

A decorative graphic of a green vine with several leaves, curving across the top of the page.

HEALTH & GREEN LIVING AND WORKING WITH PLANTS

**Collected research about the benefits plants
can bring to the work environment**

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Section 1

Existing research about plants cleaning the indoor air of toxins (VOCs)

Dr Bill Wolverton conducted early research for **NASA (early 1990's, book first published 1996)** to prove that plants absorbed toxins from the air around them, translocated it to their roots, where organisms turned the toxins into food for the plant. Wolverton published a book after his research naming a number of plants which are accepted as the most effective.

Later research from **Dr Ronald Woods, University of Technology, Sydney, Australia (2001 & 2004)** did further research both in laboratory and real life settings to show that plants removed toxins from the indoor air. Wood used Kentia Palm, Dracaena and Spathiphyllum (Peace Lily) plants.

Meanwhile research in Norway found that air in schools was cleaner once plants were introduced. Plants used in this research project by **Professor Tove Fjeld (pronounced Tova y Feld), University of Agriculture, Oslo (19 98)** were: Aglaonema commutatum, Epipremnum aureum (Scindapsus aureum) and Dracaena deremensis.

Professor Margaret Burchett, University of Technology, Sydney commented on interim research results last year (**2009**) finding that all plants work in the same way i.e. all plants remove toxins from the air.

Andrew Smith, School of Built Environment, John Moores University, Liverpool (2008) conducted research in offices in Edinburgh to show that plants removed the toxins. Plants used: Ficus Alii, Philodendron Scandens, Dracaena Compacta, Scindapsus Aureum, Dracaena Gold Coast, Calathea Triostar, Schefflera Louisiana, Schefflera Arboricola, Schefflera Gold Capella, Spathiphyllum, Calathea Ornata Sanderiana, Calathea Beauty Star, Dracaena Lemon Surprise, Ficus Elastica Melany petit, Ficus Natasja, Peperomia USA and Peperomia Red Margin.

Dr Ronald Wood, University of Technology, Sydney (2004) calculated how many plants per room under certain circumstances were necessary to clean the air.

Kwang et al, National Horticultural Institute, Korea (2008) looked at how two plants absorbed formaldehyde in laboratory conditions. The two plants he used were Ficus benjamina and Fatsia japonica.

Section 2

Existing research about O2 and CO2 exchange between man and plants

Dr Bill Wolverton, NASA, USA (early 1990's, book first published 1996) discovered the symbiotic exchange of carbon dioxide and oxygen between man and plants

Dr Manfred Weidner, Botanical Institute, University of Cologne (1990s) considers the exchange and relates leaf surface area to the absorption of CO2

Andrew Smith, School of the Built Environment, John Moores University, Liverpool (2008) found that plants reduced CO2 by 50% in a planted open plan office

Prof Margaret Burchett, University of Technology, Sydney, Australia (2010) also acknowledges the biological/scientific exchange between man and plants

Bill & John Wolverton (1990s) show that some species of plants exchange oxygen/CO2 at night



Section 3

Existing research about plants reducing absenteeism

Prof Tove Fjeld's (University of Agriculture, Oslo, Norway 1996 - 2002) research in Norway in an office, schools and the x-ray department of a hospital all showed that with plants present both complaints about minor ailments often linked to Sick building syndrome and absenteeism were reduced

Tina Bringslimark's, (University of Agriculture, Oslo, Norway 2008) study also in Norway found that there was less self-reported sickness when plants could be seen from delegates' desks

Andrew Smith's (School of the Built Environment, John Moores University, Liverpool 2008) study (UK) found that absenteeism was reduced by 50% in a planted office

Dr Leivi Sandvic, Specialist for Medical Statistics, University of Oslo, Norway (1990s) found that when plants were present delegates' complaints of named conditions were reduced by 25%

Dr Eamonn O'Moore (1982) a 'natural view' is beneficial to prison inmates

Section 4

Plants reduce stress levels

Professor Virginia Lohr, Washington State University, USA (1996) found that plants reduced the physical signs of stress i.e. blood pressure, pulse rates and skin conductivity

Helen Russell at the University of Surrey (mid 1990s) carried out similar research to Virginia Lohr with similar results

Prof Roger Ulrich, Texas A & M University, USA (1984, 91, 92, 99 & 2001) found that plants or even green views decreased stress levels of recovering surgical patients assisting faster recovery

Prof Tove Fjeld, University of Agriculture, Oslo, Norway (1996 - 2002) sites environmental psychology and the way we live now as a stress factor

Tina Bringslimark, University of Agriculture, Oslo, Norway (2008) found that office workers reported less stress related sickness when they saw several plants from their desks

Dr John Hesselink, TNO in The Netherlands (1995) found that plants had an uplifting effect

Engelbert Kotter, Bavarian State Institute of Viticulture and Horticulture (2002) concluded that plant lovers more likely to be calm

Park and Mattson, Kansas State University, USA (2008) found that flowering plants have a good effect on surgical recovery

Prof Margaret Burchett, University of Technology, Sydney, Australia 2010 found that even one plant made a difference to mood reducing anxiety, stress and depression



Section 5

Plants increase concentration, performance, motivation, productivity, mood etc

Prof Virginia Lohr, Washing State University, USA (1996) found that people working with plants in the room were as much as 12% more productive

Prof Tove Fjeld's (University of Agriculture, Oslo, Norway 1997) installation of plants in the x-ray department of Oslo radiology hospital reduced tiredness/exhaustion and improved worker output; planted classrooms afforded an increase in student concentration of 23%

John Berg, DHV AIB, The Netherlands (1995) found that a plant on or by the desk of computer users improved concentration and therefore improved performance

Amanda Read, Royal College of Agriculture, Cirencester (2005) conducted research amongst students and found that concentration improved in lecture rooms with plants

Prof Margaret Burchett's (University of Technology, Sydney, Australia 2010) research showed that plants improved mood and therefore performance

Section 6

The effect of plants on our creativity

Prof Roger Ulrich, Texas A & M University, USA (2008) found that plants and flowers had a positive effect - +15% - on our creativity

John Hesselink, TNO, The Netherlands (2009) showed that plants had a positive effect on creative tasks except in production (repetitive tasks)

Shibata & Suzuki's (Bunko & Doshiba Universities, Japan 2003) study found that plants improve creative performance

Section 7

How plants affect our well-being in various settings

Hospitals

Prof Roger Ulrich, Texas A & M University, USA (1983 +) showed that plants could speed up recovery from major surgery and lessen medication necessity

Park & Mattson, Kansas State University (2008) found – similarly to Ulrich – that plants speeded recovery from surgery with the need for less medication

Prof Tove Fjeld's (University of Agriculture, Oslo, Norway 1997) installation of plants in the x-ray department improved air quality and reduced minor sickness ailments as well as reducing absenteeism by 60%

Dr Jane Stiles, Oxford Brookes University (mid 1990's) found that plants in the reception of a hospital reduced fear of their visit



