옥상정원에 이용 가능한 혼합 인공토양의 종류 및 토심에 따른 비비추의 생육 반응

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The Growth of *Hosta longips* According to Soil Depth and Composted Growing Media Available to Rooftop Garden

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요 약

도시녹지 면적 확대의 해결책으로 부각되고 있는 옥상정원은 조성이 용이해야 하며, 옥상정원 조성에 있어 가장 문제시되는 하중 또한 고려되어야 한다. 이러한 문제들로 인해 최근 경량 인공토양의 이용 필요성이 부각되고 있으나, 자연토양에 비해 고가(高價)라는 이유로 자연토양이 주로 이용되거나, 인공토양이 이용되더라도 대부분 무기질계 단종(斷種) 인공토양으로만 시공되고 있어 식물 생육측면에서 단점 보완이 요구되고 있다.

따라서, 본 연구는 옥상정원 조성에 이용 가능한 유·무기질계 인공토양들을 혼합 조성하여 그 물리·화학적 특성을 살펴보고, 각각의 혼합 인공토양 및 토심에 따른 식물생육을 조사해 봄으로써 이용 가능성을 살펴보았다. 12종류의 혼합 경량 인공토양 및 5종류의 토심(5, 10, 15, 20, 30cm)으로 조성된 인공 지반상에 2000년 6월 7일 비비추(*Hosta longipes*)를 정식하였으며, 정식 112일 후에 최종 생육조사를 실시하였다. 혼합 경량 인공토양 및 토심에 따른 토양의 물리 화학성은 인공토양 분석법을 기초로 조사 분석하였다.

그 결과, 1) 질석:피트모스(1:1, v/v), 펄라이트:질석:피트모스(1:1:2, v/v/v), 펄라이트:피트모스:입상암면(1:1:1, v/v/v) 혼합 경량 인공토양에서 비비추의 생육이 가장 좋았으며, 물리·화학성도 다른 토양에 비해 양호하였고, 하중도 적게 측정되었다. 2) 토심에 따른 비비추의 생육에서는 토심10~20cm에서 유의적인 차이를 보이지 않아, 토심 10cm에서도 자생 초화류의 생육이 가능할 것으로 판단되었다. 3) 또한 인공토양의 물리·화학적 특성과 식물 생육(생체중)과의 상관관계를 조사한 결과 전기전도도(EC), Na함량 및 토양표면 온도가 식물 생육에 있어 다른 요인들에 비해 더 큰 영향을 끼침을 살펴볼 수 있었다.

위의 결과들을 살펴볼 때 혼합 경량 인공토양은 토심을 낮추어 하중을 감소시킬 수 있을 뿐 아니라 식물 생육측면에서도 긍정적인 효과를 나타내 기존 건물의 옥상정원에서도 이용이 가능할 것으로 보인다. 그러나

본 실험에서 더 나아가 장기적인 혼합 인공토양의 물리·화학성 변화 및 식물생육을 살펴보는 연구 또한 이루어져야 할 것으로 생각된다.

주요어 : 옥상정원, 혼합인공토양, 토심, 비비추

I. INTRODUCTION

These days, interest in artificial ground used for indoor and rooftop gardens is increasing. To data, the rooftop is an undeveloped potential green space in urban areas. Since the 1980's, the total rooftop area of buildings in Seoul has grown to about 11,900,880m^2(2916acre) appropriate 3 times area of Youido(Lee, 1998 ; Lee, 1999). However, as only 3% of these areas have been utilized for green space on rooftops, they will have much potential for development in the future.

The most significant technical factor on construction of rooftop greening areas is the load on buildings and the growth of plants(Lee, 1997). Nowadays, constructors in Korea use mostly natural soil or a composition of natural soil and some perlite because of the high cost of artificial soil(Kim *et al.*, 1998). However, this often creates some problems such as too heavy a load and unsuitable environment for plant growth.

Generally, the growing media is free from weeds and light and also hastens the growth of plants(Wilson, 1983). In the early stage, growth of lawn on natural soil was much better than on growth media but in the late stage, light growing media was more suitable for growth of plants(Kim, 1999). Growth of trees in growing media is also much better than on natural soil or similar(Hwang, 1996).

