Effects of Interior Plantscapes on Indoor Environments and Stress Level of High School Students

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Case studies were performed in two high schools (designated K and J) in Seoul, Korea in order to examine how in-class plantscapes consisting of ornamental plants affected the indoor environment and the stress level of students. Forty-two healthy female students, 16 to 17 years old, were assigned to classrooms with or without plantscapes. Although the differences were small, plants lowered the temperature, raised the relative humidity in the classrooms, and reduced the amount of airborne fine particles. Positive descriptors such as ‘clean’, ‘soft’, ‘comfortable’, and ‘fresh’ were used by the students to describe the classrooms with plants in both schools after installation of the plants. The stress level of the students was lower in rooms with plants than without in school K and but not in school J; students in control rooms in both schools did not show a significant change in stress. Saliva cortisol content, a physiological indicator of stress, was not reduced by the presence of plants in either school; however, the number of visits to the infirmary was lower for students in rooms with plants than in the control rooms at both schools. The results indicate that the presence of plants improved the physical environment, the general ambience (i.e., appropriate place for classes’ and ‘relaxed place’), and reduced the level of stress among the students. The role of the interior plantscapes in living spaces is discussed.

Key Words: classroom, image profile, relative humidity, saliva cortisol, temperature.

Introduction

Plants are known is exert positive physical and psychological effects on humans and contribute to the reduction of and recovery from stress (Lee and Lee, 2001; Lohr et al., 1996; Parsons et al., 1998; Son et al., 1997; Yhang, 1995; Yoon et al., 1997). In these reports, the influence of plants on emotional and physical changes, such as relaxation or stress reduction, were examined in experimental rooms or green spaces using the principles of horticultural therapy and healing landscapes. The concurrent assessment of environmental and emotional effects conferred by ornamental plants an actual living space, however, has been little studied (Fjeld, 2000).

Depression and/or stress among high school students is associated with age, gender, tobacco use, sexual behavior, school grade, and other factors (Brooks et al., 2002). In particular, stress has a greater impact on depressive symptoms in girls than boys (Schraedley et al., 1999) and girls are at risk for developing depression because they experience more challenges in early adolescence than boys (Petersen et al., 1991). Korean high school students often experience extensive stress due to intense competition for entrance in universities (Kang and Jung, 1999). Due to the effect of plants on humans, it was of interest to assess the possible beneficial effect of indoor plants on the classroom environment and general well-being of the students.

Personal stress can be assessed via several methods (e.g., using a specially designed questionnaire (Jung, 2000) and physiological tests, such as the saliva cortisol level). Salivary cortisol measures hypothalamic–pituitary–adrenal (HPA) activity in relation to stress and is based on plasma unbound cortisol and salivary cortisol being highly correlated. For example, plasma cortisol significantly increased in male medical students during examinations (Lavallo et al., 1986). Likewise, saliva samples can easily be obtained noninvasively (Bohnen et al., 1991; Buchanan et al., 1999; Melamed et al., 1999).

In the following study, we examined the effect of
classroom plantscapes on the physical environment, the student’s image of their environment, and the level of stress perceived by the students.

**Materials and Methods**

**Subjects**

Students in the 2nd grade of two women's high schools (designated K and J) in Seoul participated in the study. Sixty-eight students in high school K and 72 students high school J were between the ages of 16 to 17. Twenty-three students in K and 19 students in J participated in all experiments. Forty-five students in K and 53 in J participated only in the health assessment portion of the experiment.

**Methods**

The experiment was conducted for 15 weeks between March to July 2003. Mental stress, saliva cortisol, and physical symptoms were assessed three times; 1) one week prior to installation of the plants, 2) six weeks after installation, and 3) at the termination of the test. In order to assess conditions under similar stress levels, the mid (2) and post (3) surveys were performed during mid-term and final exams. The health of each student was assessed using the number of days late, absences, and leaving early, the number of visits to the infirmary, and medications used. The indoor physical environment of the classrooms was checked throughout the experiment for temperature, humidity and indoor fine particles.

**Interior plantscape**

The use of the term plantscape indicates that the plants were not merely placed in the room but were arranged in a manner to maximize their impact on the student’s environment. Plants were positioned in the classroom to create a favorable green view rate of 30% (Lee and Bang, 1996), such that the plants and furniture gave an attractive, natural image (Lee, 1994). The plant height of 85 cm was based on the desk height of students (74 cm); the plantscape accounted for about 5% of the overall volume of classroom (Fig. 1).