Schools & colleges

Prof Tove Fjeld, University of Agriculture, Oslo, Norway (1996 + 1998) found that plants in schools cleaned the air, lessened minor ailments linked to SBS, reduced stress, didn't irritate or cause asthma
Amanda Read, Royal College of Agriculture, Cirencester (2005) showed that students were more attentive and more likely to attend lectures in planted rooms

Shopping Centres

Jorn Viumdal, University of Agriculture, Oslo, Norway (mid 1990s) found that shoppers stayed an average of 20 – 25 minutes longer in planted centres
Kathleen Wolf's (Washington State University 2002) study showed that the perception of plants outside of shops in the Mall gave them a perceived high class image

Prisons

Dr Eamonn O'Moore (1982) found that view of greenery reduced the sickness of prisoners

Green spaces

Nancy Wells, Cornell College of Human Ecology, University of Michigan (2002) showed that children brought up in greener surroundings had better cognitive ability and concentration

Older Population

Dr Jeannette Haviland-Jones, Rutgers, State University of New Jersey (2002) – flowers (& plants) ease depression, inspire social networking and refresh memory as we age

Section 8

The effect of plants on our indoor atmosphere

Prof Virginia Lohr, Washington State University (1995) – plants improve humidity levels causing a reduction in particulate matter (dust)

Prof Tove Fjeld, University of Agriculture, Oslo, Norway (1996 & 1998) – in school project, the measurements showed no difference in the dust particles or the fungal spores present in either room

German environmental biologist, Manfred R Radkte (1990s) – plants are natural humidifiers, reducing dust and also keeping us healthier

Prof. Dr. Konrad Botzenhart, Hygiene Institute of the University of Tübingen (1990s) – plants improve humidity which reduces airborne dust so causing us less respiratory problems

Andrew Smith, School of the Built Environment, John Moores University, Liverpool (2008) – plants improved humidity levels to a 'comfortable' level



Engelbert Kotter, Bavarian State Institute of Viticulture and Horticulture (2002) – plants raise humidity and comfort perception levels

Hensler, Stuttgart 1992 – plants return 90+% of the water we give them, back into the air

Peter Costa, South Bank University, London (1995) – plants absorb noise

Peter Costa, South Bank University, London (1995) – grey water recycling with plants

Section 9

Energy savings with plants

German architect Dieter Schempp, LOG ID (1990s) – plants make good air conditioners

Peter Costa, South Bank University, London (1995) - using plants to minimise costs of air conditioning and heating

Section 10

Other benefits of plants

Dr Tina Marie Cade, Texas State University (2008) showed that plants affect perceptions about our quality of life especially at work

Craig Knight, University of Exeter (2009) showed evidence that enriched work environments can improve productivity by more than 15%. If the employees themselves had a say in the enrichment, then productivity improved by as much as 30%

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Section 1

Existing research about plants cleaning the indoor air of toxins

Wolverton research established the way that plants worked to absorb toxins and named plants which worked well in a sealed unit.

Dr. Bill Wolverton conducted early research for **NASA (early 1990's, book, 'Eco Friendly Houseplants' first published 1996)** to prove that plants absorbed toxins from the air around them, translocated it to their roots, where organisms turned the toxins into food for the plant. Wolverton published a book after his research naming a number of plants which are accepted as the most effective:

Spathiphyllum (which performed exceptionally well)	Kentia Palm
Dracaena Janet Craig	Gerbera
Pot Chrysanthemum	Phoenix roebelenii
Ficus robusta and benjamina	Chlorophytum
Chrysalidocarpus lutescens	Nephrolepis
Rhapis excelsa	Schefflera
Chamaedorea	Aglaonema
Scindapsus/Epipremnun	

Research by Dr Ronald Woods, University of Technology, Sydney

Wood's research used plants in sealed chambers into which toxins were pumped to confirm that they did absorb toxins. He also established that plants do not reach a saturation point for toxin absorption but in fact absorb faster the more toxin that surrounds them.

Wood's findings:

- The pot plant system really does remove VOCs from indoor air!
- The system gets better on exposure to VOCs, and maintains performance with repeated doses.
- From three to 10 times the maximum permitted Australian occupational indoor air concentrations of each compound can be removed within about 24 hours, under light or dark conditions, without saturating the system.
- The pot plant system can also remove very low residual VOC concentrations as well.
- This is apparently a general plant-potting mix phenomenon. That is, it can be expected with **any plant species**.
- It is the microorganisms of the potting mix which are the 'rapid response agents' in VOC removal.
- But the plants are also directly involved. Different species develop unique soil microflora around their roots, producing a species-specific symbiotic microcosm for growth. (Plants sometimes expend from 25 to 45% of the net photosynthetic product of their leaves, via their roots, to keep the microbes growing!)



Research by Prof Tove Fjeld from Norway substantiates that plants remove toxins from classroom air

A research project carried out by Fjeld in a school in Oslo involved 61 pupils and 8 teachers with planted classrooms and 59 pupils and 2 teachers in unplanted classrooms was carried out over a two year period.

The outcome: pupils also reported a positive appreciation for the plants, reporting that their classrooms felt fresher, generally more pleasant and attractive. These results confirm earlier findings from similar research carried out in an office environment.

A 35 % lower concentration of volatile organic compounds was found in classrooms with plants.

An added bonus for the occupants of the planted classrooms:

- 47% reduction of headaches
- 37% reduction of dry or hoarse throats
- 69% claimed they 'felt' better generally
- cold sufferers complained less of the symptoms
- rooms were perceived as bigger

Margaret Burchett, University of Technology, Sydney Plants the greenest way of improving air quality

It's true! "All plants remove toxins from the air, in fact it seems any plant will perform as well as others." according to Professor Margaret Burchett from the University of Technology in Sydney Australia.

It's all to do with the microbes that live in the potting soil (or other medium) that work incessantly hard to turn the toxins into food for the plant.

Recent studies lead by Burchett have found that plants in 20cm pots upwards can have a good effect on eating up any 'nasties' in the indoor air which are many – often more than outdoors. Where do the toxins come from? They're emitted by many everyday objects from the plastics in computers and televisions, many paints and most carpets and furnishings. The Volatile Organic Compounds released by these materials are all toxic and many are carcinogenic according to Burchett so we are definitely better off cleaning the air of them.

Introducing indoor plants into workspaces and homes will reduce the VOCs to negligible amounts making the air much cleaner for us to breathe.

"As well, their role in removing CO₂ from the air and adding oxygen means that they are the greenest way of improving indoor air quality." Says Burchett.

Andrew Smith, John Moores University, Liverpool Plants improve conditions in Scotland

Smith looked at the premise from the perspective that evidence exists about the ability of plants to balance indoor relative humidity, remove carbon dioxide and other gases, remove volatile organic compounds (chemicals linked to cancer) and remove airborne particles. (As well as evidence also available of the psychological benefits of plants such as reducing stress, affecting mood and perceived health as well as improving productivity.)



Initially Smith installed about 1 plant per 7 people, which included troughs with three plants in each. The ratio of containers to people was about 1 container for every 14 people. This minimal level of planting (at the customer's request) was installed but air quality was barely affected so around the mid point of the trial, the level of planting was increased with positive effects on air quality.

