Selection of appropriate of ornamental plant species for outdoor vertical garden

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Abstract The appropriated plant species for the outdoor vertical garden was reported using the hydroponic system. The nutrient solutions were supplied to the plants on felt panel system. The electrical conductivity value of nutrient solutions in the hydroponic system was 0.8 mS/cm. As a result, the light intensity, survival rate and beautifulness score of the plant were known. The seven plant species with more than 80% survival rate and one plant species with 19 % survival rate were observed. In addition, the average of beautifulness score of plant species was 1.00-4.00. However, the beautifulness score which was higher than four resulted in four plant species including *Schefflera* sp., *Tradescantia spathacea* Sw., *Tradescantia pallida* (Rose) Hunt, and *Rhipsalis cereuscula*. Therefore, these four ornamental plant species would be considered as an ornamental plant species for outdoor vertical garden in the future.

Keywords: Hydroponic cultivation, nutrient solution, felt panel system

Introduction

Recently, vertical gardening has become popular in many countries, including Thailand, and people are now increasingly interested in the environment, with fewer vacant areas in the city. The increasing of green space for urban residents and current urban life, living in small houses, townhouses, and condominiums these days are difficult. The space for gardening is limited. Therefore, landscaping of small empty space using the wall would be possibly interested (Sunakorn, 2011). With the advent of the modern industrial city, planners, designers and urban advocates are once again turned to plants-infrastructure as a key strategy to provide cleaner air and water and to improve living environments, human health, and mental well-being. Hydroponics is a way of growing plants in a soilless environment with the use of nutrient solutions. In this method, plants may be grown with their roots in the mineral nutrient solution in an inert or organic medium. The most important benefits of using hydroponics can be practiced even in places where ordinary gardening is impossible; green facades (Salas et al., 2010), and pergolas (Montero et al., 2010). Ecologic terraces can be used as soilless gardens at a relatively low cost. Other advantages of using these methods include faster plant growth, fewer plant infections diseases, lighter cultivation media, and the possibility to recuperate drainage to be recirculated (Salas, 2008; Salas, 2009; Van Os, 1998). The direct delivery of fertilizers through drip irrigation demands the use of soluble fertilizers and pumping and injection systems for introducing the fertilizers directly into the irrigation system. The use of hydroponic techniques with recirculating nutrient solution (Montero et al., 2010; Salas, 2009) to design a new model of gardens that means as a new way to get the profits that traditional gardening offered, as for example natural shade, vegetal covered surface or green urban landscape, with advantages, as they are the high water waste or the need of specifically prepared soil. However, there is a lack of information on vertical gardening in Thailand, especially the selection of plant species to suit the pattern of planting and the environment to maintain the beautifulness and taking care of plant species in the hydroponic system. In addition, the important factors of vertical gardening systems are an automatic irrigation system that provides fertilizer to plants together with water systems. Therefore, the objective of this study was investigated in plant species that are suitable for the outdoor vertical garden using hydroponic supplied the nutrient solutions via the felt system.

Materials and methods

The location of the study experiment was conducted at mezzanine outside the 5th-floor building, Bunnak Building of Faculty of Agricultural Technology, King's Mongkut Institute of Technology Ladkrabang, Thailand. The experiment was a Randomized complete block design with six replications and done from August 2018 to January 2019. The twelve ornamental plant species; *Schefflera* sp., *Rhipsalis simmleri cereuscula aka* 'Rice Cactus',

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Sansevieria trifasciata hort. ex Prain 'Golden Hahnii', *Gardenia augusta* (L.) Merr., *Gardenia jasminoides* 'Radicans Variegata', *Pandanus stellatus* R. Br., *Pandanus pygmaeus* Thours., *Tradescantia spathacea* Sw., *Xyphidium caeruleum* Aubl., *Neoregelia fireball* donger, *Tradescantia pallida* (Rose) Hunt. and *Rhipsalis cereuscula.* were grown under hydroponic nutrient solution in the felt system (Figure 1). The structure of the vertical building was made from the iron which adhered to the wall of the building and left the distance about 10 cm. The size of the plate was 3.0 m × 3.5 m. The curtain was made by polyvinylchloride and knitted to be plate and dovetailed with the sponge (for keeping the moisture). The plate was stitched to be squares in the size of 10 x 12 cm. Then slit the holes likely the pockets. Nutrient solutions of hydroponic use Hoagland solution formula (Hoagland and Snyder, 1933). The data record was collected as light intensity, plant survival rate, and beautifulness. The light intensity was measured using tasi digital data logging light intensity meter model: TA8133 which divided to the plate into six points and collected data monthly and measured three times at 9 AM, 12 PM and 4 PM. Survival rate was calculated as follows:

$$\text{Survival rate (\%)} = \frac{\text{Number of survival plants x 100}}{\text{Total of plants}}$$

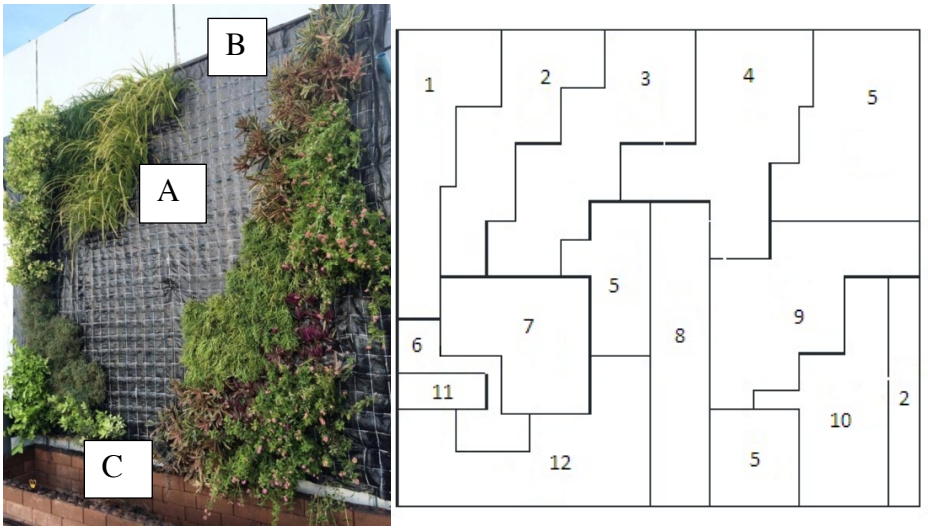

Figure 1. Vertical garden structure and the position of ornamental plants on the planting panel. A) planting panels assembled with steel frames attached to the building walls B) the water inlet is sent from the pump pressure to the top of the panel and C) the slurry tank.

The Beautifulness rate was rated by six peoples every month interval for eight months according to the method of Treenusorn et al. (2013). 0 = No beautifulness (died), 1 = Low beautifulness, 2 = Rather low beautifulness, 3 = Fairly beautifulness, 4 = Good beautifulness and 5 = Excellent beautifulness.

Results

Light intensity

The optimum light intensity for the plants in the range is around 14,000-16,000 Lux. The results of light intensity values of the plants received in each period are morning (22,547 Lux), afternoon (102,059 Lux), and evening (29,147 Lux), with a total average measured at 51,251 Lux present data record in Table 1.

Table 1. light intensity measured three times at 9 AM, 12 PM and 4 PM.

Time	Months after planting								Average
	1	2	3	4	5	6	7	8	
9 AM	23,747	23,347	24,147	21,647	21,347	21,747	23,447	20,947	22,547
12 PM	103,259	102,859	103,659	101,159	100,859	101,259	102,959	100,459	102,059
4 PM	30,347	29,947	30,747	28,247	27,947	28,347	30,047	27,547	29,147
Total	157,353	156,153	158,553	151,053	150,153	151,353	156,453	148,953	1,230,024
Average	52,451	52,051	52,851	50,351	50,051	50,451	52,151	49,651	51,251

Survival rates

Survival rates showed all species that gave different survival rates of 95%, and 19% show data records in Table 2. There were eleven species that had survival rates as up to 80%, they were *Schefflera* sp., *Rhipsalis cereuscula*, *Rhipsalis simmleri* cereuscula aka 'Rice Cactus', *Sansevieria trifasciata* hort. ex Prain 'Golden Hahnii', *Gardenia jasminoides* 'Radicans Variegated', *Pandanus stellatus* R. Br., *Pandanus pygmaeus* Thours., *Tradescantia spathacea* Sw., *Xyphidium caeruleum* Aubl., *Neoregelia fireball donger*. and *Tradescantia pallida* (Rose) Hunt. There was one *Gardenia jasminoides* 'Radicans Variegata' species which not appropriated for this gardening system that gave survival rates like 19%.