Many kinds of plants grew well on the rooftop floor using a hydroponic system, in spite of the thickness of growing media which were as thin as 75 to 100mm in the case of the rockwool. This experiment indicates that it is possible to control soil depth by utilizing a planting system like the hydroponic system(Yoshinobu *et al.*, 1989). Soil depth for lawn over 3inches is not required(Monica) and it is possible for sedum to live on even below 10mm(Kentaro, 1993) and for lawn to live on 15cm(Lee, 2000). Even though soil depth for herbaceous plants and many kinds of plants is 10cm, if they have proper water and nutrient management, it will be possible to grow sufficiently(Yoshinobu *et al.*, 1989). Trees with middle and low height as well as turf grasses can satisfactorily grow on the artificial ground with the thickness less than a half of what is said to be necessary, and even not using ordinary soils but a light-weight soil amendment matter only. Besides, the artificial ground conditions were able to support only one-tenth of load of those constructed with conventional methods(Mitsu *et al.*, 1988). On construction of rooftop greening in Korea, soil depth of herbaceous plants is stipulating as 30cm. But it is supposed to possible bring down the soil depth by using growing media and other systems.

In Korea and other countries, perlite has been usually used for a growth media on roof garden, However, it has some defects such as scattering and deficiency of water and fertilize(Lee, 1999).

Thus, this study is conducted to investigate an applicable possibility of not only perlite but also other growing media such as coir dust, peatmoss, vermiculite, sawdust, bark and granular rockwool on rooftop gardens. And we investigated the possibility of soil depth lowing by applying a hydroponic system. We analyzed physical and chemical properties of artificial soil and measured growth of native flowers according to the growing media and soil depth.

II. MATERIALS AND METHODS

To solve the problems of plant growth and soil load on construction of rooftop gardens, the growth of Hosta lognipes was measured on different organic-inorganic composted growing media. perlite, which has been used until recently is very light but it has some disadvantages such as scattering, deficiency of water and fertilizer(Lee, 1999). Thus, other growing media can compensate for the disadvantages of perlite are used in composed growing media. These growing media are being used actively as growing soil in the field of horticulture and landscape architecture. Table 1 lists the composition of 12kinds of growing media used in this experiment.

The System of rooftop gardens consisted of a perlite drainage layer(3cm) and a planting layer(5, 10, 15, 20, 30cm) above a reservoir-drainage plate(Figure 1.)

Table 1. Composition of 12 kinds of growing media used in this experiment

Abbreviations	Growing Media
P	small grain perlite
PC_{11}	perlite : coir dust (1:1, v/v)
PP_{11}	perlite : peatmoss (1:1, v/v)
PV_{11}	perlite : vermiculite (1:1, v/v)
PG_{11}	perlite : granular rockwool (1:1, v/v)
PH_{11}	perlite : humus sawdust (1:1, v/v)
PB_{11}	perlite : bark (1:1, v/v)
VC_{11}	vermiculite : coir dust (1:1, v/v)
VP_{11}	vermiculite : peatmoss (1:1, v/v)
PVC_{111}	perlite : vermiculite : coir dust (1:1:1, v/v/v)
PVP_{112}	perlite : vermiculite : peatmoss (1:1:2, v/v/v)
PPG_{111}	perlite : peatmoss : granular rockwool (1:1:1, v/v/v)

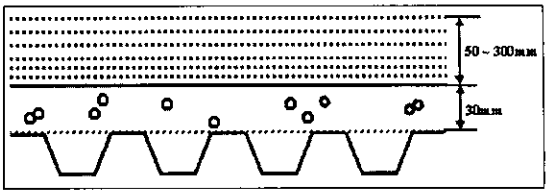


Figure 1. The system of rooftop gardens used in this experiment

Artificial soils are mixed by volume after saturation (here after called as growing media). P used small grain perlite(2.2mm) and the rest of the growing media included large grain perlite(3.5mm). We used peatmoss that was made in Canada and coir dust that was made in SriLanka. This study utilized 12 growing media and 5 soil depths(5cm, 10cm, 15cm, 20cm, 30cm) for a total of sixty experimental plots.

Hosta longipes is a native flower superior to a change of environment and possible to plant in many various environments, were used in this experiment. On June, 7, 2000, *Hosta longipes*, which had 4-5leaves, was selected and transplanted on 12 kinds of growing media.

Before transplanting, the growing media were sampled and analyzed(Walter, 1986; Helmke *et al.*, 1996; Kuo, 1996; Sumner *et al.*, 1996; CEN, 1999); Bulk density, Gravimetic water content, CEC(cation exchange capacity), pH, EC, O.M.(organic materials), Cation Ions were analyzed based on methods of artificial soil analysis.