A further 50 containers (39 were small desk bowls) were added taking the ratio to about 1 plant for every 3 people, even though many of the plants were quite small.

Daily readings were taken using a Graywolf Indoor Air Quality Monitor throughout the 6 month period of the trial. VOC readings were also taken using another monitor.

With the higher ratio of plants both Carbon Dioxide and Carbon Monoxide levels were reduced considerably as were toxins generally.

Wood's calculations for the number of plants per room

There a number of variables which affect the number of plants necessary to clean the air in a given area. These include:

- Size of the room
- Number of windows and doors open or open from time to time
- Number of people occupying the room
- Number and size of plants
- Humidity levels
- Whether or not ventilation is natural or by air conditioning

Wood's calculations involved trialling plants in 34 offices in and around Sydney where air quality measurements were taken every week for a period of 9 weeks.

Portable monitors were used on a weekly basis to measure VOC levels including Carbon Dioxide and Carbon Monoxide in each office.

Interestingly VOC levels were higher indoors than outdoors with or without the plants! However in the planted rooms the VOCs were consistently lower by between 50 – 70% than those without plants.

Wood found that 3 specimen (floor standing) plants or 6 table top plants were equally effective at cleaning the air in the office size used.

The circumstances and measurements which were used for this project include:

- A 10 - 12²m room with a height of 3 – 4m
- Occupied by one person
- 3 floor standing or specimen plants
- **Or** 6 table top plants
- VOCs in the air consistently lowered by 50 – 70%



Kwang's investigation into the efficient removal of Formaldehyde by plants

Korean researcher Kwang and his team (National Horticultural Research Institute, Korea) tested the ability of *Ficus benjamina* and *Fatsia japonica* to absorb formaldehyde from the air.

The toxin was pumped into a container housing one of the two plants or into a container holding no plants. The containers with the plants removed 80% of the formaldehyde from the container within 4 hours. In plant-less containers 7% of the Formaldehyde had been lost in 5 hours.

Kwang's observations showed that the plant leaves removed the toxin during daylight hours through plant stomata during the process of photosynthesis.

The night time removal of formaldehyde by the root zone suggests that soil microbes play an important part in the process.

Formaldehyde is a common VOC emitted by carpets, curtains, upholstery, plywoods and adhesives that is known to have negative effects on human health.

Original source:

[Efficiency of Volatile Formaldehyde Removal by Indoor Plants: Contribution of Aerial Plant Parts versus the Root Zone.](#) (*Horticultural Science* 133: 479-627.)



Section 2

Existing research about O₂ and CO₂ exchange between man and plants

Dr. Bill Wolverton, Eco-Friendly Houseplants published by Pheonix 1997

Wolverton's book published following his ground-breaking research, explains that plants are our life force. Plants produce oxygen during photosynthesis, the process when they use light to convert carbon dioxide and water into energy. And of course we produce some of the carbon dioxide which plants need to use during photosynthesis.

'Oxygen is vital to all organisms that require oxygen for respiration. The living processes of animals would deplete the atmosphere of oxygen if it were not replenished by photosynthesis. Life supporting oxygen is produced by plants and carried over the earth's surface by wind currents. The wide diversity of plant life distributed throughout the world influences the creation of many micro-climate zones. For instance, the removal of trees and other vegetation from vast areas of land causes environmental changes in soil compositions and weather patterns.'

Every individual plant creates its own micro-ecosystem both in the wild and indoors. Activity within this micro-environment is not obvious to the human eye but is a necessity for the survival of the plant.

Dr. Manfred Weidner, Botanical Institute, University of Cologne

Man needs oxygen to survive. We breathe in oxygen and convert part of it to carbon dioxide, which we then breathe out again. The greater the level of carbon dioxide in the air, the more tired and weak we feel.

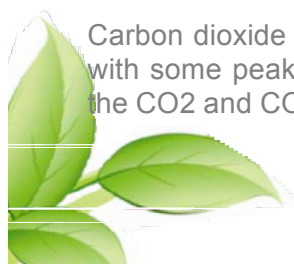
The greater the leaf surface a plant has, the more efficient it is at removing carbon dioxide from the air. It is not the size of the individual leaf that counts, but the sum of the surfaces of all the leaves on the plant, for example, banana plants, some varieties of Ficus and green-leafed vines all have a large leaf surface.

Andrew Smith, John Moores University, Liverpool

Two offices of around the same size and number of people doing similar jobs in Edinburgh were used for this research

Measurements were taken on a daily basis. Carbon dioxide (CO₂) and carbon monoxide (CO) levels were not significantly different and CO₂ was generally slightly higher in the planted offices, possibly due to the open atrium and CO₂ being heavier than air. CO and CO₂ levels were shown to decrease in the planted offices during the trials.

Carbon dioxide reduced significantly to around half its starting value and carbon monoxide reduced significantly with some peaks and troughs along the way. This data suggests that the plants did have a beneficial effect on the CO₂ and CO levels.



Prof Margaret Burchett's

latest research claims 'two-way refreshment'! In other words CO₂ absorbed is exchanged for the same amount of O₂ from the plant.

For best CO₂ absorption Burchett recommends ensuring the plant is in the right location with enough light for photosynthesis. Of course if the lighting is OK for the plant, then it is also OK for us!

CO₂ causes drowsiness and that 'heavy-head' feeling and of course lowers our concentration.

As well, their role in removing CO₂ from the air and adding oxygen means that they are the greenest way of improving indoor air quality according to Burchett.

Bill & John Wolverton

carried out a study showing that orchids and bromeliads, like succulents, absorbed VOCs including CO₂ at night whilst releasing oxygen.

In the photosynthetic process, most common indoor plants remove carbon dioxide while emitting oxygen and water vapours during the day. However, there are unique plants, such as succulents, orchids and bromeliads that behave differently during the day-night cycle.

The stomata of most plants open during the day and close at night, allowing for entry of the carbon dioxide needed for photosynthesis during the daytime. Certain plants, such as succulents, which are native to hot, dry conditions act in an opposite manner; they open their stomata at night. The opening of the stomata releases oxygen and converts carbon dioxide into organic acids at night, and the stomata are closed during the day. This allows plants to absorb carbon dioxide through open stomata but conserve water during the heat of the day.

Because this unusual metabolism of carbon dioxide was first investigated in members of the *Crassulaceae* family, it is commonly called Crassulacean Acid Metabolism (CAM). CAM plants have been found in eighteen families, including *Orchidaceae* and *Bromeliaceae*. (1)

It is interesting to note that hot, dry desert plants, such as cactus, and epiphytic (tree dwelling) bromeliads and orchids from the jungle share the same carbon dioxide metabolic pathways. In the tropics, some orchids and bromeliads have adapted to living on tree branches high above the jungle canopy where light is more plentiful.

Orchids as epiphytes adapt to their aerial environment by developing thick roots coated with spongy material that allow them to stick to the bark of trees and absorb water rapidly. To survive periods of drought, epiphytic orchids close their stomata during the day to avoid losing water. Many species have leathery leaves and thickened stems, called pseudobulbs that can store both water and food.

