



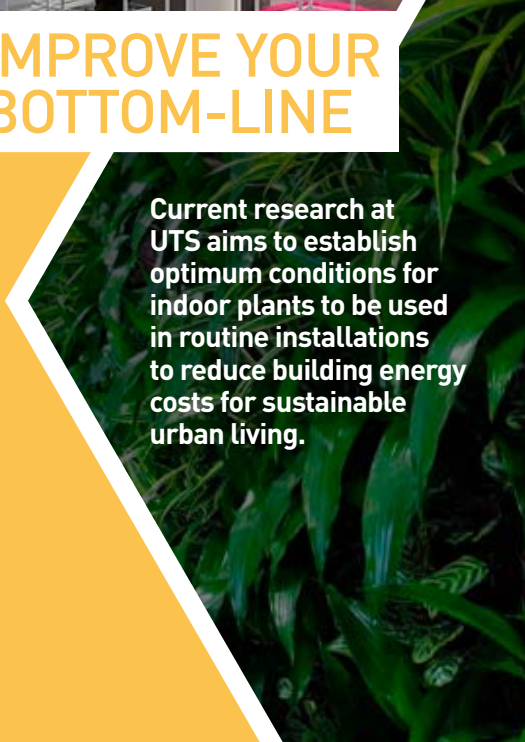
INDOOR PLANTS WORK

IMPROVE YOUR
BOTTOM-LINE

Science shows that indoor plants:

- > Reduce indoor air pollution
- > Reduce workplace illness
- > Reduce sick-leave absences
- > Reduce stress and negativity
- > Do not create unhealthy mould problems
- > Raise performance & productivity
- > Improve job satisfaction
- > Enhance business image with potential clients
- > Improve school performance & patient wellbeing
- > Contribute to meeting at least 75% of Indoor Environmental Quality (IEQ) criteria

Current research at UTS aims to establish optimum conditions for indoor plants to be used in routine installations to reduce building energy costs for sustainable urban living.



Indoor plants improve indoor air quality (IAQ)

Indoor air pollution can induce Sick-Building-Syndrome (SBS), with symptoms of coughing, wheezing, headaches, sore eyes, nose, or throat, loss of concentration and nausea^(1,2). City building air-conditioners normally filter out dust (particulates) from incoming air, but don't remove gaseous pollutants.

Indoor plants reduce all types of urban air pollution⁽³⁻¹⁰⁾ (90% of which comes from fossil fuel combustion):

- > Nitrogen and sulfur oxides
- > Carbon dioxide (CO₂) & carbon monoxide (CO)
- > Air toxics (ie volatile organic compounds 'VOCs')
- > Fine particulate matter (PM10/2.5)
- > Ozone

And indoor air is always more polluted than outdoors, even in CBD — why?

As polluted outdoor air enters it meets up with more pollutants from indoor sources:

More VOCs emitted from plastics/synthetics, in furniture/furnishings/paints/solvents/computers, etc.

UTS laboratory research (17 species/varieties) shows indoor plants⁽¹¹⁻¹⁴⁾:

- > Have strong capacity to remove VOCs; and
- > If concentrations rise, so do rates of removal
- > All species are about equally effective – main removal agents are normal root-zone bacteria; plant nourishes & regulates its microorganisms (symbiosis)
- > Hydroculture plants work also (just a bit slower to get started)
- > VOCs are removed day and night (24/7)
- > Absorbed VOCs don't accumulate — broken down to CO₂ and water

UTS office study found

- > 3 to 6 plants / office kept VOC levels below 100 parts per billion (ppb) — regarded as negligible health risk (Aust. recommended total VOC max. is 500 ppb)

Overseas laboratory studies

(> 200 species)

- > All show VOC removal

It looks like any normal indoor species will remove VOCs

> More CO₂ from us breathing

(Aust. recommended indoor CO₂ max. is 1,000 parts per million (ppm); global CO₂ levels now ~400 ppm and rising)

Any green shoot, with adequate light, will remove CO₂ (photosynthesis/sugar manufacture) and release equal amounts of O₂ — two-way refreshment! But every species, including 'indoor' plants, has its idiosyncrasies of photosynthetic function as well as appearance, so, to optimise CO₂ reduction:

- > Place species according to recognised shade tolerance
- > The more foliage the better; & targeted plant lighting could help^(16, 17)
- > UTS office study⁽¹⁵⁾ found CO₂ reductions of 10% or more
- > Preliminary UTS laboratory study⁽¹³⁾ found CO₂ uptake was a bit faster in hydroculture plants than in pot-mix (probably because of fewer non-green tissues, inc. roots & root-zone microorganisms, which all respire).

