THE EFFECT OF PLANTS AND ARTIFICIAL DAY-LIGHT ON THE WELL-BEING AND HEALTH OF OFFICE WORKERS, SCHOOL CHILDREN AND HEALTH CARE PERSONNEL

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INTRODUCTION

For centuries it has been assumed, both in Western and Eastern urban civilisations, that visual contact with plants or other natural elements might stimulate psychological well-being and have beneficial effects on man (Ulrich and Parsons, 1992). The first documented political interest in people's need for greenery dates back to the time when ancient Rome became urbanised. As the city became noisy and overcrowded, the inhabitants complained that life became very stressful. They found that the countryside or the gardens of Rome were the only places where they experienced complete recreation (Grahn, 1994).

Today, plants are widely used in urban environments, both outdoor and indoor. Only recently, however, have attempts been made to test the effect of plants on human well-being. If scientific studies could bring forward convincing evidence for beneficial effects of plants on human health and well-being, increased interest and priorities for plants might be obtained among decision makers and the public in general, and the use of plants indoors could receive an additional dimension to the pure ornamental.

Therefore, studies were started in Norway some years ago to determine the extent that indoor greenery affects health and well-being of people who spend most of their working day inside.

EXPERIMENTS AND RESULTS

Study 1. Effects of indoor foliage plants on health and discomfort symptoms among office workers

A cross-over study was conducted among 51 offices - one period with plants and one without plants in the office. All participants worked in identical single offices, with a floor area of 10 m^2 and a window covering most of the outer wall. The participants were exposed to 13 commonly used foliage plants placed in three containers on the window bench, and a terracotta container with plants in the back corner of the office.

The participants completed a questionnaire every second week with 12 different questions regarding health and discomfort symptoms over two three-month periods during the springs of 1995 and 1996. The scores should reflect problems *the same day* as the questionnaire was filled in. Each symptom was given one of the following scores: 0 (no problems), 1 (minor problems), 2 (moderate problems) and 3 (severe problems).

It was found that the score sum as a mean of 12 symptoms was 23 % lower during the period when the participants had plants in their offices, than when there were no plants. (Mean score sum was 7.1 during the period without plants, *vs* 5.6 during the period with plants (P=0.002)). Plant intervention reduced complaints such as coughing and fatigue by 37% and 30 % respectively, while the self-reported level of dry or hoarse throat and dry or itching facial skin each decreased by approximately 23 % (Fig. 1). If the symptoms were clustered, a significant reduction was obtained in neuro-psychological symptoms and in mucous membrane symptoms, while skin symptoms seemed to be unaffected by the plant intervention (Fjeld et al. 1998)

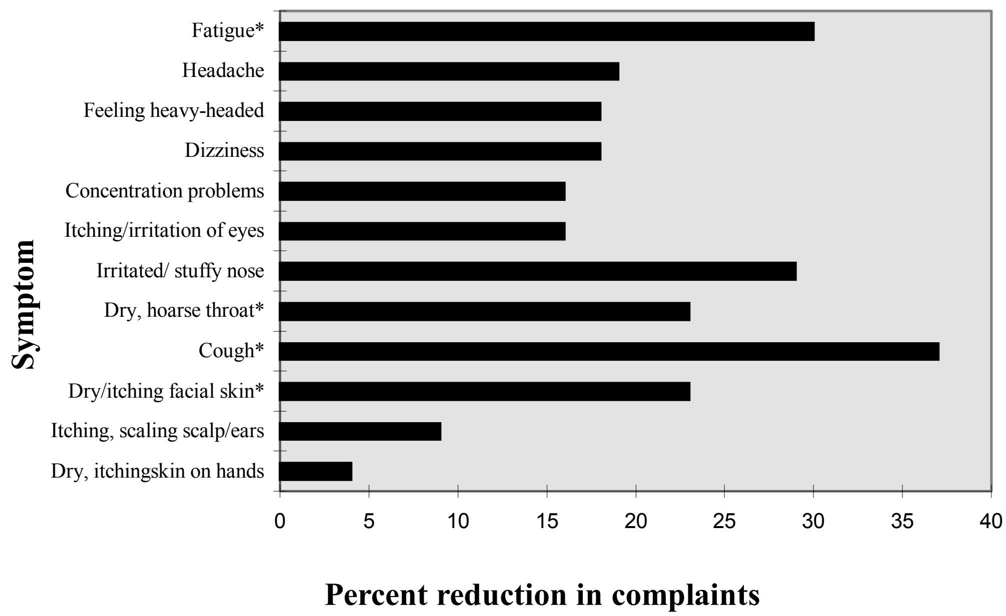

Fig. 1. Percent reduction in complaints of 12 health and discomfort symptoms during the period. *: Significantly reduced (Significance level 5%). (Fjeld et al. 1998).