Bromeliad roots are hold-fast roots used only to anchor the plant. Most bromeliads are formed of a rosette of leaves with a cup-like empty area (vase) in their centre. The leaves forming the vase are used to trap, hold and take in water and nutrients. Most bromeliad leaves are tough and leathery as those of orchids, but they are also edged with spines. The leaves are covered with scales that also help in absorbing water. Epiphytic bromeliads behave similarly to epiphytic orchids and succulents, in that they open their stomata at night to prevent excess water loss during hot days.



Section 3

Existing research about plants reducing absenteeism

Prof Tøve Fjeld

carried out three major research programmes during her time at the **University of Agriculture in Oslo**.

During the course of the study the employees were required to complete several questionnaires concerning their health. The evaluation showed that the workers in the offices with plants complained less of headaches, dry or irritated skin and coughs than the control group in the offices without plants. The mean average reduction was 23%.

The staff perceived the plants as beneficial. More than 80% of the test subjects said they felt better with plants.

Fjeld suggests that plants take effect at various levels, thereby inducing an overall increase in the sense of well-being of each individual.

Psycho-social level. The addition of houseplants to their offices gave the employees the feeling that they were the objects of special attention

Environmental/psychological level. Plants reflect nature. Against the background of psycho-biological identity, i.e. the evolution of mankind in nature and the positive reaction of mankind to nature, we can assume that plants have a beneficial influence on the human psyche

Physical factors. Plants improve the indoor climate - by reducing the levels of a number of chemical compounds in the air they also increase humidity. People complain less of minor ailments in planted workspaces

In the School

At the secondary school, 12 classrooms, 6 planted and 6 as control, were used in Fjeld's research between April 1998 – April 1999. Fjeld used a series of questionnaires to assess the changes for the pupils. The findings show that the pupils in the planted classrooms complained less – 9% - of minor ailments compared to an increase of complaints by 12% in the control group. The results from pupils with asthma and/or allergies showed no difference from those who did not suffer in this way.

In the planted classrooms:

- Headache complaints reduced by 45%
- Complaints of tiredness reduced by 32%
- Absenteeism was reduced by 33%

Tests to monitor concentration showed the capacity of the 'planted' group was 23% higher than the control group.

In the x-ray department

Tøve Fjeld, professor at the Horticultural Institute of the Norwegian College of Agriculture in Oslo, researched the effects of green plants at the x-ray department of the Oslo Cancer Hospital.



The Radiology Department led the way for the whole Norwegian health sector by spending some 50,000 Norwegian kroner on plants and spectral light (daylight). The staff completed a total of 9 questionnaires before and after the rooms had been equipped with plants.

Once the plants were installed there was a marked difference in earlier conditions experiences by the staff:

- tiredness vanished
- headaches dropped by 45%
- 30% fewer complaints of hoarseness, dry throats and tiredness

Within a year absenteeism had dropped from 13.1% to 5.8% for the nursing staff and 18.6 to just 5.3% for the administrative staff. These figures showing a 60% + reduction remained at this level for at least 5 years (i.e. this was the last time we had reports)

Tina Bringslimark,
University of Agriculture, Oslo, Norway 2008

Bringslimark, an expert in psychology, found that http://coinsdig.com/files/plant-in-office.jpg_interior planting can improve the health of office workers by reducing stress and thus reducing the number of sick days that the workers take.

305 office workers in 3 offices were analysed, each of which had differing amounts of greenery.

Results:

- The more plants a worker could see from their desk, the less self-reported sick leave there was
- Plants were also shown to lower fatigue, prevent dry throats, headaches, coughs and dry skin amongst the office workers

Andrew Smith,
John Moores University, Liverpool 2008

Taking two offices of around the same size and number of people doing similar jobs in Edinburgh were used for this research project.

One of the most positive findings was the reduction in sickness rates. In the office with the plants, sickness absence reduced by nearly 50% compared to the same period a year earlier. In the control office with no plants, absence actually increased by about 20%.

There were a few other factors that could have affected this - such as improved management training, improved absence management, better chairs, and the winter vomiting bug being less prevalent in 2008 than it was in 2007. However, these changes should in theory also have led to a reduction in the control area as they were rolled out across the whole business. More research is needed, across more businesses but these results are promising.



Dr. Leivi Sandvic,
Specialist for Medical Statistics, University of Oslo, Norway

Fifty nine people working in standardised (10 metre²) offices, completed a questionnaire to collect details of health problems referring to 12 different health complaints thought to be linked to a poor indoor climate.

Questionnaires were used in two periods of autumn and spring in consecutive years. During this time, plants were introduced into half of the others with half left 'empty' of plants. In the second year, this procedure was reversed.

The results showed that houseplants can have an effect on peoples' subjective perceptions of their state of health.

Results:

- A considerable decrease in health complaints generally
- A decrease of 25% of the named symptoms
- Plants have a perceived positive effect on well-being – 82% of respondents agreed that they felt better when there were plants in their office

Dr Eamonn O'Moore ,
Plants have a beneficial effect on the health of prison inmates

In 1982 Moore found that prison inmates whose cells had a "natural" view of the outside world reported sick less frequently than those whose windows only overlooked a part of the prison complex.

This study, like those of Ulrich, indicates that visual contact with plants can lead to savings in the healthcare service, because prisoners with a view of nature require less medical attention.

Case study evidence

BMW Munch: "Once the planting was introduced, 93% of the employees working in these areas felt healthier and more motivated to work. They praised the reduction in noise levels and favoured working in the 'green' workplace."

Australia's Powerlink HQ in Queensland: "No one gets a cold here. In a typical workplace, someone on level three gets the 'flu and everyone gets it. It's re-circulated. It doesn't happen here."

Areospace, Dorset: planting was introduced as a direct result of research to improve working conditions in the copying room. Workers in this area suffered from headaches and fatigue. The introduction proved effective with reduced headaches and improved general well-being.



Section 4

Plants reduce stress levels

Prof Virginia Lohr

working at Washington State University conducted research in a windowless computer lab with delegates all performing a similar computer programme.

Whilst delegates in both the planted and the non planted group made mistakes, and had raised adrenaline, those working in the planted lab were able to complete their task more quickly because their stress levels returned to normal more quickly i.e. their pulse rates, blood pressure and skin conductivity reduced to their norm more quickly with plants present.

Helen Russell at the University of Surrey

used the same criteria but delegates completed a mental arithmetic task rather than a computer task.

Again stress levels were measured and found to return to normal, via pulse rates and blood pressure, more quickly.

Roger Ulrich, Texas A M University

pioneered this research early on by using mere views of plants – pictures and views out of windows to assess stress levels and surgical recovery.

His findings were that

- Patients recovered more quickly
- They needed less medication
- And therefore called on nursing staff less often

A win: win situation for patient, staff and hospital costs

Prof Tove Fjeld University of Agriculture, Oslo, Norway

Fjeld sites environmental psychology as an area of reference for her research:

The specialist field covering the influence of the environment on human psyches is called environmental psychology. Studies in this area have shown obvious links between well-being, psychological stability, stress levels, other important aspects of human life and environmental factors. All these studies indicate that nature (such as plants, lakes and woods) can offer an important contribution to the reduction of stress. An urban environment, however, causes psychological stress.