Table 2. Survival rates of 12 plant species

No.	Plant species	Survival rates (%)							
		Months after planting							
		1	2	3	4	5	6	7	8
1	*Schefflera sp.*	100	99	98	98	97	96	95	95
2	*Rhipsalis simmleri* cereuscula aka 'Rice Cactus'	98	96	95	95	94	92	90	89
3	*Sansevieria trifasciata* hort. ex Prain 'Golden Hahnii'	100	98	97	96	96	95	94	93
4	*Gardenia augusta* (L.) Merr.	98	95	89	79	69	49	28	19
5	*Gardenia jasminoides* 'Radicans Variegated'	99	97	93	90	88	86	84	82
6	*Pandanus stellatus* R. Br.	97	95	93	91	88	86	85	85
7	*Pandanus pygmaeus* Thours.	98	97	93	90	89	85	48	83
8	*Tradescantia spathacea* Sw.	100	98	96	95	94	93	92	92
9	*Xyphidium caeruleum* Aubl.	100	98	97	96	95	94	93	90
10	*Neoregelia fireball* donger.	95	94	92	90	88	86	85	84
11	*Tradescantia pallida* (Rose) Hunt.	100	99	97	96	95	94	92	90
12	*Rhipsalis cereuscula.*	100	99	98	96	95	94	93	92

Beautifulness rates

After collecting the data, all species gave beautifulness differently and got different score levels. Four species got more than 4.0 scores, they were *Schefflera* sp., *Tradescantia spathacea* Sw., *Tradescantia pallida* (Rose) Hunt. and *Rhipsalis cereuscula*. Four species got more than 3.0 scores and lower than 4.0 scores, there were *Sansevieria trifasciata* hort. ex Prain 'Golden Hahnii', *Pandanus stellatus* R. Br., *Pandanus pygmaeus* Thours and *Xyphidium caeruleum* Aubl. Three species got more than 2.0 scores and lower than 3.0 scores, there were *Rhipsalis simmleri* cereuscula aka 'Rice Cactus', *Gardenia jasminoides* 'Radicans Variegata' and *Neoregelia fireball* donger. and one species had died, which was *Gardenia augusta* (L.) Merr. (Table 3).

Table 3. Beautifulness rate of 12 plant species

No.	Plant species	Beautifulness rate (score)							
		Months after planting							
		1	2	3	4	5	6	7	8
1	*Schefflera sp.*	4.50	4.50	4.50	5.00	5.00	4.67	5.00	5.00
2	*Rhipsalis simmleri* cereuscula aka 'Rice Cactus'	2.17	2.17	2.50	3.33	2.33	1.83	2.67	3.16
3	*Sansevieria trifasciata* hort. ex Prain 'Golden Hahnii'	3.67	3.67	3.67	4.17	3.83	3.83	3.67	3.72
4	*Gardenia augusta* (L.) Merr.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	*Gardenia jasminoides* 'Radicans Variegated'	3.00	3.00	2.50	3.00	2.50	2.33	1.50	1.50
6	*Pandanus stellatus* R. Br.	3.33	3.67	4.00	4.17	3.17	3.33	4.33	3.00
7	*Pandanus pygmaeus* Thours.	4.17	4.17	3.83	3.00	2.67	3.17	2.50	2.67
8	*Tradescantia spathacea* Sw.	4.00	4.00	4.17	4.50	4.67	3.33	4.83	4.83
9	*Xyphidium caeruleum* Aubl.	2.33	2.50	2.67	3.33	3.83	3.33	3.83	3.50
10	*Neoregelia fireball* donger.	2.33	2.33	3.00	2.50	2.67	3.00	3.00	2.83
11	*Tradescantia pallida* (Rose) Hunt.	4.17	4.17	3.83	4.50	4.33	4.33	4.00	4.33
12	*Rhipsalis cereuscula.*	3.33	3.33	4.50	4.33	4.67	3.33	4.17	4.83
	Mean	3.17	3.21	3.35	3.57	3.39	3.21	3.37	3.39
	CV. (%)	14.44	20.10	16.90	18.80	18.18	20.03	14.24	13.81