After transplanting, nutrient solution(NO_3-N: 7.35; NH4-N: 0.92; P:1.7; K:3.5; Ca:3.5; Mg: 1.8me · L^{-1} :UOS hydroponics) on EC 1.0dS · m^{-1} was supplied to *Hosta longipes* two days a week. And it was also irrigated two other days a week with a volume of 1000ml a day.

On Aug. 23, 29, 30 and Sep. 4, 5, temperature of growing media was recorded from 10 AM to 6 PM at 15cm and 20cm soil depth by NOVA.

To evaluate the conformity of growing media on the growth of plant, we investigated the following processes: photosynthesis(LI-COR LI-6200), transpiration (LI-COR LI-1600). They were investigated each at 112th day and at 107the day after transplanting, because they are an important process for plants to grow properly and they indicate whether the plants are adapting to the various environment well or not. In addition, we researched the growth of plants chlorophyll contents(SPAD-502, MINOLTA), leaf length, fresh weight and many other factors(No table). They were investigated at 112th day after transplanting.

III. RESULTS AND DISCUSSION

1. The Physical and Chemical Properties of Growing Media

Table 2.3.4. are analytical results of the physical chemical properties and load of growing media that are sampled before treatment.

Among these analytical factors, in general, pH is very important for plants to grow well because it decides absorption of nutrient. The ideal range of pH in natural soil is from 5.4 to 6.8(William, 1996). But it's possible for plants to grow well in range from 5.0 to 7.0(Gandner *et al.*, 1985; Na, 1997)

Cation exchange capacity(CEC)is defined simply as "the sum total of exchangeable cation that a soil can absorb"(Brady, 2000). Therefore, if a soil is very high on CEC, we can conclude the soil has a great potential to provide nutrient for plants.

Taking every analytical factor into consideration about each growing media, pH and EC of perlite were suitable for growth of plants. Both bulk density and load were also lighter than other growing media. However, OM, CEC and gravimetic water content were lower. When we use the perlite as growing media on rooftop gardens, therefore, we have to

Table 2. The physical and chemical properties of growing media used in this experiment

Growing media	$pH_{1:5}$	$EC_{1:5}$ ($dS \cdot m^{-1}$)	OM (%)	CEC ($cmol \cdot kg^{-1}$)	Bulk density ($g \cdot cm^{-3}$)	Gravimetic water content(%)
P	6.90	0.031	0.76	2.01	0.125	31.6
PC$_{11}$	6.53	0.047	30.06	19.47	0.157	33.4
PP$_{11}$	4.59	0.049	34.57	34.89	0.175	39.5
PV$_{11}$	6.93	0.078	1.14	5.81	0.200	46.2
PG$_{11}$	7.43	0.054	0.32	1.31	0.179	36.2
PH$_{11}$	7.49	0.221	36.30	24.72	0.254	49.0
PB$_{11}$	4.87	0.258	44.20	26.72	0.254	16.8
VC$_{11}$	6.34	0.068	30.65	25.11	0.151	43.0
VP$_{11}$	4.77	0.067	31.81	36.83	0.173	48.3
PVC$_{111}$	6.46	0.064	19.68	15.94	0.173	43.9
PVP$_{112}$	4.71	0.054	34.52	37.31	0.152	47.0
PPG$_{111}$	6.56	0.048	21.03	24.83	0.208	33.2

Table 3. The chemical properties of growing media used in this experiment

Growing media	T-N (%)	P ($mg \cdot kg^{-1}$)	Ex-Cation($cmol \cdot kg^{-1}$)			
			K	Ca	Mg	Na
P	0.0013	10.69	1.269	2.632	0.433	1.893
PC$_{11}$	0.0184	14.01	5.923	4.606	4.891	3.322
PP$_{11}$	0.0221	14.46	2.141	4.727	6.082	2.388
PV$_{11}$	0.0053	11.65	1.921	7.976	2.632	1.883
PG$_{11}$	0.0019	6.75	1.108	5.795	1.226	1.677
PH$_{11}$	0.0316	326.06	4.536	35.707	12.654	3.340
PB$_{11}$	0.0132	22.56	2.068	5.274	3.451	5.690
VC$_{11}$	0.0189	17.28	6.897	11.236	8.143	2.973
VP$_{11}$	0.0200	16.85	2.804	11.128	12.432	1.843
PVC$_{111}$	0.0134	14.70	5.604	8.304	4.835	2.833
PVP$_{112}$	0.0237	19.12	2.040	6.676	6.664	1.944
PPG$_{111}$	0.0134	7.09	0.916	27.790	12.825	1.762