Tina Bringslimark

A <http://coinsdig.com/files/plant-in-office.jpg> recent study found that potted plants can improve the health of office workers. Plants reduce **stress**, thus reducing the number of sick days that the workers take.

The study was performed by the researchers from the [Agricultural University of Norway](#). Its result serves as yet more evidence that plants in the work place are good for the office environment and the health of the workers too.

Tina Bringslimark, expert in environmental psychology, analyzed 305 office workers in 3 offices, each of which had differing amounts of greenery.

"We investigated the amount of self-reported sick leave and compared it with the amount of plants they could see from their desk. The more plants they could see, then the less self-reported sick leave there was," said Ms Bringslimark. Performing the study at the Norwegian institution, it also showed that plants were able to lower fatigue, prevent dry throats, headaches, coughs and dry skin amongst the office workers.

TNO, John Klein Hesselink, Dutch Institute for Work Protection (1995)

In a study carried out in 1995, John Klein Hesselink of the Dutch Institute for Work Protection threw some light on attitudes towards plants in the workplace. The purpose of the study was to give an overview of plants' influence in the workplace on the subjective perception and well-being of employees. He questioned 130 employees from 6 Dutch companies. The analysis of the answers yielded 6 factors that define the relationship between people and plants in the workplace:

- **Plants provide support.** A few of those questioned indicated that plants gave them more self confidence, made them less inhibited and insecure and caused them to feel less stressed by work
- **Relaxation and performance.** Some test subjects claimed that plants had a calming influence. They increased work enjoyment as well as providing a feeling of comfort

A later study by John Klein Hesselink for TNO, The Netherlands found that plants primarily have an uplifting effect on stressed and tired individuals. In these groups of people the differences in performance recorded in offices with and without plants, were even greater.

The study also confirmed the restorative effect of plants. Subgroups of physically exhausted students and students indicating high levels of work stress benefit from plants in the room where they perform their tasks.

Engelbert Kotter

Commissioned by The Bavarian State Ministry of Food, Agriculture and Forestry, Kotter's study aimed to find out, whether plants in office-buildings have an impact on wellbeing and would lead to an upgrading of the surroundings.

Although the study showed that due to the plants, people were sometimes distracted and liked to look around, it gained them moments of relaxation and relief, which showed positive effects on their productivity.



A further result of the study was that people who liked plants felt considerably less depressed or angry than those who didn't care about plants. These people are also more likely to be calmer and more harmonious. As the study proves, the most important effect that plants have in offices is the increased feeling of wellbeing.

Park and Mattson

A recent study by Seong-Hyun Park and Richard H Mattson, researchers from the Department of Horticulture, Recreation and Forestry at Kansas State University, provides strong evidence that contact with plants is directly beneficial to a hospital patient's health. Using various medical and psychological measurements, the study set out to evaluate if plants in hospital rooms have therapeutic influences.

Studies show that when patients have great stress associated with surgery, they typically experience more severe pain and a slower recovery period. This study (90 patients recovering from an appendectomy) showed that those with plants in their rooms did indeed have lower levels of stress (lower blood pressure and heart rate), and recovered more quickly needing less medication than their counterparts in the control group without plants in their rooms.

93% of the group found that plants were the most positive qualities of their rooms

Prof Margaret Burchett, University of Technology, Sydney, Australia

Burchett's study published in 2010 showed that plants reduced stress by as much as 50%. Her study showed that this was one of the negative mood states to be effected by just one plant either on or beside a desk.

Using psychological survey questionnaires, Burchett showed a mean average of reductions in negative mood states of between 40 – 60%. Specifically:

- Anger - 44%
 - Depression - 58%
 - Fatigue - 38%
 - Confusion - 30%
 - Overall negativity - 65%
 - Overall stress - 50%
 - Anxiety - 37%
- In the control group with no plants, stress levels rose by 20%.

Just one plant either on the floor or on the desk was enough to affect the difference.



Section 5

Plants increase concentration, performance, motivation, productivity, mood etc

Prof Virginia Lohr, Washington State University

Prof Lohr's study showed that houseplants in offices help reduce stress and increase productivity. 96 volunteers – mainly young men and women participated in the experiment in a computer room without daylight. All test subjects were experienced in using computers.

Speed of reaction is one of the factors that make a major contribution to productivity. A computer program was specially designed for the study to measure this. The program displayed an image on the monitor, selected from a choice of three images. The volunteers were required to press the key that corresponded to the image immediately after the image was shown.

This program induced stress in the test subjects while measuring their productivity. This type of programme, where volunteers are given a choice, necessitates complex mental functioning and is therefore thought to be a suitable tool for measuring performance under stressful or tiring conditions.

The volunteers were required to carry out the computer tasks in 2 different situations, with and without plants. Plants were visible to all participants in the planted room.

After the experiment the recorded values of the test subjects in each situation were compared. The volunteers in the room with plants felt more alert, were able to concentrate better and also had lower blood pressure, which is another indicator of lower stress. While those tested in an unplanted environment experienced the opposite.

The study showed that the presence or absence of plants had no effect on the number of errors made by the volunteers. However, the speed of reaction of the subjects in the room with plants was **12% higher**.

Prof Tove Fjeld

found that hospital workers (x-ray department) were tired, listless and with no energy after lunch prior to the installation of the plants. Once the plants were installed these symptoms disappeared

Once the new lights and plants were introduced, the staff no longer felt exhausted, headaches and other ailments, tiredness vanished and work output improved.

It is a well known scientific fact that Carbon Dioxide makes us feel tired so its removal by the installed plants would have had this effect.

Fjeld also found that once plants were installed in a classroom, student concentration was **improved by 23%**.



**John Berg,
DHV AIB Engineering, Amersfoort**

John Bergs studied the effects plants have on office workers. Whilst spatial design and office technology - from air conditioning to computerisation - has changed considerably in the last 30 + years, consideration has not been given to the effects of these changes on the workers.

Berg found that for workers who spent 4 hours or more a day in front of a computer screen, the introduction of plants made a significant improvement to their efficiency, concentration and general well-being.

During his study, Berg looked at a number of earlier studies which all considered factors which affected productivity including office environment, building-related complaints and sick leave. In the follow-up studies conducted by DHV, questions were added concerning quantity (number of hours lost) and quality. These studies revealed that, on average, 15% of employees report that building-related complaints have a (highly) inhibiting influence on their productivity.

**Amanda Read,
College of Agriculture, Cirencester**

Amanda Read conducted a behavioural study of a group of 34 students attending weekly seminars, monitoring attendance and behaviour over the course of an academic year. Each week the location of lectures alternated between a planted and a non planted lecture room.

The audience was videoed and observed for behavioural signs of inattention including daydreaming, talking, fidgeting and yawning. Each incident was recorded and the total number of incidents per lecture calculated.

Results showed that in the planted room students inattentiveness was reduced by 70 %. In terms of attendance, the percentage of students returning to the lecture following a break was 97.8 %. In the room without plants this figure was 86.4 %.