Cleaner air enables clearer thinking

A European study by engineers/physicists found a 1% reduction in dissatisfaction with IAQ resulted in a 10% increase in productivity!⁽¹⁸⁾ — that means: Indoor plants repay more than the cost of their keep!

Office plants promote occupant health and wellbeing

Medical research shows workplace stress reduces productivity and performance, & leads to illness; stress-related illness is a widespread urban health concern; and staff illness & sick-leave absences are used as direct indicators and measures of lost productivity⁽¹⁹⁻²¹⁾.

International research shows Indoor plant presence reduces illness and absences⁽²²⁻²⁴⁾:

- > Sick-leave — from 20 to >60%
- > Coughing & wheezing — 35%
- > Dry eyes, nose, throat — 20%
- > Perceptions of pain — 25%

And reduces feelings of stress and negativity⁽²⁵⁻²⁷⁾:

- > Lowered tension levels, using EEG, EMG, blood pressure readings
- > Survey questionnaires probing stress and/or negativity

INDOOR
PLANTS
A Bonus for Business!



> **UTS office study** (55 staff; single offices) recorded average scores of reductions in stress and negative mood feelings of over 40%

Indoor plant presence increases productivity, performance, job satisfaction, by >10%, measured by⁽²⁸⁻³¹⁾:

- > Faster times to complete computer tasks
- > Creative task performance
- > Sorting and editing tasks
- > Attention capacity
- > Job satisfaction (on all 10 criteria tested)
- > Promotes good office relationships

Indoor plant presence improves business image⁽³²⁻³⁶⁾

Surveys show workplace plants give perception that the company is:

- > Trustworthy
- > Warm and welcoming
- > Stable and balanced
- > Well-run
- > Patient and caring
- > Concerned for staff wellbeing
- > Not mean — spends money on added beauty and calmness
- > Provide a healthier, cleaner atmosphere

Indoor plants also aid school performance^(22, 36, 37)

- > Primary school absences reduced 23%
- > **UTS-IPA study** — (Qld) (4 pots/classroom) Mathematics, science & spelling scores improved 11-12% compared with no-plant rooms
- > **Portuguese study** — 6 hanging-plant baskets/classroom reduced: CO2 by 45%; Total VOCs -27%; PM10 -30%, compared with no-plant rooms

And aid patients in healthcare facilities⁽³⁸⁻⁴¹⁾

- > Hospital — recovery from surgery — fewer pain-killers & other medications; fewer complaints
- > In rehabilitation care — more positive outlook
- > Residential care for dementia — stimulated awareness; more positive emotions(ref)

Think green zones, desk-tops, file-top hedges; vertical gardens, lift areas, foyers, etc. – there’s a living-green contributor to performance and wellbeing in any workplace building.

Q. How do indoor plants reduce stress and increase productivity?

Environmental-psychologists and human-ecologists agree that⁽⁴⁵⁻⁵¹⁾:

- > Humans developed in a green leafy landscape, and we’re therefore hard-wired for the feeling of ‘green-is-the-good-place-to-be’ (think real-estate prices as a reality check!).
- > As a consequence of this ‘native landscape of origin’, urban populations suffer ‘green deprivation’ compared with our ancestors (again, think real-estate & ‘get-away’ camping weekends):
 - In 1800, only 3% of global population lived in urban areas
 - Now it’s > 50%, and rising
 - It’s about 80% in developed countries, where we urbanites spend 90% of time indoors

- Where brief glimpses of living greenery in our immediate environment (eg. on desk or thereabouts) provide us with unconscious feelings of calm and a wider space, even if we don’t notice the plant presence
- This momentarily relaxes us, resetting our ‘attention-button’, & preventing development of attention fatigue — so we work better — for longer — giving better performance — and we feel happier about it all too.



