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Effects of Shading on the Growth of *Hedera rhombea* Bean and *Pachysandra terminalis* Sieb. et Zucc.

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ABSTRACT This experiment was conducted to investigate the effect of different levels of shading (0, 35, 55, 75, 95% to incident sunlight) on the growth of *Hedera rhombea* Bean and *Pachysandra terminalis* Sieb. et Zucc. in order to determine optimum light intensity for ground cover plants. *H. rhombea* showed a upright growth type under 95% shading and *P. terminalis* was highest under 35% shading. Number of branches was not significantly affected by shading levels. Stem diameter and length were reduced under shading from 35% to 95%. Leaf growth was vigorous under 35% and 55% shade condition. Leaves became longer with decreasing light intensity, but shorter in 95% shading than control. There was a slight trend that total chlorophyll and chlorophyll a, b contents increased with decreasing light intensity, and so did chlorophyll a/b ratio. Fresh and dry weight of both plants were higher under 35, 55, and 75% shading than control and 95% shading. Specific leaf weight tended to decrease with reduction of light intensity. Thus, optimum light intensity for growth of them may be 35 and 55% shading of incident sunlight. In addition, it is possible to grow them under even 75% shading of incident sunlight.

Additional key words: ground cover plants, light intensity, shade tolerance

Introduction

Ground cover plants used in Korea have been limited to zoysiagrass, *Juniperus* species, *Liriope* species, and so on. Especially, only a few evergreen ground cover plants have been used (Lee et al., 1991b). The poor uses of evergreen ground cover plants are attributed to lack of understanding and ground cover plant materials. And appropriate planting considering its growth characteristics was not done, because of lack of investigation in plant growth condition and propagation. It is necessary to plant them according to their own growth condition, and to introduce them through mass propagation. *Hedera rhombea* Bean (Nakai) (Japanese ivy), belongs to Araliaceae, is native to Korea, which shows a decumbent growth habit in juvenile phase and has drought resistance with evergreen characteristics. *Pachysandra terminalis* Sieb et. Zucc (Japanese spurge), belongs to Buxaceae, is an introduced plant from Japan. It has evergreen leaves, short plant height, and adaptability to harsh environment. Thus, *H. rhombea* and *P. terminalis* have a potentiality to substitute for lawn. However, a few studies were conducted on the effect of light intensity on the growth of *H. rhombea* (Kim and Lee, 1978), and none of *P. terminalis*. The objectives of this study were to investigate the effect of shading on the growth of *H. rhombea* and *P. terminalis*, which make it possible to be planted according to their own favorable condition.

Materials and Methods

Plant materials

This experiment was carried out with rooted cuttings of *H. rhombea* and *P. terminalis*. Cutting was carried out at the benches with perlite media on Apr. 27, 1997. Rooted cuttings were planted in 1m ×0.5m subplot at Crop Experiment Farm on May 27 and June 27 for *H. rhombea* and *P. terminalis*, respectively, and arranged in a completely randomized block design with 4 replications. The metal frame structure for experiment was constructed in 1m×1m×0.6m (length×width ×height). It was covered with black polyester woven shade cloth which provided 0, 35, 55, 75, and 95% shading to incident sunlight.

Data collection and analysis

Plant height, number of leaves per plant, length of the longest stem, number of nodes, number of branches, and internodal length (the fifth internode from the apex) were measured monthly during the experiment. Leaf thickness, leaf length, and leaf width of the third or fourth fully expanded leaf from the apex were measured. Leaf area, leaf chlorophyll content, fresh and dry weights of stems, roots, and leaves were measured at the end of the experiment. Leaf area was determined with leaf area meter (LI-3100; LI-COR, Lincoln, Nebraska). For dry weight measurement, tissue was oven-dried at 80℃ for 3 days. Leaf chlorophyll and carotenoid contents of the third or fourth fully expanded leaves from the apex were measured. Chlorophyll was extracted from leaf (0.5g) using 100% MeOH (20mL) for 24hr in the dark at ambient temperature and diluted 8 times before spectrophotometric analysis. Absorbance (A) was measured with UV-Spectrophotometer (UV-1606; Shimadzu, Japan) at 665.2nm, 652.4nm, and 470 nm. Then, chlorophyll and carotenoid contents were calculated as follows (Hipkins and Baker, 1986):

$$\text{Chlorophyll a (Chl.a)} = 16.72 \times A_{665.2} - 9.16 \times A_{652.4}$$

$$\text{Chlorophyll b (Chl.b)} = 34.09 \times A_{652.4} - 15.28 \times A_{665.2}$$

$$\text{Total chlorophyll (Total Chl.)} = 1.44 \times A_{665.2} + 24.93 \times A_{652.4}$$

$$\text{Carotenoid} = (1000 \times A_{470} - 1.63 \times \text{Chl.a} - 104.96 \times \text{Chl.b})/221$$

Results and Discussion

Plant height

Plant height of *H. rhombea* was highest when grown under 95% due to upright growth type (Fig. 1, Table 1). The others showed a decumbent growth type, resulting in short height. In *P. terminalis*, plant height was higher under 35, 55, and 75% shading than under control and 95% shade condition. As a result, plant height under moderate shade condition was higher than that of control.