**Margaret Burchett,
University of Technology, Sydney, Australia**

Prof Burchett's research showed that plants reduce feelings of negativity. In a more positive frame of mind we are more productive.



Section 6

The effect of plants on our creativity

Prof Roger Ulrich, Texas A M University

Prof Ulrich conducted an 8 month study finding that plants and flowers in the workplace improve idea generation, creative performance and problem solving.

- 101 delegates took part in Workplace Productivity study (USA)
- Asked to perform 2 creative tasks and one attention demand test in 1 of 3 random controlled office environments: either with fresh flowers & plants, with abstract sculpture or with no embellishment at all

Results:

- Men 15% more ideas generated in flower & plant room
- Women generated more flexible solutions to problems in same conditions

Dr. John Klein Hesselink et al, TNO Work & Employment 2008

Plants in the offices of people working in the service industry have been found **to stimulate creativity**. This is the conclusion drawn from a scientific survey carried out by TNO Quality of Life, Leiden.

Plants primarily have an uplifting effect on stressed and tired individuals. In these groups of people the differences in performance recorded in offices with and without plants, were even greater.

In fact, the desired effect can actually be achieved with just one plant. The effects are not enhanced by more plants in the office.

The survey by TNO, which was commissioned by the Horticultural Marketing Board, VHG and the Flower Council, is the first practical survey to confirm that plants **improve performance in the execution of creative tasks**.

Shibata & Suzuki, Bunko and Doshisha Universities, Japan

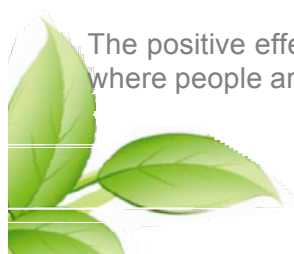
This study reinforces the position that plants have a positive effect on employees, this time to show that they improve creative performance.

There study asked 90 students randomly assigned to one of three rooms – with plants a 1.5 m high *Dracaena fragrans* Massangeana, with magazines, with no enhancement – and to perform a word association task.

The resulting findings were:

- Females performed task better with plant in the room
- Mood responded positively when plant or magazine in room as an alternative to nothing
- With no plant, participants assessed themselves as less confident and less energised

The positive effect only appears in cases where a relaxed attitude contributes to solution finding and not in those where people are focused on their activities such as repetitive production work.



Section 7

How plants affect our well-being in various settings

Hospitals

Prof Roger Ulrich, Texas A M University

pioneered this research early on by using mere views of plants – pictures and views out of windows to assess stress levels and surgical recovery.

- His findings were that
- Patients recovered more quickly
- They needed less medication
- And therefore called on nursing staff less often

A win: win situation for patient, staff and hospital costs

Park & Mattson

A recent study by Seong-Hyun Park and Richard H Mattson, researchers from the Department of Horticulture, Recreation and Forestry at Kansas State University, provides strong evidence that contact with plants is directly beneficial to a hospital patient's health. Using various medical and psychological measurements, the study set out to evaluate if plants in hospital rooms have therapeutic influences.

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93% of the group found that plants were the most positive qualities of their rooms

Prof Tove Fjeld's study at the Oslo Cancer Hospital

The positive results of Fjeld's study of the effects of green plants in the work environment at the Radiology Department at Oslo's Cancer Hospital led the way for the whole Norwegian health sector by spending some 50,000 Norwegian kroner on plants and spectral light (daylight).

According to the head of administration, the staff used to feel exhausted by 1 p.m. There were complaints of headaches, lack of energy and most had difficulties getting through the rest of the day.

Once the new lights and plants were introduced, the staff no longer felt exhausted, headaches and sinusitis became rarities, tiredness vanished and work went with a swing. After the plants were installed the incidence of headaches dropped by 45% there were 30% fewer complaints of hoarseness, dryness of the throat and tiredness



Within a year the number of sick reports by radiologists and administrative staff had dropped by more than 60% (from 13.1% to 5.8% and 18.6 to just 5.3%.)

In addition the “green lungs” had a purifying effect on the air. The smell of chemicals vanished once the developers were screened by plants.

Dr Jane Stiles

carried out a long-term research project in the lobby of a hospital designed as an atrium. The study looked at the influence of interior landscaping i.e.

- how the atrium was used (observations)
- the levels of fear of the visitors (questionnaire to determine the level)
- the way in which visitors experienced the atrium (questionnaire)

The results showed a 4.1% increase in the use of the waiting area when plants were present. It was also found that both men and women preferred a seat opposite the plants and sat where they had a view of them. Stiles concluded that the average level of fear among test subjects in the atrium with plants was lower than without plants.

Findings: since plants influence reactions to buildings, they can have a (demonstrable) positive psychological influence. Interior landscaping generates positive reactions to a building.

Schools

Prof Tove Fjeld

Fjeld did two studies, one in a primary school and the other in a secondary school.

In the first study, health complaints decreased considerably when plants were introduced into the classroom. Pupils found their planted classrooms fresher, more attractive and more comfortable. Their general well-being improved and the classrooms looked more attractive and lighter.

The study in the secondary school (April 1998 – April 1999), six classrooms were planted with tropical plants in wooden boxes with bio-process systems. Lighting was changed to full-spectrum fluorescent light 600 – 800Lux. Six classrooms with no planting or light changes were used as the control.

During the period of the research, Fjeld found that in the planted classrooms, symptoms such as headaches and dry throats were less frequent, with 69% of pupils in the classrooms containing plants said they felt better and 82% wanted to have plants in their classrooms in future.

The questionnaires used with the pupils, showed 9% less complaints in the planted classrooms, compared to a 12% increase of complaints in the non-planted classroom (the control). Specifically

- Headaches complaints reduced by 45%
- Complaints of tiredness reduced by 32%
- Absenteeism in the planted classroom was reduced by 33%

Interestingly, pupils already suffering with asthma and/or allergies prior to the introduction of plants, showed no difference from those who did not suffer in this way.



Amanda Read, Royal Agricultural College, Cirencester

Read conducted a behavioural study of a group of 34 students attending weekly seminars, monitoring attendance and behaviour of the students over the course of an academic year. Lectures alternated each week between a room with plants and a room without plants.

The students were videoed and observed for behavioural signs of inattention including daydreaming, talking, fidgeting and yawning. Each incident was recorded and the total number of incidents per lecture calculated.

Results showed that in the room where plants were present students inattentiveness was reduced by 70 %. In terms of attendance, the percentage of students returning to the lecture following a break was 97.8 %. In the room without plants this figure was 86.4 %.

Shopping malls

Norwegian Jorn Viumdal's

study at the Metro Senter, Norway found that plantscaped shopping malls attract people: 4 million people visit this Senter every year.

The study also showed that the presence of plants encouraged people to stay longer and consequently spend more in "green" shopping malls.

Green shopping malls not only attract people and improve their shopping experience but they create oases of calm.