Since the reduction of volatile organic pollutants in the air by plants depends on the species present and the composition of the volatiles, several species of plants were used to maximize the beneficial effect on indoor air quality (Son et al., 2000). Based on previous data, the species included in the test were *Spathiphyllum wallisii*, *Nephrolepis exaltata* ‘Bostoniensis’ (Turner, 1994), *Pachira aquatica*, *Scindapsus aureus* (Son et al., 1998; Son et al., 2000), *Acorus gramineus*, *Araucaria excelsa*, *Kalanchoe blossfeldiana*, *Pilea cadierei* ‘Guillaum’, *Rhododendron schippenbachii*, and *Guzmania* sp.

**Temperature and relative humidity**

The temperature and relative humidity were monitored at the same time on a weekly basis. During the month of May, information was monitored continuously using an HOBO data logger (H8 Logger for RH/Temp/Light/External, Onset, Bourne, USA).

**Measurement of particulate matter in the air**

Collection dishes were placed in three locations in each classroom and checked once a week (Lohr and Pearson-Mims, 1996). The dishes were initially dried for 24 hours at 60°C and the weight recorded. They were subsequently placed in each of the rooms and collected a week later, redried, and weighed.

**Questionnaire**

The questionnaire included demographic questions, satisfaction with classroom environment, image profile of classroom (Kim, 1993), medical records, and medications currently being taken. Each question about satisfaction with classroom environment and image profile of classroom was composed of 5 stages.

**Stress measurement**

The individual students' personal level of stress was assessed using a stress measurement questionnaire (Jung, 2000). It was comprised of 58 questions to be answered by each of the students, addressing: study and school life (16); personal relations (10); domestic problems (11); individual problems (10); and environmental problems (11). Each question was composed of 5 stages.
Saliva cortisol

Cortisol concentration was measured in saliva samples collected between 2 and 5 o’clock PM. The students rinsed their oral cavity with cold water 15 minutes before sampling; the saliva sample was placed in a plastic container and frozen for mucin precipitation. The cortisol concentration was determined a radioimmunoassay procedure (i.e., Coat-A-Count Cortisol Kit, Diagnostic Products Co., Los Angeles, USA) by a commercial laboratory in Seoul.

Health condition

A general assessment of the overall health condition of the students was determined using the numbers of days the students were late for class, absences, leaving school before the end of the day, and the number of visits to the infirmary. Sixty-eight students were monitored (34 in the experimental group and 34 in the control group) for school K and 72 students for school J (35 in the experimental group and 37 in the control group).

Analysis

JMP (SAS Institute, Inc., Cary, N.C. USA) statistical software program was used for all statistical analyses. Wilcoxon’s rank test was used to test for satisfaction with classroom environment and image profile of classroom, ANOVA for stress and cortisol, and t-test for environment conditions.

Results

Effects of interior plantscape on environmental conditions

The room temperature, relative humidity, and indoor fine particles were determined to assess the effect of the plants on the physical conditions within the rooms. The monthly mean temperature of the rooms with plantscapes was significantly lower (0.6°C) than the control rooms (P<0.05) in school K and 0.4°C (P<0.001) in school J (Fig. 2). The monthly mean relative humidity in the rooms with plants was 4% higher than control rooms (P<0.001) in school K and 8% (P<0.001) in school J (Fig. 2). The amount of fine particles collected in both the plantscape and control rooms showed similar curves; however, the rooms with plants had statistically lower values than the control rooms in both school [i.e., school K (P<0.05); school J (P<0.05)] (Fig. 3).

Effects of interior plantscape on image profiles and environment questionnaire

The student’s general image of the classrooms containing plants indicated higher ratings for positive descriptors such as ‘clean’, ‘soft’, ‘bright’, ‘comfortable’, and ‘fresh’ (Fig. 4). Two descriptors (i.e., ‘warm-cold’ and ‘active-calm’) were not statistically significant in both schools.

In school K, 31% of the students were ‘very dissatisfied’ with the classroom environment (i.e., an appropriate place for classes) before the introduction of the plantscape; this dropped to 0 after the plants were added. Similarly, the 31% that were ‘dissatisfied’ decreased to 15% (Table 1). The number of students that were initially ‘satisfied’ with the environment before introduction of the plants increased from 7 to 23%. Collectively, there was a significant improvement in the students’ perception of their learning environment between before and after installation of the plants (P<0.05) in school K; a similar trend was found in school J (P<0.01). For assessment of the classroom as an ‘appropriate place for classes’, none of the students was ‘dissatisfied’ before the introduction of the plants; however, after introduction of the plantscape, ‘moderate’ decreased from 92% to 33%, ‘satisfied’ increased from 8% to 42%, and ‘very satisfied’ from 0 to 25%, indicating that the students’ degree of satisfaction with the classroom increased substantially with the addition of the plantscape (Table 1). Collectively, a significant difference was observed between the answers before and after installation of the plantscape using Wilcoxon’s rank test (P<0.01).

