Effects of tree shade on solar ultraviolet exposures to humans

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Abstract. This paper investigates how much solar UV protection is provided by the shade of Australian trees and the anatomical distribution of personal UV exposures in the shade of these trees. Personal UV exposures in tree shade are of a high enough value to require additional UV reduction strategies. A well planned strategy using a combination of protective methods can minimize the level of exposure to harmful solar UV radiation in tree shade.

Introduction

The usage of shade is recommended by Health authorities for the minimization of solar ultraviolet exposures (Department of Architecture 1995, 1996, 1997). The UV irradiances in tree shade have been measured (e.g. Parisi *et al*. 2001; Parsons *et al*. 1998), along with comparison of the UV spectrum (Parisi and Kimlin, 1999) and the diffuse UV (Parisi *et al.* 2000) in tree shade and adjacent sun. Additionally, the UV irradiances in open tree canopies have been modeled (e.g. Grant and Heisler, 1999). The use of tree shade will reduce the level of UV exposure, but it is essential that the usage of shade be with sufficient understanding of the scientific data on the UV environment in tree shade. This paper aims to clarify the issues related to the amount of UV protection provided by Australian tree shade.

Methods

The trees were a range of up to 50 typical Australian evergreen trees in the grounds of the University of Southern Queensland (USQ) campus, Toowoomba, Australia (27.5^{o}S) and isolated from other trees and structures by 5 to 10 m. The UV albedo of the ground cover was less than 5%. Details of the UV instrumentation can be found in Parisi *et al*. (2001). In summary, the solar UV spectrum in both tree shade and full sunlight was measured at 1 nm increments with a UV spectroradiometer, based on a dual holographic grating (1200 lines/mm) monochromator, whose calibration is traceable to the Australian UV standard lamp housed at the National Measurement Laboratory.

The broadband UV irradiances were measured on a horizontal plane at ground level in the tree shade and adjacent full sun with a radiometer (model 3D V2.0, Solar Light Co., Philadelphia, PA, USA) fitted with a UVA (320-400 nm) detector and an erythemal UV (UV_{ery}) detector. Diffuse irradiances were measured by holding a shadow band approximately 15 cm above the respective detector to shadow it. The UV_{ery} detector is sensitive to wavelengths shorter than 385 nm with a response that approximates the erythemal action spectrum (CIE, 1987). Each detector was calibrated against the spectroradiometer with the solar UV as the source.

The erythemal UV exposures to selected anatomical sites on a model of a human in tree shade were measured with polysulphone dosimeters. The polysulphone film was cast at the USQ and fabricated into dosimeters. The dosimeters have an active area of approximately 1 cm^2 and an overall size of 3 cm x 3 cm. The pre and post exposure optical absorbency of the polysulphone dosimeters was measured at 330 nm in a spectrophotometer and each batch of film was calibrated. The well-established method of deploying the dosimeters on rotating manikins to average out the directional variation was employed as it was not practical nor convenient to use human subjects wearing the dosimeters in the tree shade over the period of a day. The manikins were moved throughout the day to maintain them in the tree shade.

Results

The UV spectra in full sun and adjacent tree shade for a typical gum tree are shown in Figure 1 for a solar zenith angle (SZA) of 6^{o} and the solar disc clear of cloud. The protection factors provided by the shade of gum trees for each ten nanometre waveband are in Figure 2. These results are for a tree with a canopy that provided a reduction to 15% in the visible waveband and for a relatively cloud free day and SZA range of 40 to 62^{o} at the sites of the approximate centre of the shade and the shade of the trunk.

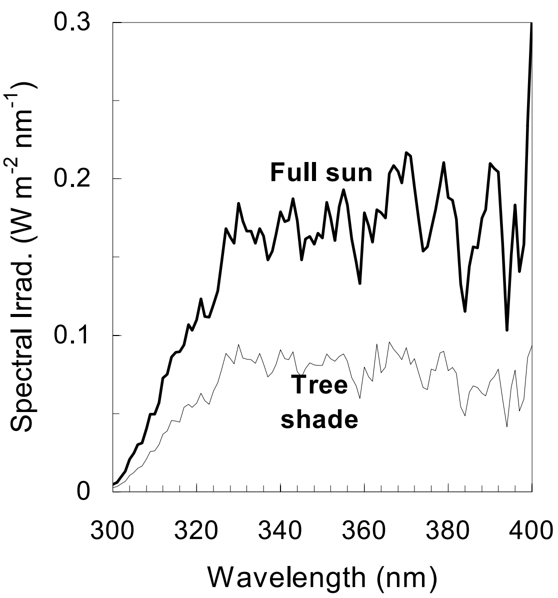


Figure 1. Comparison of the spectral UV in full sun and adjacent tree shade.