American Professor Kathleen Wolf

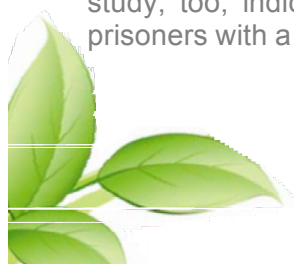
found that the effect of planting outside of retail outlets could have a positive effect on consumer spending habits.

Retailers commonly found the presence of exterior planting less important than the consumers they were trying to attract and even sometimes saw it as a reduction of visibility both of signs and entrances and felt it discouraged customers.

The consumers, however, preferred the use of vegetation not only because the street or centre felt more inviting but also it implied a more exclusive type of shop so that by implication they were prepared to spend more in these environments.

Prisons

In 1982 **Dr Eamonn O'Moore** found that prison inmates whose cells had a "natural" view of the outside world reported sick less frequently than those whose windows only overlooked a part of the prison complex. Thus this study, too, indicates that visual contact with plants can lead to savings in the healthcare service, because prisoners with a view of nature require less medical attention.



Green spaces

**Prof Nancy Wells,
University of Michigan**

Results from a study at Cornell College of Human Ecology, part of the University of Michigan has confirmed that being brought up in a green environment made profound improvements in the mental development of children.

Wells, Assistant Professor of Design and Environmental Analysis, found that the statistical findings from the study were significant.

Taking documented information from mothers of children living in poor-quality housing with no gardens or surrounding green spaces about the child's behaviour and performance at school as the starting point, then moving the families to better quality housing with gardens and green surroundings.

One year on, the same mothers answered the same questions. Even taking the better quality housing into consideration, the findings showed a profound improvement in cognitive ability and concentration with the greatest improvements noted in children who had gained the greatest in terms of 'greenness'.

**Dr Jeannette Haviland-Jones
Rutgers, State University for New Jersey**

The study demonstrates that flowers ease depression, inspire social networking and refresh memory as we age.

More than 100 seniors participated in the Rutgers research study, in which some received flowers and others did not. The results shed new light on how nature's support systems help seniors cope with the challenges of aging. The results are as follows:

- Flowers Decrease Depression (81%): study participants showed a significant increase in happiness and positive moods when flowers were present
- Flowers Refresh Recent Memory (72%): seniors performed higher on everyday memory tasks and experienced enriched personal memories in the presence of flowers.
- Flowers Encourage Companionship (40%): those who received flowers re-engaged with members of their communities and enlarged their social contacts to include more neighbours, religious support and even medical personnel

"Happier people live longer, healthier lives and are more open to change," said Haviland-Jones. "Our research shows that a small dose of nature, like flowers, can do a world of wonder for our well-being as we age."



Case Study Maravilla Residential Rainforest

American award winning* senior citizen residential home houses an indoor rainforest. Owner, Dr Anbar cites clean air as one of the main factors for including the rainforest within the development.

Anbar claims “Plants have been shown to absorb toxins while releasing oxygen. Research also demonstrates that people who live in rainforests do not suffer from allergies and related disorders triggered by synthetic surroundings. By creating the Maravilla concept, our hope was to offer the facility’s residents an environment in which cleaner air would improve their health, comfort and longevity.”

It seems it may have worked. One staff member has weaned themselves off long-term asthma medication since working there. Residents claim to feel healthier and more energetic and even visitors say they feel better within 30 minutes of arrival at Maravilla.

Source www.greenplantsgivinggreenbuildings.com

N B Maravilla was built in 2000 and has won numerous awards including:

- o Interiorscape Magazine’s Grand Award – Best Project 2001
 - o Illinois Landscape Contractors Association 2001 Gold Award for Landscape Excellence
 - o Florida Nurseryman’s Association Grand Award for 2001
- Associated Landscape Contractors of America Grand Award for 2001



Section 8

The effect of plants on our indoor atmosphere

**Prof Virginia Lohr,
Washington State University**

Plants increase indoor relative humidity by releasing moisture into the air, which may increase the comfort level for humans, especially in heated interior spaces (Lohr, 1992b).

Vegetation acts as a natural filter, causing particles to be deposited on the vegetative surface through sedimentation, impaction, or precipitation. Trees in urban areas have been shown to collect dust on their leaf surfaces.

Taking the numerous studies that showed this ability of outdoor vegetation, particularly trees, to trap various airborne particles, including radioactive trace elements, pollen, spores, salt, and precipitation, Lohr looked at whether indoor plants behave in the same way.

Using both a windowless computer lab and an office, Lohr measured particulate matter accumulations when plants were both present and not present. Collection of particulate matter was in 12 dishes mainly around the periphery of the room some near and some not near the plants and also far away from the plants in the centre of the room.

Use of the lab was monitored throughout and collections from both locations were over an 11 week with and 11 week without plants duration.

Both locations saw a rise in humidity when the plants were present; more particulate matter accumulated in the collection dishes by the doors (due to more human activity in these areas).

Overall, Lohr's experiment showed that dust particles could be reduced as much as 20% by adding foliage plants.

**Prof Tove Fjeld,
University of Agriculture, Oslo**

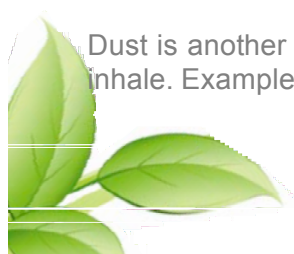
Between April 1998 – April 1999, 6 classrooms were planted with tropical plants in wooden boxes with bio-process systems. Lighting was changed to full-spectrum fluorescent light 600 – 800Lux. 6 classrooms with no planting or light changes were used as the control.

During the period of the research, 2 measurements were taken to measure air quality, 1 in a planted room and 1 in a control room. The concentration of VOCs in the planted room were 35% lower than in the control room.

German environmental biologist, Manfred R Radtke

The measurements showed no difference in the dust particles or the fungal spores present in either room.

Dust is another potentially harmful everyday indoor substance, because it picks up harmful toxins, which we inhale. Examples of these are Cytotoxin formaldehyde as well as solvents belonging to the benzole family.



Both of these are emitted by modern everyday 'materials' such as adhesives, floor coverings, paints, and ceiling tiles. They are also present in fabrics including upholstery, paper products, plywood (formaldehyde) and photocopiers, electrographic printers and tobacco smoke (benzene). So they are inescapable in our modern lives.

But plants come to the rescue by trapping dust particles. Hairy and lipophile leaf surfaces attract the dust in the air directly and absorb the toxins that it contains. Dust particles will also take up moisture in the air and the damp saturated particles will sink to the floor where we are less likely to inhale the toxins. For this to happen, humidity levels have to be at 40 % saturation.

If attempts to raise the humidity levels have been attempted in our offices and homes, either by natural ventilation or by use of expensive, technical means, the air being re-circulated still contains bacteria.

Prof. Dr. Konrad Botzenhart, Hygiene Institute of the University of Tübingen

Humid air is not as dusty as dry air which causes dust to remain suspended for longer. When the humidity is above 40%, dust quickly sinks to the floor – or to leaf surfaces.

As dust has a negative impact on health, irritating our respiratory organs, humidity helps to keep us healthier.

