach a wide range of plants placed near the window.

As plants for the indoor green curtains, herbaceous plants of five families and seven species (Morning glory *Ipomoea nil*, Cucumber *Cucumis sativus* L., Bitter gourd *Momordica charantia* var. *pavel*, Lavender *Lavandula angustifolia*, Sunflower (short stem type) *Helianthus annuus*, Chamomile *Anthemis recutita* L., Grape tomato *Solanum lycopersicum*) were employed and grown from seeds. These plants which grow in outdoor in general were chosen to examine the suitability of the indoor green curtain. The cultivation of these plants performed by two steps of seeding and cultivating in 2019. Seeding performed on 22nd March, and all kinds of shoots were obtained after seeding under the condition between around 20 ºC and 25 ºC at room temperature (Table 1). Subsequently, these shoots were cultivated with the two planters from 6th April under the condition over 25 ºC (Table 2). These planters had many vertical slits on the side for ventilation, and the side exposed to sunlight was covered with reflective sheet (Daiso-Sangyo Ltd.). Further, soft materials were used as the cultural soil in order to make it easier for plants to extend their roots to the water supply tray. The 20 L planter placed on the right side and the 30 L planter placed on the left side of the window frame (Figure 1a). Then, two shoots of cucumber and sunflower were grown even outdoors, respectively. The cucumber shoots died outdoors by the cold, while sunflower shoots grew as shown on the package (data no shown).

During the cultivation, for unknown reasons, the straw was removed because small flies grew out of the 30 L planter. Instead, white plastic pebbles that reflected light well were spread over the surface of the planter, and no small flies occurred. While the 20 L planter did not generate small flies, so it was left as it is. The growth of the plants used for the indoor green curtains peaked on around 14th June, about 85 days after seeding (Figure 1e), and thereafter the growth vitality gradually declined probably due to outdoor thermal radiation and poor indoor ventilation. In addition, the influences of allelopathic effects can also be considerable [4]. The chlorophyll color of these plants was clearly lighter than when grown outdoors probably due to that the sunlight entering indoors was weaker than the outdoors. While, ornamental foliage plants grown as a comparative experiment grew lushly and well (Supplementary Figure 1d).

Here, the results of the individual plants employed for indoor green curtains are described (Table 2). The cucumber and bitter gourd flowers partially performed artificial pollination. As the results, small cucumbers and small bitter gourds were observed (Figure 1a), however most of these did not grow any more. Only two cucumbers were harvested (Figure 2b). Not only that, cucumber and bitter gourd were also unsuitable for indoor green curtains due to their green odor. Another crop was two Grape tomatoes, although the growth rate of the stalk was slow (Fig-

ure 2c). These tastes of two cucumbers and two Grape tomatoes were the same as ordinary vegetables. The growth rate of Lavender, Sunflower, and Chamomile were very slow probably due to not suitable for indoor cultivation. The most suitable plant examined in this study was Morning glory, which grew fast, was odorless, and had many flowers (Figure 2d). Finally, Morning glory produced many seeds (over 100 seeds; Figure 2e).