Table 4. The load of growing media used in this experiment

Growing media	Load($kg \cdot m^{-2}$)					
	3[a]	5	10	15	20	30
P		6.3[b]	12.5	18.8	25.0	37.5
PC$_{11}$		7.9	15.7	35.6	31.4	47.1
PP$_{11}$		8.8	17.5	26.3	35.0	52.5
PV$_{11}$		10.0	20.0	30.0	40.0	60.0
PG$_{11}$		7.0	17.9	26.9	35.8	53.7
PH$_{11}$	2.7	12.7	25.4	38.1	50.8	76.2
PB$_{11}$		12.7	25.4	38.1	50.8	76.2
VC$_{11}$		8.7	17.3	26.0	34.6	51.9
VP$_{11}$		7.6	15.2	22.8	30.4	45.6
PVC$_{111}$		10.4	20.8	31.2	41.6	62.4
PVP$_{112}$		7.6	15.1	22.7	30.2	45.3
PPG$_{111}$		8.7	17.3	26.0	34.6	51.9

[a]: Soil depth; [b]: cm

consider carefully the water and nutrient management.

Coir dust has been studying as an alternate growing medium to peatmoss. There are little differences between the EC of PC_{11}(Perlite+Coir) and that of PP_{11}(Perlite+Peatmoss). However, pH of PC_{11} was within the proper range but that of PP_{11} was a little lower. Bulk density and load on both growing media are so light that they can be utilized as growing media on rooftop garden. All chemical properties of PC_{11} and PP_{11} were very similar except for K concentration. We supposed that PP_{11} would be more favorable on growth of plants because OM, CEC and gravimetic water content of PP_{11} are higher than those of PC_{11}.

pH, EC and chemical properties of PV_{11} (Perlite+Vermiculite) had a few disadvantages on the growth of plants. Gravimetic water content of PV_{11} was about 46.2%. OM and CEC were very low because both perlite and vermiculite are inorganic material. PG_{11} (Perlite+Granular Rockwool) was similar to PP_{11} on Bulk density and load but pH of PG_{11} was observed as 7.43 which deviated from general proper range 5-7.

EC, N, P and Ca concentration of PH_{11} (Perlite+Humus Sawdust) was very high because of humus with animal feces. Generally, proper concentration of Phosphorus is 30-50mg/L(Jones, 1997). However, phosphorus of PH_{11} was so high that was presumed to take an excess symptom. pH was also high as 7.49 but little differences in OM, CEC were observed among other growing media. Bulk density and load were heavier and gravimetic water content was higher at 49%. As seen in Table 5, the average surface temperature of growing media is higher than other growing media. Therefore, it was supposed to affect on the growth of plants.

EC of PB_{11} was as high as that of PH_{11}. Bulk density and load were heavier than other growing media. In chemical properties, concentration of Na was high but gravimetic water content was as low as 16.8%. It indicated that we should take notice of irrigation management.

EC, OM, bulk density and load showed little differences on VC_{11} (Vermiculite+Coir), VP_{11} (Vermiculite+Peatmoss). It has possibilities as a growing media on rooftop gardens, because load of VC_{11}, VP_{11} was lighter than that of PC_{11}, PP_{11}. Gravimetic water content of VP_{11} and VC_{11} was higher.

Properties of VC_{11}, VP_{11} were similar to those of PVC_{111}(Perlite+Vermiculite+Coir) and PVP_{112} (Perlite+Vermiculite+Peatmoss). PPG_{111} (Perlite +Peatmoss+Granular Rockwool) is so good on most properties that it had great potential as growing media on rooftop gardens.