Study 2. Effects of indoor foliage plants together with full-spectrum fluorescent light on health and discomfort symptoms among personnel working in a hospital radiology department

Information regarding 12 different health and discomfort symptoms were sampled among 48 employees. The information was collected by means of a questionnaire (as used in study 1) four times during September and October 1997, to record the pre-intervention level of the health situation among the employees.

The location was a room of approximately 80 m^2 with no windows and no natural light. The room was used for the examination of X-ray films. In the middle of November the room was changed as follows: 23 units/containers with one or more commonly used indoor foliage plants were placed in the room. Light sources in the ceiling and in the film viewers were changed to full spectrum fluorescent light (True-Lite form Duro-Test). Health and discomfort information was sampled 5 times during November-February.

A 25 % decrease in complaints was observed after introducing plants into the rooms and changing to full spectrum light (mean score sum was 9.0 before intervention, *vs* 6.7 after intervention, (P= 0.001)), with particularly significant effects for the following symptoms: fatigue, feeling heavy-headed, headache, dry, hoarse throat and skin symptoms on hands. Grouping subjects by percentage of work time spent in the planted location, showed a 34% decrease in complaints among those who spent most of their day in the room, compared to 21% and 17 % respectively among those working approx. 50% or less than 40% in the room.

Table 1. Mean score of 12 symptoms. Symptom scores indicate the self-experienced health and discomfort the same day as the questionnaire was completed. Number of subjects: 48. 0=no symptoms, 1=minor symptoms, 2=moderate symptoms, 3=severe symptoms.

Symptom	**Before inter-vention**	**After inter vention**	**P-value**	**% change after intervention**
Fatigue	1.24	0.84	0.001	-32
Feeling heavy-headed	1.16	0.78	0.004	-33
Headache	0.72	0.40	0.009	-45
Feeling dizzy	0.20	0.15	0.297	-25
Concentration problems	0.40	0.41	0.778	2,5
Itching, irritated eyes	0.66	0.56	0.298	-15
Irritated/«running»/stuffy nose	0.81	0.72	0.589	-11
Dry, hoarse throat	0.97	0.76	0.0009	-22
Cough	0.34	0.21	0.84	-38
Dry, irritated facial skin	0.79	0.70	0.146	-11
Scaling, itching scalp or ears	0.37	0.30	0.256	-19
Dry/itching skin on the hands	1.23	0.97	0.0025	-21

No changes in the concentration of fungi spores were observed due to the introduction of plants and improved lighting (Fjeld & Bonnevie 1999).

The department head reported that short term absence due to sickness decreased from approximately 15 % to 5-6 % during the period that this experiment took place, which according to her were mainly due to the changes in the environment (Langli, T. pers. com.)

A follow-up study by Bingen et al (1999) showed that complaints due to health and discomfort 11 months after the introduction of plants and lighting improvements remained at a lower level than before intervention.

Study 3. Effects of indoor foliage plants and full-spectrum fluorescent light on health and discomfort symptoms among school children

Significant problems with the indoor air quality in the classrooms was the background for establishing a total of 6 classrooms with plants and full-spectrum fluorescent lighting in two Norwegian schools. Six additional classes were kept as control classes. In August 1998 the six classrooms were supplied with tropical, indoor plants in a Bioprosess system (indoor air flows through the soil/root-zone). The light source was changed to full-spectrum fluorescent lamps (True-Lite from Duro-Test), and the irradiance level was increased to 600-800 lux. At the junior high school windows were changed to improve airflow.

From April 1998 to April 1999 a survey was conducted among pupils and teachers, using 4 different questionnaires. Information regarding well-being, health and discomfort symptoms, as well as the ability to work in a concentrated manner, was sampled

The results indicated significant changes due to the change in the indoor environment: The semantic survey showed that pupils in intervented classrooms gave a more positive evaluation of their classrooms than the control-group. The self-experienced indoor air quality was also rated higher among pupils who worked in the planted classrooms (Table 2).