In school K, the students’ assessment of the classroom as a ‘relaxed place’ changed from 38% ‘very dissatisfied’ before installation to 0% after; similarly ‘very dissatisfied’ and ‘dissatisfied’ decreased from 53% to 23% (Table 2). The percentage of ‘satisfied’ and ‘moderate’ responses increased accordingly. In school J, the students that were ‘satisfied’ increased from 0% to 33%, while ‘dissatisfied’ decreased from 33% to 8% and ‘very dissatisfied’ was from 17% to 0% (Table 2). Changes in the assessment of the classroom as a ‘relaxed place’ were not significantly different (P = 0.0565) in school K, but were significant (P<0.001) in school J and, collectively, highly significant (P<0.001) between before and after installation of the plantscapes.

Changes in stress level and saliva cortisol before and after installation of the plantscape

The level of stress in students in the room with plants in school K was significantly lower than that in the control room (Table 3). Changes were especially seen in the study and school life section and personal relations section. In school J, there were no significant changes in either group (Table 3).

The cortisol content of saliva of students in school K increased mid-test and significantly decreased post-test in both groups (Table 4). In school J, saliva cortisol contents did not show significant changes (Table 4).

Changes in health conditions before and after installation of the plantscape

Based on infirmary records, the numbers of visits (excluding external wounds due to accidents) decreased in both schools after installation of the plantscapes, while visits by students in the control rooms increased with
time (Fig. 5). The monthly average was 5.9 (both schools) in the experiment group, significantly ($P < 0.05$) lower than 10.2 in the control group (Fig. 5).

The numbers of days (9 in School K, 118 in school J) the students were late for class, absences, and leaving school before the end of the day for experiment rooms of both schools were lower than those (12 in School K, 141 in school J) for control rooms, but were not statistically significant (data not shown).

**Discussion**

The installation of plantscapes favorably affected the environmental conditions in the classrooms (Figs. 2 and 3). Although the differences were small, plants in the classrooms decreased the temperature and increased the relative humidity (Fig. 2). These results are in accord with the previous work reported by Son et al. (1998) and Jung and Park (1999). Both the temperature and relative humidity in the classrooms of the experiment groups were closer to what is considered a comfortable range (Lee, 1990; Rhee and Yoon, 1998) than in the control classrooms. The mean temperature of the rooms with plantscapes was lower than the control rooms especially in the morning and daytime (data not shown), suggesting that transpiration by plant photosynthesis and evaporation from soils might be involved. The increased relative humidity was due to transpiration by the plants and evaporation from the media within the plant pots (Asumi et al., 1995).

The amount of fine particles in the air of the

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**Fig. 2.** Change in temperature and relative humidity in treatment (solid line) and control (dotted line) classrooms of school K (A) and J (B) from March to July.

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classrooms with plants was significantly less than that of control rooms (Fig. 3), substantiating earlier work by Lohr and Pearson-Mims (1996) and Lohr et al. (1996) that tested the effect of plants in a computer laboratory and an office. The effects of plants on improving the environment (e.g., temperature, humidity, and fine particles) were further substantiated using the student questionnaire.

Plants in the classroom improved the student's perception of their environment (e.g., 'clean', 'soft', 'comfortable', and 'fresh') in both high schools with the exception of 'warm-cold' in school J (Fig. 4). Lohr and Pearson-Mims (2000) also reported that foliage plants increased positive perceptions such as 'fresh air' and 'comfortable'. Likewise, plants and fluorescent lighting increased positive descriptors such as 'brighter', 'comfortable', and 'good air quality' (Fjeld, 2000).

The stress level was lower in the plantscape room than in the control room in school K but not in school J (Table 3). In both instances, students in the control rooms did not show any significant changes in any of the assessment periods. Improvements in the physical environment and the students' positive perception of their classroom environment due to the presence of plantscapes are reflected by increased positive characterizations such as 'appropriate place for classes' (Table 1) and 'relaxed place' (Table 2) and reduced stress among the students.