Table 5. Average temperature of 12 kinds of growing media from 10AM to 6PM for 5 days

Growing media	Temperature of growing media(℃)					Average temperature (℃)
	10	12	14	16	18	
Air	27.9*	30.4	32.4	29.5	26.8	29.4
Concrete	36.6	42.3	44.1	38.7	28.3	38.0
P	26.6	32.1	33.3	31.3	27.6	30.2
PC_{11}	26.9	31.1	33.6	32.0	28.4	30.4
PP_{11}	26.5	31.4	33.4	31.2	27.7	30.0
PV_{11}	26.3	31.3	33.1	30.8	27.9	29.9
PG_{11}	26.8	31.7	33.1	31.0	27.7	30.1
PH_{11}	28.5	33.0	34.8	33.2	29.3	31.8
PB_{11}	28.5	33.8	36.0	34.2	30.6	32.6
VC_{11}	27.1	31.0	33.4	30.9	27.7	30.0
VP_{11}	26.9	31.0	32.8	30.7	27.8	29.8
PVC_{111}	27.0	31.7	33.1	31.5	28.1	30.3
PVP_{112}	26.5	30.3	33.2	30.8	28.2	29.8
PPG_{111}	26.4	30.6	32.5	30.5	27.3	29.5

*: unit: cm

The temperature of each growing media was measured from 10AM to 6PM for 5 days on Aug. 23, 29, 30 and Sep. 4, 5(NOVA digital temperature) because it can have an influence on growth of plants, air temperature and microclimate and so on. The average temperature of PH_{11}(Perlite+Humus Sawdust) and PB_{11}(Perlite+Bark), which were 31℃

and 32°℃ respectively, was higher than that of other growing media. At 2PM, it was the highest temperature at 34.8℃ and 36.0℃ respectively. Other growing media were almost the same temperature from 29.5℃ to 30.4℃.

The surface temperature of a rooftop, concrete floor without greening, was as high as 44.1℃ Therefore, in summer, greening will have effect to bring down the temperature from 8 to 10℃(Table 5).

Before and after peak afternoon heat, the temperature of the growing media increased rapidly and retained more heat than the air. The temperature of the concrete increased rapidly most. It can also give rise to the phenomenon of heat island(Jo and Ahn, 1999).

In conclusion, among these 12 kinds of growing media, most growing media with the except on of PH_{11}, PB_{11} that have some problems such as Na, P, load and temperature, didn't have great problems on plant growth. Especially, on measurement of temperature, we conjectured that the green of rooftop gardens will reduce the effects of high urban temperature caused by artificial materials like concrete(Lee, 1996; Jo and Ahn,1999; Takakura, 2000).

2. The Growth of *Hosta logipes* on Different Growing Media

To observe growth of plants grown on 12 kinds of growing media, we investigated several factors which affect growth of plants and growth quantity.

Generally, photosynthesis rate and transpiration rate increase when plants grow well and rapidly. Table 6, 7 are the results of photosynthesis rate and transpiration rate of *Hosta longipes*. There was a little difference on photosynthesis rate and transpiration rate of Hosta logipes by growing media and soil depth.

On growing media PH_{11} and PB_{11}, photosynthesis

Table 6. Photosynthesis of *Hosta longipes* grown under different growing media and soil depth

Growing media	Photosynthesis(μmol · m^{-2} · s^{-1})				
	5	10	15	20	30
P	6.52cd[a]±1.37[b]	8.67a±1.11	5.71cd±0.63	8.19a±1.60	7.58a±0.72
PC_{11}	4.95efg±1.21	7.43ab±1.00	7.99a±0.94	6.01cd±0.80	7.40ab±0.43
PP_{11}	7.03bcd±0.95	6.49b±1.05	7.34ab±0.49	7.99a±1.07	7.27ab±1.08
PV_{11}	6.08cdef±1.14	7.66ab±1.02	7.67ab±0.76	6.22bc±0.76	6.69abc±0.46
PG_{11}	7.52abc±0.91	8.05ab±1.21	7.05ab±0.65	7.05abc±1.31	6.32bcd±0.72
PH_{11}	4.14g±0.71	6.59b±1.74	6.40bcd±0.52	7.65ab±0.84	6.78abc±0.75
PB_{11}	4.67fg±1.31	4.75c±1.25	5.41d±0.69	4.80d±0.81	5.25d±1.01
VC_{11}	6.01def±0.67	7.57ab±1.88	7.44ab±0.40	8.13a±0.67	6.39abcd±
VP_{11}	0.718.71a±0.70	7.68ab±0.70	6.93abc±1.84	6.91abc±0.69	7.48ab±1.28
PVC_{111}	6.81cd±1.16	6.67b±1.05	7.93a±1.32	8.19a±0.90	5.88cd±0.52
PVP_{112}	8.28ab±0.78	8.65a±1.05	6.81abc±0.89	7.14abc±1.04	6.65abc±0.61
PPG_{111}	6.37cde±0.72	7.61ab±0.46	7.64ab±1.10	8.44a±0.89	7.23ab±1.15