Table 2. Change in satisfactory level of 7 characteristics in the classroom between April 1998 and April 1999. A decrease in score-level means that the pupils are more satisfied with their classroom. (Fjeld et al. 2000)

Characteristic	**Control**	**Intervention group**	**P-value**
Exiting – Boring	+0.46	+0.04	0.006
Special – ordinary	-0.06	+0.20	0.18
Beautiful – ugly	+0.73	-0.10	0.0000
Sufficient space – little space	+0.48	+0.37	0.57
Bright – dark	+0.29	-0.19	0.0015
Comfortable – uncomfortable	+0.45	-0.14	0.0009
Good air quality – poor air quality	+0.13	-1.20	0.0000

Sum of symptoms (sum of health complaints) was reduced by 9% during the project period among pupils in intervented classrooms, while the control group reported an increase of 12 % during the same period (Table 3). Pupils with asthma and/or allergic problems showed the same trend in symptoms as the rest (data not shown).

Table 3. Sum of symptom scores for 10 health and discomfort symptoms among control (n=148) and intervention group (n=140) of pupils. The DIFF presents the difference in sum of symptom scores between April 1998 and April 1999. (Fjeld et al. 2000)

Time	**Control**	**Intervention**
April 1998	11.9	12.2
November 1998	13.0	10.1
February 1999	13.5	11.9
April 1999	13.3	11.1
DIFF	1.4	-1.1
P-value	0.0013	

Complaints of fatigue, eye irritation, as well as coughing, were significantly lower among pupils in intervented classrooms. A significantly higher ability to work in a concentrated manner was found among pupils who had plants in their classrooms. These pupils also showed a significant reduction in sickness absence during the school year 1998/99.

A 35 % lower concentration of volatile organic compounds was found in classrooms with plants. There were, however, no differences in fungi spores between the two types of classrooms – which means that plants and growth medium seemed to have no effect on presence of fungi or fungi spores (Fjeld et al. 2000).

Study 4. Evaluation of the use of foliage plants and artificial day-light among office workers on health and discomfort complaints, well-being and sickness absence.

Building on the background of the previous studies, there was a need for trying to separate effects of plants from effects from artificial day-light. A small investigation was established among workers in Nordea Bank, Oslo, during the period November 2001 –March 2002. All together 48 office workers participated. Information regarding health and well-being was sampled from the participants twice before intervening the work environment, and three times after intervention. The work environment was intervened as follows: 16 people had plants on their office tables close to their personal computer, 10 people were given a new light environment by changing the light sources to a more day-light-like spectrum, 10 people received both plants on their work tables, as well as a new light environment, while 12 people served as a control group.

Table 4. Effects of different work environments on self reported health and discomfort complaints among office workers. 1 = no complaints 2 = a little, 3 = some, 4 = severe complaints. Participants reported how they had felt during the last week. (Fjeld and Bonnevie 2002)

COMPLAINTS↓	**ENVIRONMENTAL CHANGE ⟶**	**Plants**	**New Light Env.**	**Plants + New Light**	**Control**	**Sign. level**
Fatigue		2.1	2.4	2.2	2.5	Ns
Heavy headed		2.1	2.3	1.6	2.6	***
Headache		1.7	1.7	1.4	2.1	*
Concentration problems		1.7	1.9	1.9	1.9	Ns
Itching, irritated eyes		1.8	2.1	1.2	2.4	***
Dry, itching or irritated, hoarse throat		1.7	2.0	1.7	2.3	Ns
Cough		1.5	1.7	1.6	2.2	**
Dry, irritated facial skin		2.0	2.4	1.6	2.5	*
Dry, irritated skin on hands		2.2	2.7	1.5	3.0	***
Stiff, aching shoulders and/or neck		2.3	2.5	2.2	2.5	Ns
Mean level of complaints		**1.9**	**2.2**	**1.6**	**2.4**	***

Table 4 shows that the level of complaints was significantly lower among workers that had plants on their office tables. Lowest level of complaints was found if plants were supplied in combination with a change in light environment. A smaller reduction in complaints was found if only the light environment was changed to artificial day-light

Semantic evaluation of the work environment by the participants concluded that a change in light environment alone, did not affect the satisfaction level of the visual environment. By introducing plants on the work tables or establishing a combination of plants and a change in light levels, a significantly more positive evaluation of the work environment was reported: The score level was found to be 2.9 among the control group and the group of participants that got a change in light environment, as opposed to 2.4 if plants were introduced, and 2.2 if a combination of plants and new light environment was established (scores: 1 = very satisfactory, 3 = medium satisfaction level, 5 = very unsatisfactory) (Fjeld and Bonnevie 2002).