INDOOR PLANTS
A win-win-win for people, profits, planet
The triple-bottom-line

Indoor plants contribute to at least 75% of Indoor Environmental Quality (IEQ) Criteria*

IEQ criterion	Indoor plants
Air pollution mitigation	Reduce all types of UAP ⁺⁺ ; healthy plants do not contribute to unhealthy mould spore concentrations ⁺⁺⁽⁴²⁾
Low Emitting Materials	Absorb toxic emissions — VOCs etc. ⁺⁺
Ventilation effectiveness	Increase effectiveness; remove CO ₂ /replace with O ₂ ⁺⁺ ; & lower indoor particulate levels ⁽⁴³⁾
Lighting	OK for Plants? — OK for staff also ⁺⁺
Noise	Absorb & buffer noise ⁺⁽⁴⁴⁾
Views	Add aesthetics & calming greenery; lower stress ⁺⁺
Thermal comfort	Not directly influenced — but tend to stabilise humidity in human comfort zone, so could have unquantified effects here ⁺
Systems controllability	Not directly influenced — but stabilisation of temperature and humidity (as well as enhanced CO ₂ reduction) could lower air-con. energy consumption

*Criteria list: NSW Gov. Workplace Guidelines, 2010. ⁺Overseas studies; ⁺⁺ O/S & UTS studies