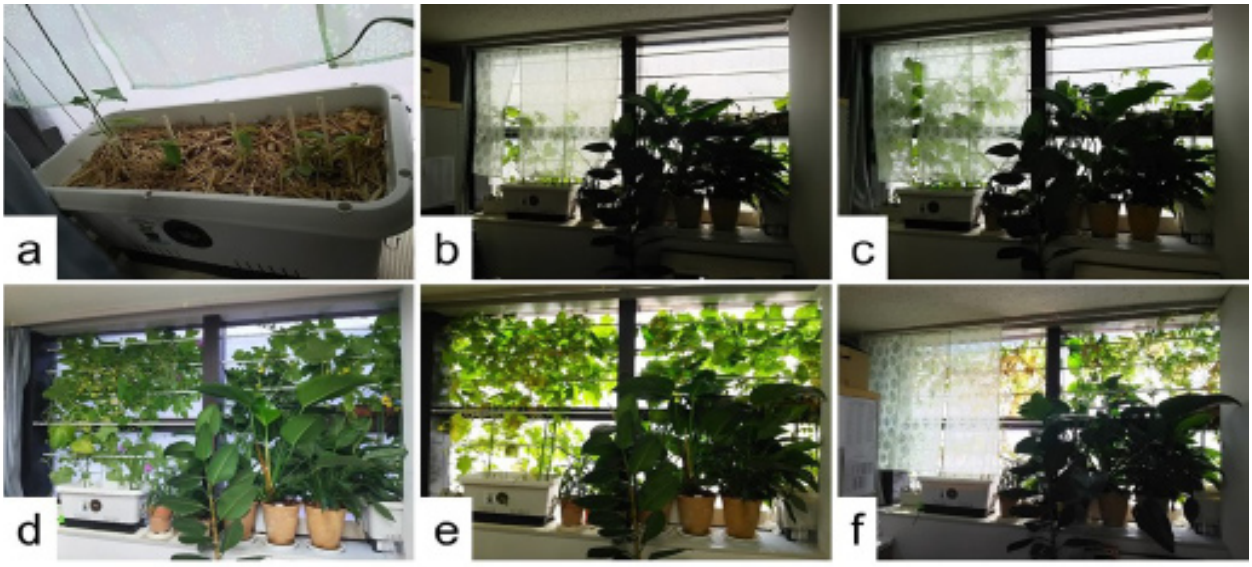

Figure 1: Time course of indoor green curtain formation in 2019. **(a)** 30 L planter on 14th April, **(b)** 8th May, **(c)** 16th May, **(d)** 2nd, Jun, **(e)** 14th Jun, **(f)** 3rd August.

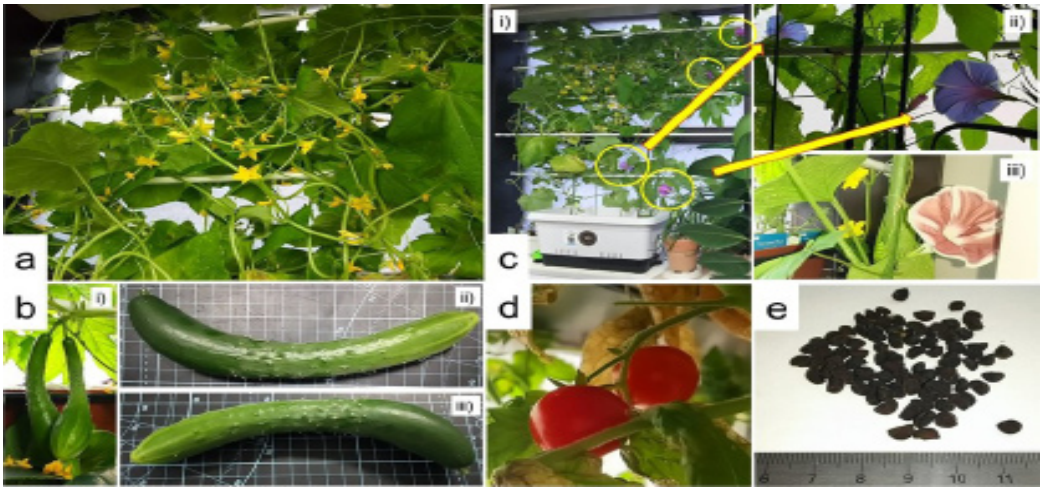

Figure 2: Products obtained by indoor green curtains. **(a)** Flowers and small fructifications of Cucumber and Bitter gourd, **(b)** cucumbers (i; 14th Jun, ii & iii; 29th Jun), **(c)** flowers of Morning glory (i & ii; 2nd Jun at 30 L planter, iii; 16th May at 20 L planter), **(d)** Grape tomatoes (2nd June), **(e)** Morning glory seeds.

Table 1: Seeding of herbaceous plants used in this study.

Plants	Species	Family	Life-span	Stem	Number of seedings	Number of shoots
Morning glory	*Ipomoea nil*	Convolvulaceae	Annual	Vine	3	3
Cucumber	*Cucumis sativus* L.	Cucurbitaceae	Annual	Vine	4	4*
Bitter gourd	*Momordica charantia* var. *pavel*	Cucurbitaceae	Annual	Vine	4	2
Lavender	*Lavandula angustifolia*	Lamiaceae	Perennial	Stalk	Several seeds X 4 points	Several shoots
Sunflower	*Helianthus annuus*	Asteraceae	Annual	Rod	4	4**
Chamomile	*Anthemis recutita* L.	Asteraceae	Annual	Stalk	Several seeds X 4 points	Several shoots
Grape tomato	Solanum lycopersicum	Solanaceae	Perennial	Stalk	4	4

* Two shoots blighted in outside probably due to low temperature. ** Two shoots were grown in outside.