Discussion

In our study, the optimum photosynthetically active radiation (PAR) of the garden includes wavelengths from 450-700 nanometres (Gislerod et al., 2010). Light intensity is one of the main factors for many plants that grow in the vertical garden. The plant different of species required different light intensity The different of plant species require different light intensity some species required dimly light or didn't require directed light but some species required directed light such as Helianthus annuus and Rosa sp. (Joanna, 2009). Phonpho and Saetiew (2017) study on indoor plants were required a different level of light intensity (500–2,000 LUX). Five species (*Monstera delicosa*, *Scindapsus pictus*, *Anthurium crystallinum*, *Caladium lindenii*, and *Philodendron erubescens*) were suitable for growth on 1,7000 LUX – 2,000 LUX. The results of this study in light intensity values of the plants received total average measured at 51,251 Lux

A study of twelve ornamental plant species, it was found that there were eleven plants that could survive and have the plants that passed the selection criteria that were used for vertical gardening outside the building, which has an average beautifulness score with higher than 4.0 and with a survival rate up to rr 95%. There were eight ornamental plant species did not meet the criteria, and there were three types of plant species because the average beautifulness score was less than 3.0 points and there were one species of survival which are caused by the following; 1) a plant that could survive up to 80% and the beautifulness scores that pass the criteria that were used for vertical gardening outside the building, which is 3.0 points or more for eight plant species, with two levels of beautifulness, which are, an average of beautifulness rating 4.0 to 5.0 points with four plant species which are *Schefflera* sp., *Tradescantia spathacea* Sw., *Tradescantia pallida* (Rose) Hunt. and *Rhipsalis cereuscula* Aubl. There has been a very beautiful level due to strong, durable and did not find any problems, that were not found diseases and insects, easy to be handling, grow quickly. Therefore, did not need to trim much, and just removed or discarded old leaves. The average beautifulness rating ranges from 3.0 to 4.0 points. There are four types of plant species: *Sansevieria trifasciata* hort. Ex Prain 'Golden Hahnii', *Pandanus stellatus* R. Br., *Pandanus pygmaeus* Thours and *Xyphidium*. *caeruleum* Aubl. The problem was the burning of the leaf tip during hot weather and exposed to sunlight light. The tree could not adapt itself in time, which causes the thinnest part of the leaves. The end of the leaf evaporates too much water until it could dry out. The practice was performed by cutting wilt and severe burns leave. Plants could survive up to 80% and have an average of beautifulness score of less than 3.0, which did not meet the criteria to be used. There are 3 types of plant species, which are *Rhipsalis simmleri* cereuscula aka 'Rice Cactus', *Gardenia jasminoides* 'Radicans Variegata' and *Neoregelia fireball* donger.

Because it was found that the plant had abnormal symptoms such as *Phytophthora* sp. Rot in *Rhipsalis simmleri* cereuscula aka 'Rice Cactus', yellow leaf in *Gardenia jasminoides* 'Radicans Variegated' and dry, dry leaf atrophy in the *Neoregelia fireball* donger. because the root system had a growing system. slow and had few roots due to strong winds, trees are constantly moving, making roots difficult to hold, so plants often come out of their pockets often. Therefore, these plants are not suitable for use and one type of plant that could not grow is *Gardenia augusta* (L.) Merr., which has been found the insect damage. The insects found are the oleander hawkmoth destroyed the leaves and flowers during the buds of the spotted dwarf plant. Causing the flowers to rot fall away and could not bloom, and it is positioned at the bottom of the planting panel, which has trapped water causing the plant to get too much water.