Stem growth

Number of branches in *H. rhombea* was least under 95% shading level (Table 1). It is consistent with general opinion that number of branches is positively correlated with light intensity and depends on the photosynthetic efficiency (Kim et al., 1995; Choe and Kwack, 1973). Stem diameter, stem length, and number of nodes were higher under 35% and 55% shading than those of control. In *P. terminalis*, number of branches and nodes were not affected by shading treatment (Table 1). Stem diameter was highest under 35% shading,

Table 1. Effects of different levels of shading on stem growth of *H. rhombea* and *P. terminalis* at 120 days and 90 days after planting, respectively.

Shading levels (%)	Plant height (cm)	No. of branches (ea)	Stem diameter (mm)	Stem length (cm)	No. of nodes	Internodal length[z] (cm)
			H. rhombea			
0	9.50 d[y]	3.75 a	3.43 b	41.75 c	19.25 b	2.61 b
35	14.25 b	5.50 a	3.99 a	88.63 a	25.00 a	4.61 a
55	12.88 bc	3.25 ab	3.96 a	83.00 ab	23.38 a	4.10 a
75	11.75 c	3.50 ab	3.37 b	73.13 b	22.76 a	4.16 a
95	25.13 a	1.25 b	2.86 c	22.56 d	12.38 c	1.99 b
			P. terminalis			
0	7.32 bc	1.00 a	3.10 b	6.26 bc	2.63 a	2.55 b
35	9.10 a	1.00 a	4.06 a	8.00 a	2.13 a	4.81 a
55	8.25 ab	1.00 a	3.49 b	7.25 ab	2.63 a	3.94 a
75	9.33 a	1.00 a	3.18 b	8.23 a	2.75 a	4.21 a
95	6.58 c	1.00 a	3.11 b	5.56 c	2.75 a	2.61 b

[z]Length of the fifth internode from shoot apex.
[y]Mean separation within columns in each plant by DMRT, at 5% level.

Table 2. Effects of different levels of shading on leaf growth of *H. rhombea* and *P. terminalis*.

Shading level (%)	No. of leaves (ea)	Leaf thickness[z] (mm)	Leaf length (cm)	Leaf width (cm)	Leaf L/W[y] ratio	Total leaf area (cm^2/plant)	Average leaf area (cm^2/leaf)
			H. rhombea				
0	41.0 b[x]	0.96 a	3.53 b	4.55 c	0.78 a	207.6 c	5.08 b
35	59.4 a	0.91 a	4.94 a	6.23 ab	0.80 a	592.2 a	10.5 a
55	41.8 b	1.03 a	5.45 a	6.70 a	0.81 a	494.7 ab	12.9 a
75	37.3 b	0.89 a	5.03 a	6.56 a	0.76 a	416.5 b	11.5 a
95	13.1 c	0.70 b	4.18 b	5.50 b	0.76 a	132.6 c	10.3 a
			P. terminalis				
0	16.9 ab	0.63 ab	4.06 bc	1.68 b	2.46 a	52.21 b	1.92 b
35	20.5 a	0.59 ab	5.08 a	2.44 a	2.10 ab	69.42 a	3.36 a
55	17.9 ab	0.71 a	4.65 ab	2.33 a	2.05 b	52.23 b	2.94 a
75	19.5 a	0.60 ab	5.00 a	2.40 a	2.11 ab	62.09 ab	3.49 a
95	14.4 b	0.55 b	3.43 c	1.63 b	2.11 ab	23.34 c	1.64 b

[z]Measured with the third or fourth fully expanded leaf from the apex.
[y]Length and width, respectively.
[x]Mean separation within columns in each plant by DMRT, at 5% level.

followed by reduction with decreasing of light intensity. Internodal lengths of both plants were increased with medium shading. Gawronska et al. (1995) observed that plants grown in medium and low irradiance developed the same number of internodes as control plants, but plants in darkness developed fewer internodes.