Table 2: Cultivation to Form indoor green curtains.

Planters	Plants	Number of nurseries	Number of survivals	Growth rate	Results
20 L	Morning Glory	2	2	Fast	Many flowers and many seeds
	Cucumber	1	1	Fast	Many flowers and 2 cucumbers
	Bitter Gourd	1	1	Fast	Many flowers
	Grape tomato	4	4	Slow	Several flowers and 2 tomatos
30 L	Morning glory	1	1	Fast	Many flowers and many seeds
	Cucumber	1	1	Fast	Many flowers
	Bitter Gourd	1	1	Fast	Many flowers
	Lavender	Several nurseries	0	Very slow	
	Sunflower	2	0	Very slow	
	Chamomile	Several nurseries	0	Very slow	

Discussion

When cultivating plants outdoors, the use of organic fertilizers is preferred in consideration of the soil ecosystem. However, when plants are grown indoors, the organic fertilizer causes molds and insects to appear. The occurrence of the small flies in this study may also be due to the use of the organic matters. Namely, considering that plants are autotrophs, it is desirable to grow plants indoors using only inorganic matters such as chemical fertilizers.

In this study, seven species of plants were cultivated in the limited space of the window frame. The aim was to promote competition between the plants and increase the density of the green curtains. As a result, competitive growth was observed among the three vine plants trying to fill the window, although the chlorophyll of these plants was less than when grown outdoors. According to a recent report, the possibility of such competitive culturing causes of reduction of total growth rates [5]. Therefore, the author plans to control the growth rate of Morning glory applying this knowledge that utilizes genetically the same species for future experiments. While, Morning glory seed is used as herbal medicines, but is also known to be toxic. This problem can be solved if Morning glory is bred so that it does not produce the seeds.

This study applied the effect of scattered sunlight by the non-woven cloth to make the indoor green curtains. This was because the non-woven cloth was less transparent than the lace curtain, scattered the sunlight evenly, and could illuminate the interior of the room brightly. This effect is based on the characteristics of Japanese paper (washi) used in traditional Japanese houses. If non-woven cloth was not used in this study, the plants used for the green curtains might have grown to cover the surface of the window glass evenly. On the other hand, in this study, the growth peak of the plant reached before summer, and the amount of chlorophyll was smaller than that of the ornamental foliage plants. Therefore, as a working environment, an effect of appropriately illuminating the room with sunlight entering through windows was obtained.

In addition, this study required two planters for the indoor green curtains to be placed in the window frame due to space limitations. However, considering the effect of the temperature rise of the planter due to the irradiation of sunlight, it is desirable that the planter be placed on a floor not exposed to sunlight. If the planters could be tested on the floor, the plants used for the green curtains could have grown until summer or autumn.

Plants are known to not only purify the air by absorbing indoor light and carbon dioxide gas emitted by a person through the photosynthesis, but also to heal the person in the room. In particular, with regard to carbon dioxide, there is a concern about the influence on human health due to its increased indoor concentration [6]. Therefore, it is reasonable to place the ornamental foliage plants indoors. However, although the ornamental foliage plants are suitable for indoor cultivation, they are not suitable for filling windows. On the other hand, with the indoor green curtain examined in this study, it was shown that the vine plants could absorb sunlight entering the window and indoor carbon dioxide, while suppressing the rise in room temperature.

The issue of the indoor green curtain is how to control indoor humidity. However, in recent buildings such as high-rise condominiums, the airtightness is high, and the interior of the room has been continuously ventilated in consideration of the human health. Considering such a background, there is a possibility that the merits of placing the green curtain indoors may be enhanced including the above-mentioned healing effect.

Conclusion

In this study, the possibility of the indoor green curtains was investigated employing general plants at seven species. For this purpose, the non-woven cloth was stuck to a window to scatter the sunlight, and the state of green curtain formation by plants was observed. As the results, it was found that Morning glory was suitable for the indoor green curtains. In conclusion, the indoor green curtain showed the possibility to prevent insects from entering, cool down the room by photosynthesis, absorb carbon dioxide gas, maintain a good indoor environment, and be able to have the effect of healing residents. As the future experiments of the indoor plant ecology, the author plans to build an indoor aquaponics system that combines the function of a producer with a green curtain and the function as a decomposer of microbial flora that lives in a sand filter.

Conflicts of interest

The author declares that he has no conflict of interest.

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