DISCUSSION

There may be several explanations for the results obtained:

1. Effect on air quality:

During the 1980's reports were published indicating that indoor plants may have the ability to reduce the level of chemical compounds in the air. Leaves, stems and roots work together with micro-organisms that live in the root zone, creating an ecosystem that can function as an air filtering system.

Bill Wolverton and his research group showed in laboratory studies that plants used as ordinary houseplants may reduce the level of different chemical compounds in the air. If the plants were exposed to high concentrations of chemicals in sealed growth chambers, the concentration was reduced by the plants. Chemicals tested were f. ex. formaldehyde, benzene, trichloroethylene, carbon mono-oxide and NOx. Approximately 20 different plant species were included (Wolverton et al. 1989).

More recent studies from Germany and Australia have confirmed the ability of plants and the ecosystem of plants and micro-organisms to be possible powerful air purifiers, even if the concentration of chemicals is low (Schmitz 1995, Wood et al. 1999). This air-purifying ecosystem will need a period of time (approximately 14 days) to adapt to the chemicals that occur in the air. The system seems to be independent of light – which means that the photosynthetic activity of the plants is less important than the symbiotic activity of roots and microorganisms – at least after the system has become adapted to the environment.

The human body is also able to detect changes in the indoor air quality far below the guideline concentrations, as shown by Forsberg and his team (1997) of occupational medicine experts. This means that even small changes in chemical impurities of the air, may influence health and discomfort symptoms.

Tests carried out both in the US and in the UK, have shown that plants may also increase the indoor air humidity. It has been shown that if the air is not ventilated, the increase in humidity may be from 0 to almost 15%. In a ventilated room, the increase may be 3-5 % (Lohr 1992a). Plant species with a high transpiration rate, increases humidity most. The numbers of plants will of course have a large impact. The humidifying effect of the plants might be important, since many indoor environments suffer from low air humidity.

Plants in a room may reduce the dust level of the air, as found by Lohr and Pearson-Mims (1996). The dust content of the indoor air is often too high, and might irritate mucous membranes in eyes and respiratory organs (throat, nose). An increase in air humidity may bind more of the dust, and thereby reduce the health complaints. The large leaf surface of plants probably promotes sedimentation of dust from the air, thereby reducing the dust level. We would expect that plants placed close to the computer – where both dust level and the level of static electricity is often high, might reduce irritations in respiratory organs caused by charged particles. The supposed changed micro-climate around the plant material is more likely to affect people's perception of the physical air quality if the plants are placed close to the persons, and at a place where people will be exposed for this micro-climate for some time during their working days. This corresponds with results found by van Dortmont and Bergs (2001), who concluded that work efficiency and well-being were significantly higher among workers that spent more than 4 hours at their computer desk if their desks were supplied with plants.

2. Psychological effects

Plants represent a part of the original ecological system in which the human species evolved. The plant species we know today, have been the same for approximately 140 million years. The development of the human being started only 3-4 million years ago, ending with the occurrence of *Homo sapiens* less than 50,000 years ago. In other words, the whole human evolution took place in close contact with nature and vegetation.

Interestingly, only very small changes in the biology, physiology and genetic constitution of man have occurred during the last period. We are basically the same sort of humans as we were in the Stone Age 10,000 years ago.

On the other hand, a tremendous change in the environment has taken place since then, especially during the very last period. The most significant changes started with the industrial revolution 250 years ago, leading to the modern urbanization of the last 50-100 years. Never- the-less, it often seems that today's modern man has forgotten that his existence was as a participant in the living biosphere, since this development has brought us from a situation in close contact with and dependence on nature, to a situation where we live surrounded by, and in close contact with artificial elements and manmade constructions.

The human being has a great ability to adjust to the environment, to new demands and to new situations. On the other hand, we find significant indications of the fact that this adjustment has its limits. The increase in asthma, allergy, diabetes and cardio-vascular illnesses indicates that the steadily increasing number of artificial elements in our environment, the change in our diet, and the reduced physical activity, and possibly even an increase in mental stressors, are exceeding the flexibility of our biological system. It should on the other hand, not be too difficult to foresee that the body would respond this way, since we know that it was developed to cope with the challenges from nature and natural occurring components. In addition no significant genetic changes have occurred the last 100 years to adjust the human body to the new, man made, more or less artificial environment.

In terms of the psychological aspects of our health and well-being, modern lifestyle also exposes man to new situations. Studies of how the environment and our surroundings affect us mentally, are called environmental psychology. Studies in this field have clearly shown that well-being and levels of psychological and physiological stress are significantly influenced by our surroundings.