Saliva cortisol content was not reduced by the plantscapes in either school (Table 4). Saliva cortisol is a popular measure of HPA activity in related to human stress (Bohnen et al., 1991; Buchanan et al., 1999; Melamed et al., 1999). Buchanan et al. (1999) suggested that HPA is a dynamic system influenced by changes with negative effects; for example, plasma cortisol significantly increased in male medical students during examinations (Lavall et al., 1986). The cortisol level
Table 1. Responses to the statement: “The classroom is suitable for study”, before and after introducing the interior plantscape in schools K and J.

<table>
<thead>
<tr>
<th></th>
<th>Very satisfied</th>
<th>Satisfied</th>
<th>Moderate</th>
<th>Dissatisfied</th>
<th>Very dissatisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>School K</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>0% (0)</td>
<td>7% (1)</td>
<td>31% (4)</td>
<td>31% (4)</td>
<td>31% (4)</td>
</tr>
<tr>
<td>After</td>
<td>0% (0)</td>
<td>23% (3)</td>
<td>62% (8)</td>
<td>15% (2)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>Significance</td>
<td>* (n=13)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>School J</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>0% (0)</td>
<td>8% (1)</td>
<td>92% (11)</td>
<td>0% (0)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>After</td>
<td>25% (3)</td>
<td>42% (5)</td>
<td>33% (4)</td>
<td>0% (0)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>Significance</td>
<td>** (n=12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Percentage (frequency of responds).
** indicate significant at \( P < 0.05 \) or \( P < 0.01 \) by Wilcoxon’s rank test using semantic scale data transformed as follows: very satisfied = 1, satisfied = 2, moderate = 3, dissatisfied = 4, and very dissatisfied = 5.

Table 2. Responses to the statement: “The classroom is suitable for relaxing”, before and after introducing the interior plantscape in schools K and J.

<table>
<thead>
<tr>
<th></th>
<th>Very satisfied</th>
<th>Satisfied</th>
<th>Moderate</th>
<th>Dissatisfied</th>
<th>Very dissatisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>School K</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>0% (0)</td>
<td>8% (1)</td>
<td>39% (5)</td>
<td>15% (2)</td>
<td>38% (5)</td>
</tr>
<tr>
<td>After</td>
<td>0% (0)</td>
<td>15% (2)</td>
<td>62% (8)</td>
<td>23% (1)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>Significance</td>
<td>NS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>School J</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>0% (0)</td>
<td>0% (0)</td>
<td>50% (6)</td>
<td>33% (4)</td>
<td>17% (2)</td>
</tr>
<tr>
<td>After</td>
<td>8% (1)</td>
<td>33% (4)</td>
<td>51% (6)</td>
<td>8% (1)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>Significance</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Percentage (frequency of responds).
NS, **, *** indicate non-significant, significantly different at \( P < 0.01 \) and \( P < 0.001 \) by Wilcoxon’s rank test using semantic scale data transformed as follows: very satisfied = 1, satisfied = 2, moderate = 3, dissatisfied = 4, and very dissatisfied = 5.

Table 3. Changes in stress values pre-, mid-, and post-experiment with or without the plantscape in schools K and J.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Pre-Test(^a)</th>
<th>Mid-Test</th>
<th>Post-Test</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>School K</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>120.9 ± 37.7(^b)</td>
<td>130.2 ± 45.1 (1.08)</td>
<td>130.2 ± 44.1 (1.07)</td>
<td>(1.08)</td>
</tr>
<tr>
<td>Plantscape</td>
<td>132.3 ± 35.2</td>
<td>115.4 ± 22.9 (0.89)</td>
<td>121.7 ± 36.7 (0.92)</td>
<td>(0.91)</td>
</tr>
<tr>
<td>Significance(^e)</td>
<td>Plants *</td>
<td>Time NS</td>
<td>Plants x Time NS</td>
<td></td>
</tr>
<tr>
<td><strong>School J</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>128.3 ± 25.3</td>
<td>117.1 ± 27.9 (0.91)</td>
<td>118.0 ± 34.5 (0.92)</td>
<td>(0.92)</td>
</tr>
<tr>
<td>Plantscape</td>
<td>103.7 ± 19.0</td>
<td>100.6 ± 16.5 (0.99)</td>
<td>105.0 ± 20.4 (1.04)</td>
<td>(1.02)</td>
</tr>
</tbody>
</table>

* Pre-Test: before introduction of the plantscape, Mid-Test: 7 weeks after the introduction of the plantscape (mid-term), Post-Test: 15 weeks after introduction of the plantscape (termination of experiment).
\(^{b}\) Mean ± SD. Control group (n = 10) and plantscape group (n = 13) in school K. Control (n = 7) and plantscape (n = 12) in school J.
\(^{c}\) Mid- and Post-Test data were standardized by Pre-data; raw data were divided by Pre-data.
\(^{d}\) NS: non-significant; * significant at \( P < 0.05 \) by 2-way ANOVA. Factors were treatment (control and plantscape) and time (Mid- and Post-Test).
was especially high at mid-term in school K (Table 4), perhaps due to the proximity of examinations or other factors (Brooks et al., 2002) that might influence the level.