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Selected bibliography

1. Wargocki P, Wyon DP, Sundell J, 2000, The effects of outdoor air supply rate in an office on perceived air quality, sick building syndrome (SBS) symptoms and productivity, *Indoor Air*, 10, 4, 222-236.
2. Apte MG, Fisk WJ, Daisey JM, 2000, Associations between indoor CO2 concentrations and Sick Building Syndrome symptoms in UA office Buildings: An analysis of 1994-1996 BASE study data, *Indoor Air*, 10, 246-257.
3. Papinchak H, Holcomb EJ, Orendovici BT, Decoteau DR, 2009, Effectiveness of houseplants in reducing the indoor air pollutant ozone, *HortTechnology*, 19, 2, 286-290.
4. Wolverton BC, McDonald RC, Mesick HH, 1985, Foliage plants for the indoor removal of ...carbon monoxide and nitrogen oxides, *J. Mississippi Acad. Sci.*, 30, 1-8.
5. Coward M, Ross D, Coward S, et al., 1996, Pilot Study to Assess the Impact of Green Plants on NO2 Levels in Homes, *Bldg Res. Establishment Note N154/96*, Watford, UK.
6. Kwang JK, Myeong IJ, Dong WL, Jeong SS, Hyoung DK, et al., 2010, Variation in formaldehyde removal efficiency among indoor plant species, *HortScience*, 45, 10, 1489-1495.
7. Aydogan A, Montoya LD, 2007, Formaldehyde removal by common indoor plant species and various growing media, *Atmos Environ*, 45, 16, 2675-2682.
8. Liu Y-J, Mu Y-J, Zhu Y-G, Ding H, Arens NC, 2007, Which ornamental plant species effectively remove benzene from indoor air? *Atmos Environ*, 41, 3, 650-654.
9. Tani A, Hewitt CN, 2009, Uptake of aldehydes & ketones at typical indoor concentrations by houseplants, *Environ. Sci. Technol.*, 43, 21, 8338-8343.
10. Yang DS, Pennisi SV, Son K-C, Kays SJ, 2009, Screening indoor plants for volatile organic pollutant removal efficiency, *HortScience*, 44, 5, 1377-1381.
11. Wood RA, Burchett MD, Alquezar R, Orwell R, Tarran J and Torpy F, 2006, The potted-plant microcosm substantially reduces indoor air VOC pollution: I. Office field-study, *Water Air Soil Pollut*, 175, 163-180.
12. Orwell R, Wood R, Burchett M, Tarran J, Torpy F, 2006, The potted-plant microcosm substantially reduces indoor air VOC pollution: II. Laboratory study, *Water Air Soil Pollut*, 177, 59-80.
13. Irga PJ, Torpy FR, Burchett MD, 2013, Can hydroculture be used to enhance the performance of indoor plants for the removal of air pollutants? *Atmos Environ*, 77, 267-271.
14. Torpy FR, Irga PJ, Moldovan D, Tarran J, Burchett MD, 2013, Characterisation and biostimulation of benzene biodegradation in the potting-mix of indoor plants, *J Appl Hort*, 15, 1, 10-15.
15. Tarran J, Torpy F, Burchett M, 2007, Use of living pot-plants to cleanse indoor air research review, *Proc. 6th Internat. Conf. Indoor Air Quality, Ventilation & Energy Conservation - Sustainable Built Environment*, Sendai, Japan, Ill, 249-256.
16. Park, S.A., Kim, M.G., Yoo, M.H., Oh, M.M., Son, K.C., 2010, Comparison of indoor CO2 removal capability of five foliage plants by photosynthesis. *Korean J Hort Sci Technol*, 28, 5, 864-870.
17. Torpy FR, Irga PJ, Burchett MD, 2014, Profiling indoor plants for the amelioration of high CO2 concentrations, *Urb Forestry Urb Greening*, 13, 2, 227-233.
18. Djukanovic R, Fanger PO, 2002, Cost-benefit analysis of improved air quality in an office building, *Proceedings: Indoor Air*, 808-813.
19. Kopp MS, Stauder A, Purebl G, Janszky I, Skrabski A, 2007, Work stress and mental health in a changing society. *Europ J Pub Health*, 18, 238-244.
20. European Environment Agency, 2014, *Urban stress - The problem in Europe's Environment - The Dobris Assessment*, Ch. 37 (<http://www.eea.europa.eu/publications/92-826-5409-5>).
21. Dewa CS McDaid D, 2011, Investing in the mental health of the labor force: Epidemiological and economic impact of mental health disabilities in the workplace. In IZ Schultz, ES Rogers (eds), *Work, Accomm. & Retention in Mental Health*, 1st Ed., Spr Sci, Pt 1, 33-51.
22. Fjeld T, 2000, The effect of interior planting on health and discomfort among workers and school children, *HortTechnology*, 10, 1, 46-52.
23. Lohr VI, Pearson-Mims C, 2000, Physical discomfort may be reduced in the presence of interior plants, 2000, *HortTechnology*, 10, 1, 53-58.
24. Fjeld T, 2002, The effects of plants and artificial daylight on the well-being and health of office workers, school children and health-care personnel. *Proceedings of International Plants for People Symposium*, Floriade, Amsterdam, NL. pp. 25-27.
25. Chang C-Y, Chen P-K, 2005, Human response to window views and indoor plants in the workplace, *HortScience*, 40, 1354-1359.