Andrew Smith, John Moores University, Liverpool 2008

A number of measurements were monitored in Smith's research study at insurance offices in Edinburgh – indoor air quality, sickness absenteeism and humidity.

In fact one of the main issues for the company prior to the trial had been that relative humidity was too low. After the study in two same-size open plan offices. One with and without plants, humidity levels moved to within the recommended range (40 – 70%RH) for comfort.

Engelbert Kötter, Bavarian State Institute of Viticulture and Horticulture

During a two year study with 94 offices and 139 people, Engelbert Kötter found that the introduction of houseplants caused an increase in humidity levels of between 2 and 5%. Even this small increase made a considerable difference to comfort on an otherwise 'dry' atmosphere where humidity levels were below 36%.

Participants in the study claimed that the humidity in the room had 'increased significantly' after the introduction of the plants.

Henseler (1992)

Indoor air humidity can be raised naturally by introducing water loving, green plants, such as bird's nest fern, banana, African hemp, the umbrella plant or Schefflera.

Three 1.5 metre high Schefflera can achieve an optimal humidity of 50% at 22°C in one day. On average, houseplants return about 90% of the water they receive, back into the air.

Other plants that contribute to a pleasant indoor atmosphere include Aphelandra, creeping fig, cottonweed, timber bamboo, paper plants, asparagus and spider plants.



**Peter Costa, Prof. R.W. James,
South Bank University, London**

As well as all the other attributes for plants, they also help reduce noise. In open-plan offices their absorption capacity can help keep down office noise, but they are less effective when it comes to actual sound insulation.

Plants absorb noise on their resilient leaf surfaces, stifling the sound waves. Plants cannot be used for complete sound insulation but are effective at reducing noise i.e. banks of plants between desks or section can buffer noise.

Research into using plants for improving indoor acoustics has shown that plants dampen sound waves, especially at higher frequencies, thereby reducing the level of noise in a room. The acoustic effects of plants vary depending on the frequency and the type of room. Their absorption capacity depends on the variety and size of the plant, the pot size, the moisture content of the pot substrate and the type of mulch. Plants should be big, healthy and lush to achieve good acoustic effects.

The materials used in a room also affect the absorption capacity of plants. For example, the acoustic performance of plants is best in a room with hard surfaces i.e. marble and glass walls and uncovered concrete or stone floors. In rooms with soft materials e.g. carpets, the acoustic effects of plants are far less noticeable.

For design and acoustic effect, groups of three to five plants should be arranged at several spots in a room, as this is more effective than a concentration of plants in a single spot. If large-scale plant arrangements are not an option, it is far more effective to arrange plants along the walls and in the corners of a room than in the centre.

**Peter Costa,
South Bank University, London**

Costa's research highlights the extended economic benefits of plants if they are used for waste-water recycling.

Costa explains that a biological water purification plant is no more or no less than a miniature marsh. The purified water can be re-used for flushing toilets or watering plants. According to Costa, the best systems achieve the same results as modern industrial equipment while looking considerably more attractive.



Section 9

Energy savings with plants

Dieter Schempp, LOG ID plants as indoor air conditioners

Plants can play an important role in conditioning the air around us through shade. Foliage absorbs and reflects light and also transpires – emits water - to remain cool. The cooled air from the leaf canopy sinks and is eventually felt by those beneath the canopy.

Environmentally friendly glass buildings can use this natural cooling method to great effect especially during the summer months. It is possible to create an entire micro-climate within a building using plants.

Peter Costa, South Bank University, London

Thanks to the positive effects plants have on room climate, they can be used to create a low cost building system that emits negligible amounts of pollutants to the environment.

Building systems technology has become a complex field of engineering. In our society there will always be buildings that demand a high level of maintenance, but the trend towards simple systems is growing. The trend is towards greener solutions and sustainability, so increasing numbers of architects, engineers and clients see high-maintenance, air-conditioned, hermetically sealed rooms as a thing of the past.

Biologically orientated solutions are needed to improve the indoor climate. They should be on-site solutions that take the pressure off an already overburdened infrastructure. New solutions result in naturally ventilated buildings with windows that open. They make use of daylight, cut energy consumption and involve low maintenance costs. Plants can play an important part in implementing these ecological concepts.

Providing shade with the help of foliage is one method of keeping temperatures down in buildings that are exposed to a lot of sunlight.

Plants can only improve their rate of evaporation if they receive enough water. If this is not the case, the plants will evaporate less water and the cooling effect will be reduced correspondingly. The shade provided by foliage in summer reduces the effects of sunlight. Since less heat penetrates the building, the burden on the air-conditioning system is reduced. In winter, on the other hand, deciduous plants shed their leaves allowing the sun's rays to penetrate, cutting central heating costs.

Tree planting effects energy consumption in buildings by:

- Reducing the effects of the sun (windows, walls, roofs) by providing shade
- Reducing thermal irradiation by providing shade
- Providing protection from wind, thus reducing the need for cooling or heating, depending on the weather
- Restricting heat inflow, since the shade they provide and the water they evaporate serve to lower the ambient temperatures of the micro-climate in summer
- Possibly increasing the latent load on the air-conditioning system by evaporating water and thus adding moisture to the micro-climate of the outside air



The increase in humidity caused by the evaporation of water from plants is especially important in winter, when relative humidity sometimes sinks below the level normally considered comfortable in offices. One solution is to switch on the expensive, energy-intensive air-conditioning system to produce the necessary vapour and moisture to reduce the build-up of static charge. But plants can also be used to increase humidity, but without using energy (except possibly for additional lighting).

In engineering terms, interior landscaping is a green solution which helps to keep energy consumption, operating and maintenance costs to a minimum.



Section 10

Other benefits of plants

Dr Tina Marie Cade,
Associate Professor of Horticulture, Texas State University

Cade's study reported a project designed to investigate whether interior planting or views of exterior planting affected perceptions of job satisfaction.

Using a digital job satisfaction survey, Cade cited several conditions for respondents: job satisfaction, physical work environments, the presence or absence of live interior plants and also windows, environmental preferences of the office workers, and demographic information.

The collected data showed significant differences in workers' perceptions of those who worked in offices with plants or window views compared to employees who worked without one or both.

Findings indicated that people who worked in offices with plants and windows reported that they felt better about their job and the work they performed.

Those with plants

- Rated their job satisfaction higher
- Were more positive about their nature of work, their bosses and their colleagues higher
- They considered themselves happier or more content

Those without plants were generally more dissatisfied with their quality of life.

Craig Knight,
University of Exeter/Prism

Craig Knight produced experimental evidence that clearly shows enriched work environments (plants can be a part of enrichment) can result in productivity improvements of over 15%. It also showed that if the office workers themselves had a say in the enrichment, then productivity could be increased by 30%.

Knight used a series of surveys including one downloadable from a news report on the BBC news website. A total of 1300 participants completed the assessments.

The questionnaires related to the physical aspects of the participants' work space, examined workers' sense of identification with their employers and colleagues, and explored their sense of job satisfaction.

The results showed that there is a positive relationship between having some say over the way your workspace is designed and feeling good about the work that is being done and the organisation for whom the work is being performed.