Leaf growth

Number of leaves in *H. rhombea* trended to decrease with an increase shading from 35% to 95%, which was highest under 35% shading (Table 2). Decreased light below 75% significantly reduced leaf thickness. Leaves became longer with decreasing light intensity. Maximum leaf length was observed under 55%. There was a tendency that leaf width increased under shade condition. Though both leaf length and leaf width increased under shade condition, leaf L/W ratio was not significantly affected by low light intensity. *P. terminalis* showed the same results as shown in *H. rhombea*. However, leaf thickness did not show a definite trend according to increasing shade. Leaf growth was consistent with the general opinion that leaves expanded under low light differ from those which develop under high irradiance having a thinner leaf blade with well-developed palisade mesophyll, a higher proportion of intercellular space, a lower ratio between internal and external surface area, and large spaces between veins (Allard et al., 1991; Dengler, 1980; Di Benedetto and Cogliatti, 1990).

Maximum total leaf area was observed under 35% shading, while minimum under 95% shading. There was a tendency that reduced light intensity increase total leaf area, but not under 95%. Regnier et al. (1988) reported that plants compensated for low irradiance by increasing the amount of photosynthetically active area in proportion to aboveground plant mass primarily by decreasing leaf thickness. Schultz and Mark (1993) concluded that shade plant adapted to low irradiance by investing proportionally more into light interception by leaves than supporting structures.

Chlorophyll content

Total chlorophyll, chlorophyll a, chlorophyll b contents, and chl. a/b ratio were not significantly affected by reduced light intensities in both plants, except 95% shading (Table 3). Chl. a/b ratio tended to decrease as light intensity decreased. It may be due to higher increasing rate of chlorophyll b content than that of chlorophyll a under reduced light conditions (Lee et al., 1991a; Peacock and Dudeck, 1981). Shade tolerant plant had higher

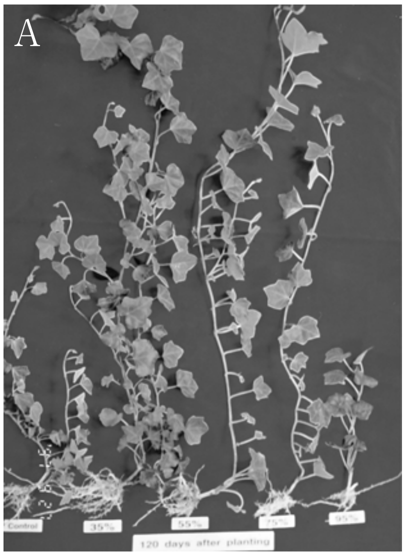

Fig. 1. *H. rhombea* (A) and *P. terminalis* (B) grown under different levels of shading at 120 and 90 days after treatment, respectively. Left to right: 0, 35, 55, 75, and 95% shading.

Table 3. Effects of different levels of shading on chlorophyll and carotenoid contents in leaves of *H. rhombea* and *P. terminalis*.

Shading levels (%)	Chlorophyll content (μg/g)[z] a	b	total	Chl. a/b ratio	Carotenoid (μg/g)
		H. rhombea			
0	0.88 b[y]	0.30 b	1.18 b	2.94 a	0.35 b
35	0.92 b	0.31 b	1.25 b	2.82 a	0.36 b
55	0.88 b	0.30 b	1.18 b	2.87 a	0.34 b
75	0.84 b	0.31 b	1.14 b	2.74 a	0.33 b
95	1.43 a	0.55 a	1.98 a	2.61 a	0.54 a
		P. terminalis			
0	0.65 b	0.21 b	0.86 b	3.19 a	0.29 b
35	0.89 b	0.28 b	1.18 b	3.19 a	0.35 b
55	0.77 b	0.25 b	1.02 b	3.05 ab	0.30 b
75	0.81 b	0.27 b	1.08 b	3.03 b	0.32 b
95	1.55 a	0.52 a	2.07 a	2.98 b	0.52 a

[z]Measured with the third or fourth fully expanded leaf from the apex.
[y]Mean separation within columns in each plant by DMRT, at 5% level.

Table 4. Effects of different levels of shading on fresh and dry weight of *H. rhombea* and *P. terminalis*.