[a]: Means separation within colums by Duncan's multiple range test, 1% level; [b]: Means±SD

Table 7. Transpiration rate of *Hosta longipes* grown under different growing media and soil depth

Growing media	Transpiration rate(μg · cm^{-2} · s^{-1})				
	5	10	15	20	30
P	7.50a[a]±0.66[b]	9.44a±1.93	8.37a±1.17	7.95ab±0.27	8.01a±0.15
PC_{11}	7.39a±0.61	8.44ab±0.73	7.88a±0.32	8.85a±0.61	8.93a±1.05
PP_{11}	7.65a±0.31	8.34ab±0.51	8.21a±0.90	9.23a±0.50	8.63a±0.11
PV_{11}	7.40a±0.80	8.49ab±1.50	8.64a±0.82	7.37ab±1.51	8.56a±0.33
PG_{11}	7.84a±1.09	8.74ab±1.88	8.57a±0.33	7.26ab±0.50	7.56ab±0.65
PH_{11}	6.52a±0.64	7.33ab±1.58	7.66a±0.70	8.37a±1.38	7.44ab±0.54
PB_{11}	7.40a±0.31	5.89b±0.42	6.89a±0.54	5.58b±1.09	5.75b±0.96
VC_{11}	7.88a±0.24	8.09ab±0.84	7.98a±1.06	7.58ab±1.03	8.57a±0.78
VP_{11}	7.90a±1.02	9.90a±0.54	8.16a±1.06	8.11a±0.87	7.54ab±0.98
PVC_{111}	7.39a±0.87	7.77ab±0.66	8.71a±0.79	7.71ab±1.73	8.02a±0.89
PVP_{112}	7.98a±0.85	7.93ab±0.64	8.26a±1.09	7.34ab±0.55	8.18a±1.12
PPG_{111}	7.53a±1.13	9.79a±1.29	8.76a±0.83	8.47a±0.52	7.78a±0.74

[a]: Means separation within colums by Duncan's multiple range test, 1% level; [b]: Means±SD

rate was inactive. It was supposed that physical and chemical properties and high surface temperature of growing media were not suitable for *Hosta longipes*. Photosynthesis rate and transpiration rate on PPG_{111}, PVP_{112} and VP_{11} was higher than other growing media because of good physical and chemical properties. The second high rate growing media group was P, PP_{11}, PG_{11}. The photosynthesis rate and transpiration according to soil depth, these were higher on 10-20cm soil depth than on 5, 30cm soil

Table 8. Chlorophyll contents of *Hosta longispes* grown under different growing media and soil depth

Growing media	Chlorophyll contents (SPAD)				
	5	10	15	20	30
P	36.7ab[a]±0.52[b]	36.4cd±1.53	35.9cde±1.92	32.9e±0.17	34.5bc±0.96
PC_{11}	32.5de±2.08	36.0cd±1.38	34.7defg±1.56	35.6d±0.58	28.0g±0.90
PP_{11}	40.8a±0.59	35.5cde±1.81	33.8efg±0.71	37.0cd±0.74	33.9cd±0.90
PV_{11}	36.1bcd±1.27	35.7cd±0.64	37.8bc±1.10	36.0d±1.52	31.8def±0.93
PG_{11}	33.6cde±1.06	35.4cde±0.70	36.3bcd±1.14	35.8d±0.79	32.8cde±0.92
PH_{11}	34.2bcd±5.10	32.4e±1.42	32.5g±1.96	33.0e±0.93	30.5f±0.98
PB_{11}	31.1e±0.62	35.2cde±1.79	33.2fg±1.37	29.6f±0.39	27.2g±2.38
VC_{11}	33.4cde±0.13	40.3ab±1.44	35.7cdef±0.88	35.4d±1.06	31.8def±0.33
VP_{11}	37.9ab±1.15	37.0cd±1.65	40.4a±0.75	40.8b±1.64	36.6a±1.29
PVC_{111}	33.5cde±1.31	34.4de±1.21	33.8efg±0.97	36.1d±1.39	30.1f±0.42
PVP_{112}	33.5cde±1.02	37.9bc±1.20	38.6ab±1.08	38.6c±1.19	31.3ef±0.99
PPG_{111}	38.5ab±1.73	42.1a±1.52	37.6bc±1.27	43.3a±1.55	34.1ab±0.94

[a]: Means separation within colums by Duncan's multiple range test, 1% level; [b]: Means±SD

depth.