Conclusion

Growing ornamental plants in the vertical outdoor garden system by evaluating the beauty of the growth of plants from all twelve species, the criteria for selecting plants that are suitable for vertical gardening building exterior, which must have a survival rate up to 80% or more and an average beautifulness rating of 3.0 points or more. The eight types of plant species could meet the criteria used in vertical outdoor garden systems as follows: the survival rate of 80% or above and beautifulness between 3.0 and 4.0 score. There are four types of plant species; *Sansevieria trifasciata* hort. ex Prain 'Golden Hahnii', *Pandanus stellatus* R. Br., *Pandanus pygmaeus* Thours and *Xyphidium caeruleum* Aubl. These plants are easy to handling and no need to trim often. It just removes the wilted leaves or with severe burns out and survival rate of 80% or above and beautifulness scores between 4.0 and 5.0 score. There are four types of plant species: *Schefflera* sp., *Tradescantia spathacea* Sw., *Tradescantia pallida* (Rose) Hunt. and *Rhipsalis cereuscula*. These plants had the characteristics of easy handling, plant growth quickly, so it does not require much trimming, only picking old leaves or discarded leaves, except the purple heart tree with rapid growth, therefore having to take care by cutting once a month

References

Gislerod, H. G., Mortensen, L., Torre, S. and Pettersen, H. 2012. Light and energy saving in modern greenhouse production. Acta horticulturae 956(956):85-97.

Feifei, H., Lihua, Z., Dong, M. and Zhenhui, R. 2019. Study of LED array fill light based on parallel particle swarm optimization in greenhouse planting. Journal of Information processing in Agriculture, 6: 73-80.

Hoagland, D. R. and Snyder, W. C. 1933. Nutrition of strawberry plant under controlled conditions. (a) Effects of deficiencies of boron and certain other elements, (b) susceptibility to injury from sodium salts. Proceedings of the American Society for Horticultural Science. 30: 288–294.

Joanna, K. 2009. Indoor Plant&Frowers. Hong Kong: Octopus Book Limited.

Montero, J. L., Salas, M.C. and Mellado, P. 2010. Hydroponic pergola as an example of living furniture in urban landscape. II International Conference on Landscape and Urban Horticulture. Bologna (Italy). Acta Hort. 881:355-358.

Phonpho, S. and Saetiew, K 2017. Selection of Appropriate Species of Plants for Indoor Vertical Garden. International Journal of Agricultural Technology,13(1): 119-129.

Salas, M.C. 2008. Los cultivos sin suelo y su contribución a la producción en los sistemas hortícolas intensivos. Phytoma 199:36-40.

Salas, M.C. 2009. Fertirrigacion y recirculacion de la solucion nutritiva en cultivo sin suelo. Revista Agropecuaria 79 (918):368-371.

Salas, M. C., Montero, J.L. and Villegas, J.A. 2010. Hydroponic system for growing ground cover plants on vertical surface. II International Conference on Landscape and Urban Horticulture. Bologna (Italy). Acta Hort. 881:421-424.

Sunakorn, P. 2011. "Green Wall". Research Specialization Building Innovation to Preserve the Environment, Kasetsart University. Bangkok. Thailand.

Sunakorn, P. 2013. Secret of Vertical and Roof Garden. In: Sunakorn, P. and Siriwetchadarak, T. ed. Vertical & roof garden. Bangkok, Amarin Printing & Publishing Public Co., Ltd., pp. 122-141.

Garden. Kasetsart University. Bangkok. Thailand: Amarin Printing and Publishing Public Co., Ltd.

Treenusorn, P., Nuntagij, I. and Phonpho, S. 2013. Development of Vertical

Garden for Indoor and Outdoor Decoration. The thesis of Master of Science in Horticulture, Faculty of Agriculture. King Mongkut's Institute of Technology, Ladkrabang, Bangkok, Thailand.

Van Os, E.A. 1998. Closed soilless growing systems in the Netherlands: The finishing touch. Acta Hort. 458:279-291.