Shading levels (%)	Fresh weight (g/plant) Leaf	Stem	Root	Dry weight (g/plant) Leaf	Stem	Root	T/R ratio[z]	Specific leaf weight (g/㎠)[y]
				H. rhombea				
0	9.51 bc[x]	6.43 c	3.54 a	2.99 c	1.74 c	0.70 a	7.39 b	0.014 a
35	19.82 a	14.04 a	3.03 a	5.64 a	3.40 a	0.75 a	13.05 a	0.010 b
55	18.11 a	12.84 ab	3.57 a	4.78 ab	2.90 ab	0.62 a	12.97 a	0.010 b
75	13.98 ab	9.94 bc	2.40 ab	3.60 bc	2.08 bc	0.45 b	12.73 a	0.009 b
95	4.14 c	1.91 d	1.83 b	0.95 d	0.45 d	0.21 c	6.68 b	0.007 b
				P. terminalis				
0	1.28 b	0.53 b	0.74 b	0.29 c	0.13 b	0.14 c	3.16 a	0.011 a
35	1.94 a	1.03 a	1.42 a	0.56 a	0.26 a	0.30 a	3.20 a	0.008 ab
55	1.44 ab	0.91 a	1.09 a	0.42 b	0.21 a	0.20 bc	3.31 a	0.008 ab
75	1.68 ab	0.97 a	1.29 a	0.26 c	0.22 a	0.21 b	2.33 a	0.004 b
95	0.48 c	0.59 b	0.44 b	0.14 d	0.10 b	0.07 d	3.37 a	0.006 b

[z]Ratio of top dry weight to root dry weight.
[y]Leaf dry weight per unit area.
[x]Mean separation within columns in each plant by DMRT, at 5% level.

chlorophyll contents under shade condition than shade intolerant plant (Boardman, 1977).

Therefore, we concluded that *H. rhombea* and *P. terminalis* are shade tolerant plants. Carotenoid content was highest under 95%. It was consistent with the report that carotenoid content of *Ficus benjamina* increased under shading condition (Lance and Guy, 1992). Carotenoids serve as accessory pigments which help chlorophyll for light absorption under low irradiance condition, and play an important role in photoprotection of chlorophyll under high irradiance (Taiz and Zeiger, 1991).

Fresh and Dry weight

Fresh weight of leaf, stem, and root of both plants were high under 35, 55, and 75% shade conditions (Table 4). As the shading level increased from 35%, dry weight of leaf, stem, and root were significantly declined in *H. rhombea*. T/R ratio was high under mild shading condition from 35 to 75%, indicating more top growth than control. Specific leaf weight tended to decrease with reduction of light intensity. In *P. terminalis* leaf dry weight was highest in 35% shading. Stem and root dry weight were also high under shading, except 95% shading. T/R ratio did not show a significant trends. Specific leaf weight showed the same result as in *H. rhombea*.

Allard et al. (1991) reported that production of total plant dry matter was reduced at low irradiance. And shoot/root ratio as well as leaf area ratio (leaf area per plant dry weight) were higher for plants grown at low irradiance than for those grown at high irradiance. At low irradiance, partitioning of dry matter among plant parts and development processes within the leaf blade were shifted to favor production of leaf blade area per unit dry matter. Fitter and Hay (1983) also suggested that increased leaf area ratio and low specific leaf weight indicate an increased investment of energy into the enlargement of the light interception surface and can, as such, be regarded be beneficial to plant survival under low light conditions.

However, *H. rhombea* and *P. terminalis* showed a decrease in fresh and dry weight under 0% shading condition. It may be due to photoinhibition under high light intensity (Öquist et al, 1992).

Thus, optimum light intensity for growth of them may be 35 and 55% shading of incident sunlight. In addition, it is possible to grow them under even 75% shading of incident sunlight.

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차광수준이 송악과 수호초의 생육에 미치는 효과

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초　록

본 연구는 차광수준이 송악과 수호초의 생육에 미치는 효과를 알아보기 위해 차광수준을 입사광의 0, 35, 55, 75, 그리고 95% 수준으로 실시하였다. 송악은 95%에서 생육이 억제되었으며 직립형의 성질을 나타냈고, 수호초는 35%에서 초장이 가장 높게 나타났다. 분지수는 차광수준에 따른 차이를 보이지 않았으며, 줄기의 직경과 초장은 35%부터 95%로 차광률이 높아지면서 감소하였다. 잎의 생장은 35%와 55% 차광수준에서 가장 좋았으며, 75%에서도 생육이 좋아서 내음성이 양호한 것으로 생각되었다. 잎은 광도가 감소함에 따라 길어졌으나, 95% 차광시에는 대조구보다 짧게 나타났다. 전체 엽록소, 엽록소 a, b 함량 및 엽록소 a/b 비율은 차광에 의해서 대조구보다 다소 증가하는 경향을 보여서, 95% 차광에서 가장 높게 나타났다. 생체중과 건물중은 35, 55, 75% 수준에서 대조구나 95% 차광수준에서보다 높았다. 비엽중은 광도가 감소함에 따라 감소하는 경향을 나타내었다. 이상의 결과로부터, 송악과 수호초의 생육에 적합한 광도는 35%~55% 차광수준이며, 75% 차광하에서도 생육에는 지장이 없을 것으로 보인다.

추가 주요어 : 지피식물, 광도, 내음성