Our studies support the view that settings with predominant vegetation are preferred among humans. According to Ulrich and Parsons (1992) this seems to be independent of their cultural background. View-settings with dominant vegetation can even foster restoration from stress (Ulrich et al. 1991). According to Roger Ulrich, environmental psychophysiologist at Texas A & M University, even a fairly brief visual contact with plants might be important for promoting restoration from the detrimental effects of commuting, work pressure and other stressors that most urbanites encounter daily.

Our urban lifestyle means that we - at least in the Scandinavian countries - spend 80 to 90 % of our time indoor. This should indeed underline the importance of the quality of the indoor environment, not only when it comes to the physical and chemical constitution of the indoor air, but also regarding how the indoor settings may affect us psychologically.

In an American study, graduate students were shown a stress-inducing movie from a work accident followed by either a videotape of urban environment lacking nature, or a videotape with natural (green) settings (Ulrich & Parsons 1992). The findings indicated that the recovery from the induced stress was much faster and more complete when the students were exposed to the natural settings, which was dominated by green vegetation. Greater recovery was indicated by faster and larger reduction in blood pressure and muscle tension.

Several studies show that even the view through windows may affect our well-being and health. In a hospital study the beneficial influences on patients of a natural view of nature from a bedside window were considered (Ulrich 1984). Recovery data after surgery were compared from two groups of patients that were essentially identical apart from their window view: one group of patients looked out onto trees, whereas the other had a view of a brick wall. Patients with the 'green' view had shorter post-operative hospital stays, required fewer injections of strong pain reducing drugs, and tended to have fewer minor post-surgical complications such as persistent headache or dizziness.

A Swedish study concluded that if office personnel could view greenery through their office windows, significantly less stress was reported during their working days compared with office workers that had view to non-vegetated areas, such as streets and parking lots (Grahn 1993).

Virginia Lohr at Washington University conducted a computer based test on students, and found that the systolic blood pressure was lower, and the performance, measured as reaction time during the test, was higher, if plants were present in the computer lab, than when they weren't (Lohr et al. 1996).

It is, thus, likely that indoor vegetation may change the environment in such a way that it corresponds better with our positive response patterns towards elements of nature, and hence may influence the measurable stress level in the body. When people intuitively express a positive preference for plants - indoor or outdoor, and thereby say that their well-being is improving, or that the environment is 'nice' or more relaxing, it probably reflects the interaction between the psychological effect and the physiological body response.

3. Effect of light environment

In three of the Norwegian studies, full spectrum fluorescent lamps were used, in order to establish a light environment that resembles natural daylight. A change in the light environment might have both visual and non-visual effects. Results of studies on seasonal affective disorder (winter depression known as SAD) give reason to believe that both light level and light quality might influence health and well-being - especially by having neuro-psychological effects (Lingjærde 1996, Slotten 1997, Rosenthal et al. 1984). Effects obtained in study 2 and 3 therefore might be an interaction of plant-effects and light-effects.

4. The 'Hawthorne' effect

An explanation of the findings in the Norwegian studies, may also be an effect of increased attention (or the so-called 'Hawthorne-effect') – employees responding positively because of the increased attention they are receiving during the project. In all studies in a practical work setting, people will be influenced by the psychological factor of receiving attention. An attempt to minimise this effect was performed in the office study by giving the control group the opportunity to have a nature poster on the office wall, and by giving them a little extra attention from the Health Care personnel.

In the radiology-department study, 6 of the participants were interviewed 11 months after intervention (Bingen et al. 1999) to get information on long-term effects. This follow-up clearly indicated that the effects of the changed environment were still having a significant impact. A 'Hawthorne-like' effect should, however, not withstand a duration of 11 months.

Thus, we consider this effect of increased attention to be of **minor** importance as an explanation in the present studies.

CONCLUSION

Our studies did not aim to separate possible factors that were interacting, and hence responsible for the results that we obtained. Therefore we are not able to quantify the effects **due to a change in air quality** from effects **due to psychological or stress-reducing responses.**

However, if the present Norwegian results are considered together with documentation from laboratory studies in plant physiology and documentation within the field of environmental psychology, the ability of indoor plants to act as an interesting tool in the effort of improving the indoor environment is clearly documented. We may even anticipate that use of indoor plants may affect productivity, work satisfaction and even absence due to sickness. From an economical point of view, it should be of great interest to include plants as a work environment asset, since only small investments are necessary in order to establish a "green" indoor environment. In addition - and probably just as important - the personal well-being and the quality of the every day working situation may be increased for the employees.

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