In general, plants with high chlorophyll content grow well. Chlorophyll content of Hosta logipes planted on perlite were high on 5cm 10cm soil depth. They decreased as soil depth increased.

Chlorophyll contents of *Hosta longipes* planted on PC_{11} were the highest at a 10cm soil depth and those of PP_{11} were best 5cm soil depth. PV_{11} was high on 5-15cm soil depth. PG_{11} was high a 10-20cm soil depth.

On PB_{11}, chlorophyll contents were highest on 5cm soil depth. However, growth of plants on PB_{11} was the worst among other growing media. Chlorophyll contents of Hosta logipes planted on VC_{11} were very high at 40.29 on 10cm soil depth. VP_{11} was also high on 15cm and 20cm soil depth. Chlorophyll contents of PVC_{111} were the highest on 15cm and 20cm soil depth, and those of PPG_{111} were the highest on 10cm and 20cm soil depth. Chlorophyll contents of Hosta logipes planted on VP_{11}, PVP_{112} and PPG_{111} were higher than other growing media. Chlorophyll contents according to soil depth were generally higher on 10-15cm soil depth.

Leaf length and leaf width of Hosta logipes by growing media and soil depth were similar to the results of photosynthesis and transpiration rate(No Table). PH_{11} and PB_{11} were the worst and VP_{11}, PVP_{112} and PPG_{111} were the highest for plant growth. The growth of plants was generally poor on 5cm soil depth. However, there was no significant difference from 10cm to 20cm.

There was many leaves on PVP_{111}, PP_{11}, PV_{11}, PG_{11}, VP_{11} and PVC_{111} and on soil depth of 10-20cm(No Table).

Table 9. Fresh weight of *Hosta longispes* grown under different growing media and soil depth

Growing media	Fresh weight (g/plant)				
	5	10	15	20	30
P	27.4abcd[a]±10.3[b]	38.8ab±16.0	26.2bcd±5.0	54.2ab±7.1	46.2abc±11.5
PC_{11}	14.0cde±3.3	32.4ab±7.8	36.8abc±23.3	35.2bc±19.8	33.8bc±10.8
PP_{11}	28.2abc±6.2	33.8ab±7.8	37.2abc±10.5	34.4bc±8.0	37.6bc±11.3
PV_{11}	18.4bcde±4.2	36.6ab±13.4	43.6abc±10.4	40.2abc±10.0	45.6abc±9.2
PG_{11}	21.2abcd±8.0	37.4ab±14.3	42.8abc±13.9	41.2abc±8.5	37.4bc±8.1
PH_{11}	13.0de±4.5	21.8bc±15.1	20.0cd±9.9	22.2cd±5.9	13.2de±5.5
PB_{11}	5.0e±2.0	5.0c±0.0	3.5d±1.9	3.8d±1.3	5.8e±3.3
VC_{11}	15.8bcde±5.8	37.6ab±12.0	41.4abc±12.4	60.2a±13.2	28.4cd±6.3
VP_{11}	35.6a±4.1	49.4a±7.3	47.4ab±7.5	60.4a±17.3	41.0abc±17.8
PVC_{111}	22.0abcd±14.1	21.0bc±10.7	45.0abc±25.0	47.8ab±21.7	41.6abc±8.0
PVP_{112}	30.0ab±4.5	37.8ab±6.8	56.4a±11.9	59.4a±11.1	58.0a±13.2
PPG_{111}	28.8ab±10.4	44.4ab±12.6	42.8abc±11.4	37.0abc±3.5	49.8ab±10.7

[a]: Means separation within colums by Duncan's multiple range test, 1% level; [b]: Means±SD

Fresh and dry weight of Hosta longispes were heavier on VP_{11}, PVP_{112}, PPG_{111} and VC_{11} than other growing media as seen in the above results. Hosta longispes grown on PH_{11} and PB_{11} were lighter in fresh weight than other media, and there was no significant difference on 10-30cm soil depth.

Growth was generally good on 15-20cm soil depth. In addition, it was also not bad on 10cm soil depth. Physiological activity and growth were good on VP_{11}, PVP_{112} and PPG_{111} in spite of lower pH of peatmoss at about 4.7. Likewise, VC_{11} was good too. What is more, VP_{11}, PVP_{112}, and PPG_{111} were better than other growing media for growth of plants, because they were high on gravimetic water content, OM and CEC. Particularly, the load of VP_{11} and

PVP_{112} were so light that these had high potential for using of growing media on rooftop gardens.