The positive benefit of plants in classrooms is also indicated by the decreased number of students visiting the infirmary when compared with the control rooms in both schools (Fig. 5). Fjeld (2000) reported a significant reduction in neuropsychological symptoms (headache, concentration problems) and in mucous membrane symptoms (itching eyes, dry or hoarse throat) in office workers and students in environments with plants. The presence of interior plants (Lohr and Pearson-Mims, 2000) and simply viewing trees (Ulrich, 1983) have been reported to reduce physical discomfort and pain.

These results indicate that additional studies on the effect of adding plants to rooms in which the occupants are under some degree of stress should be continued. It appears that there may be a time lag between the introduction of plants and changes in the subjects. Previous experiments focused predominately on the measurement of physical changes induced by simply looking at plants or landscapes while sitting in a specific place (Lee and Lee, 2001; Son et al., 1998; Yi, 2003).

The positive effect of indoor gardens (plantscapes) on the physical environment and students in classrooms was confirmed; however, the results of satisfaction with the classroom environment and the students’ image of the classroom did not show the same change in school K and J (Fig. 4 and Tables 1 and 2). The plants were arranged in a similar ratio in consideration of the size of the classroom of each experimental group, but the structure of the classroom in school J required the plants to be placed only on one side, adjacent to where the students sit, while in school K the students were exposed to a much broader views of the plants. In order to efficiently enhance the effect of plants (e.g., stress reduction and immunity improvement), it is recom-

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**Table 4.** Changes in saliva cortisol levels (µg/dL) during pre, mid, and post experiment with or without plantscape in the classroom in schools K and J.

<table>
<thead>
<tr>
<th></th>
<th>Pre-Test</th>
<th>Mid-Test</th>
<th>Post-Test</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>School K</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.065 ± 0.030</td>
<td>0.162 ± 0.108 (3.01)</td>
<td>0.119 ± 0.091 (2.02)</td>
<td>(2.51)</td>
</tr>
<tr>
<td>Plantscape</td>
<td>0.088 ± 0.0030</td>
<td>0.247 ± 0.124 (3.13)</td>
<td>0.130 ± 0.084 (1.79)</td>
<td>(2.46)</td>
</tr>
<tr>
<td>Significance*</td>
<td>Plants</td>
<td>NS</td>
<td>Time</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Plants × Time</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>School J</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.096 ± 0.050</td>
<td>0.070 ± 0.057 (0.80)</td>
<td>0.106 ± 0.048 (1.54)</td>
<td>(1.17)</td>
</tr>
<tr>
<td>Plantscape</td>
<td>0.100 ± 0.047</td>
<td>0.078 ± 0.110 (0.80)</td>
<td>0.073 ± 0.067 (0.83)</td>
<td>(0.82)</td>
</tr>
<tr>
<td>Significance</td>
<td>Plants</td>
<td>NS</td>
<td>Time</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Plants × Time</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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* Pre-Test: before introduction of the interior plantscape, Mid-Test: 7 weeks after introduction of the plantscape (mid-term), Post-Test: 15 weeks after introduction of the plantscape (termination of experiment).
* Mean ± SD. Control group (n = 10) and plantscape group (n = 13) in school K. Control (n = 7) and plantscape (n = 12) in school J.
* Mid- and Post-Test data were standardized by Pre-data; raw data were divided by Pre-data.
* NS: non-significant; * significant at P < 0.05 by 2-way ANOVA. Factors were treatment (control and plantscape) and time (Mid- and Post-Test).

**Fig. 5.** Comparison of the number of student visits to the school nurse in rooms with and without plantscapes in schools K (A) and J (B).
mended to investigate the preference of occupants and the overall visual impact of the proposed arrangement of the plants. In addition, only female students were employed in this study. Further studies are needed to better determine the potential of interior plants to enhance the perception of well-being by both sexes.

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Literature Cited