26. Burchett M, Torpy F, Brennan J, Craig A, 2014, The influence of office plants in reducing feelings of stress and negativity in building occupants. (submitted for pub.)
27. Lohr VI, Pearson-Mims CH, Goodwin GK, 1996, Interior plants may improve worker productivity and reduce stress in a windowless environment. *Environ Hort*, 14, 97-100.
28. Shibata S, Suzuki N, 2004, Effects of an indoor plant on creative task performance and mood. *Scand. J Psychol*, 45, 373-381.
29. Chang C, Chen P, 2005, Human response to window views and indoor plants in the workplace. *HortScience*, 40, 5, 1354-1359.
30. Dravigne A, Waliczek TM, Lineberger RD, Zaljicek JM, 2008, The effect of live plants and window views of green spaces on employee perceptions of job satisfaction, *HortScience*, 43, 183-187.
31. Knight C, Haslam AS, 2010, The relative merits of lean, enriched, and empowered offices: An experimental examination of the impact of workspace management strategies on well-being and productivity. *J Exptal Psychol: Applied*, 16, 2, 158-172.
32. Aitken JR and Palmer RD, 1989, The use of plants to promote warmth and caring in a business environment, *Proc. 11th Ann. Meet. Amer. Culture Assoc.*, St Luis, MO.
33. Ceylan C, Dul J, Aytac S, 2008, Can the office environment stimulate a manager's creativity? *Human Factors and Ergonomics in Manufac. Serv. Industries*, 18, 6, 589-602.
34. Weinmaster M, 2009, Are green walls as "green" as they look? An introduction to the various technologies and ecological benefits of green walls. *J Green Building*, 4, 4, 43-18.
35. Smith AJ, Tucker M, Pitt M, 2011, Healthy, productive workplaces: Towards a case for interior plantscaping, *Facilities*, (online, accessed 05/06/2014).
36. Daly J, Burchett M, Torpy F, 2010, Plants in the Classroom can Improve Student Performance. Report to IPA [Aust.].
37. Pegas PN, Alves CA, Nunes T, Bate-Epey EF, Evtuygina M, Pio CA, 2012, Could houseplants improve indoor air quality in schools? *J Toxicol Environ Health, Pt A*, 75, 22-23; 1371-1380.
38. Park S-H, Mattson RH, 2009, Patients recovering from surgery, *J Alternat. Complement. Med.* 15, 9, 975-980.
39. Raanaas RK, Grindal Patil G, Hartig T, 2010, Effects of an indoor foliage plant intervention on patient well-being during a residential rehabilitation program, *HortScience*, 45, 3, 387-392.
40. Dijkstra K, Pieterse ME, Pruyn A, 2008, Stress-reducing effects of indoor plants in the built healthcare environment: The mediating role of perceived attractiveness. *Prevent Med*, 47, 279-283.
41. Rappe E, Lindén L, 2002, Plants in health care environments: experiences of the nursing personnel in homes for people with dementia, *ISHS Acta Horticulturae*, 639.
42. Torpy FR, Irga PJ, Brennan J, Burchett MD, 2012, Do indoor plants contribute to the aeromycota in city buildings? *Aerobiologia* [online].
43. Lohr VI, Pearson-Mims CH, 1996, Particulate matter accumulation on horizontal surfaces in interiors: Influence of foliage plants, *Atmos Environ*, 30, 14, 2565-2568.
44. Costa, P.R., & James, R.W. (1999). Air conditioning and noise control using vegetation. In: *Proc Indoor Air 99*, Internat Conf Indoor Air Quality and Climate. Edinburgh, Scotl., 3, 234-239.
45. Kaplan R, Kaplan S, 1990, Restorative experience: the healing power of nearby nature. In M Francis, RT Hester Jr (Eds.). *The Meaning of Gardens: Idea, Place and Action*. Camb, MA: MIT Press, 238-243.
46. Grinde B, 1996, The biology of visual aesthetics. *J. Soc. Evol. Systems* 19, 31-40.
47. Crawford C, Krebs D, 1997, *Handbook of Evolutionary Psychology: Ideas, Issues and Applications*, LEA, NY, USA.
48. Reed KE, 1997, Early hominid evolution and ecological change through the African Plio-Pleistocene, *J Human Evoln*, 32, 2-3, 289-322.
49. Herzog TR, Herbert EJ, Kaplan R, Crooks CL, 2000 Cultural and developmental comparisons of landscape perceptions and preferences. *Environ Behaviour*, 32, 323-337.
50. Orians GH, Heerwagen JH, (1992), Evolved responses to landscapes, In Barkow JH, Cosmides L, Tooby J (Eds), *The adapted mind: Evolutionary Psychology & Generation of Culture*, pp. 555-579, NY, US: Oxf Univ Press, xii, 666 pp.
51. Grinde B, Grindal Patil G, Biophilia: Does visual contact with nature impact on health and well-being? *Int. J. Environ. Res. Public Health* 2009, 6, 2332-2343.
52. Maller C, Townsend M, Pryor A, Brown P, St Leger L, 2006, Healthy nature healthy people: 'contact with nature' as an upstream health promotion intervention for populations, *Health Promot Int*, 21, 1, 45-54.

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