IV. CONCLUSION

These days, rooftop gardens, which are considered as a way for the greening of cities, could be constructed easily. The most significant technical factors on construction of rooftop greening are the load on building and growth of plants. In general, the specific character of the structure and the load depend on soil types used for the gardens. Thus, it is necessary to use light soils for maintaining flexible formation and light load. Therefore, this study was conducted to determinate light growing media and optimal soil depth adapted to rooftop gardens.

The growth of *Hosta longipes* and physical and chemical properties of soil were measured in the 12 kinds of different light growing media composition and 5 soil depths.

1. The highest growth rate of Hosta logipes was obtained when the plants were planted on VP_{11}(vermiculite+peatmoss;1:1, v/v), PVP_{112} (perlite+vermiculite+peatmoss;1:1:2, v/v/v), and PPG_{111}(perlite+peatmoss+granulate rockwool;1:1:1, v/v/v) growing media. In addition, the load and physical-chemical properties of soil were also more stable on these growing media.

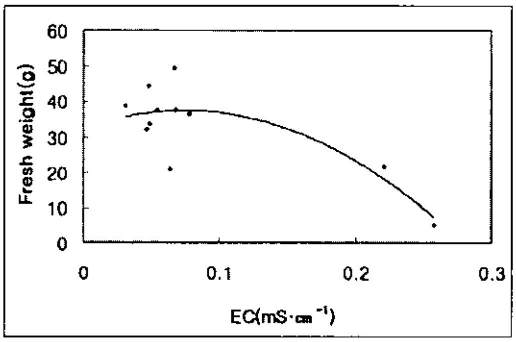
2. The plant growth was not different within the range from 10 to 20cm soil depth, which indicates that there are some possibilities to reduce the soil depth to 10 cm. As a result of the data, we can conclude the composed growing media are effective on reducing the load and increasing the growth.

3. We investigated a correlation between properties of growing media and fresh weight of Hosta logipes to determine which factors of growing media significantly affect growth of Hosta logipes.

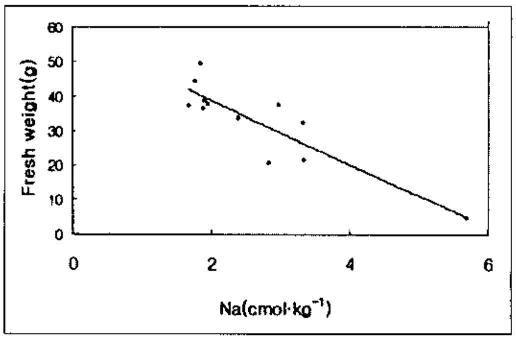
$Y=-902.48x^2+135.76x+32.406$ ($R^2=0.6636$) (formula a)

$Y=0.1195x^2-10.026x+58.39$ ($R^2=0.7773$) (formula b)

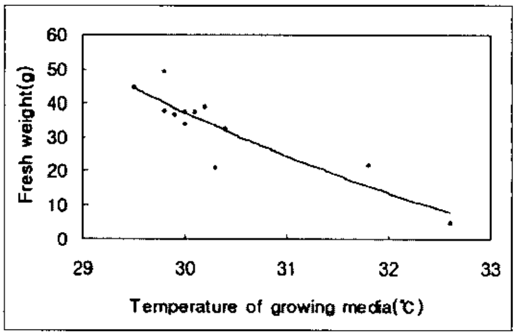
$Y=0.9737x^2-72.21x=1327.2$ ($R^2=0.7916$) (formula c)



a: The correlation of EC(Electric conductivity) and fresh weight



b: The correlation of Na contents and fresh weight



a: The correlation of Electric conductivity and fresh weight

Figure 2. Effects of physical and chemical properties of growing media for fresh weight of *Hosta longipes*

Like Figure 2. among physical and chemical properties of growing media, the temperature of surface, EC and contents of Na had high correlation with fresh weight of Hosta logipes. pH, OM, CEC and cation contents except for Na had little affect on growth. The growth of *Hosta longipes* was decreased according to the temperature of surface rise. EC of 0.05-0.1dS/m range. Na contents of above 2.0-3.0cmol/kg suppressed the growth of Hosta logipes.

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