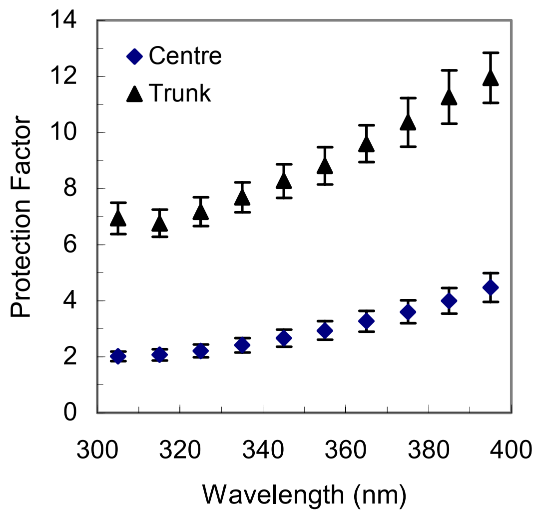


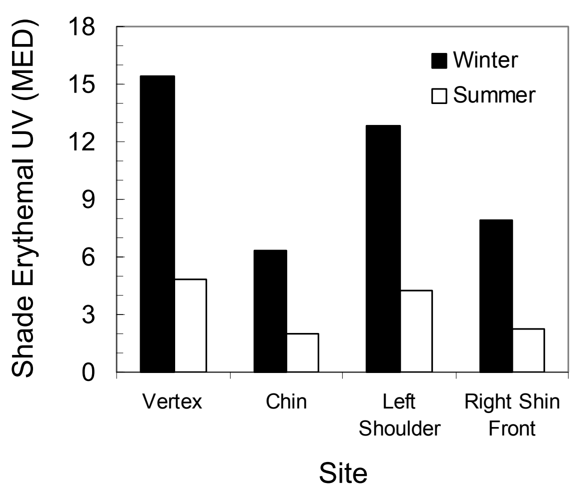
Figure 2. Variation with wavelength of the protection factor provided by tree shade.

The broadband UV_{ery} data in the shade of 50 trees was analysed for the influence of tree canopy density, canopy width, tree height and height to the start of the tree canopy. Usage of multiple regression established that the UV_{ery} in the tree shade depended on the tree canopy density and the height of the start of the canopy above the ground, with no significant dependence on the other parameters.

Table 1 shows the percentage of the UV_{ery} and UVA radiation in tree shade that is due to the diffuse component compared to the percentage that is due to the diffuse component in full sun. These results are for summer at the three times of the day.

Table 1. Percentage diffuse UV at ground level in summer for each of the three times.

	Percentage diffuse UV			
	Erythemal UV		UVA	
	Tree shade	Full sun	Tree shade	Full sun
morning	60±2	39±2	54±2	26±2
noon	60±2	26±1	57±2	20±2
afternoon	61±2	46±3	56±2	28±2



The erythemal UV to the various anatomical sites for a full day in the tree shade for an upright posture are shown in Figure 3. These are averaged over each day of the respective seasons. The ranges of exposures are 6.4 MED (minimum erythemal dose) to 15.4 MED in summer and 2.0 MED to 4.8 MED in winter for the sites of the chin and vertex of the head respectively.

Figure 3. The erythemal UV to the anatomical sites for a full day in the tree shade.

Discussion

The protection from solar UV_{ery} provided by the tree shade ranged from a factor of approximately 2 to 4 in the shade centre and 7 to 12 in the trunk shade for the wavelength range 300 to 700 nm respectively. Tree shade does provide protection from solar UV, however, it is not total protection and it is not as effective at providing protection at the shorter wavelengths where the erythema action spectrum and the action spectra for other biologically damaging processes have higher effectiveness.

High personal UV exposures in excess of the occupational limit (NHMRC, 1989) may be experienced in the shade of trees in Australia. Personal UV exposures depend on the cloud conditions. This has been addressed by taking measurements throughout the seasons for the range of cloud conditions between nil cloud and 7 okta cloud.

Over the summer, approximately 60% of the erythemal UV radiation in the tree shade is due to the diffuse component. Similarly, approximately 56% of the UVA radiation in the tree shade is due to the diffuse component. These values approach the percentage diffuse UV component in full sun for winter. This high diffuse UV component in the shade may result in high UV exposures to not only parts of the body on a horizontal plane that are not protected, but also, equally high UV irradiances to parts of the body, including the eyes and face, that are not UV protected.

In summary, the research allows the following recommendations regarding solar UV exposures in Australian tree shade:

- UV irradiances in tree shade are of a high enough value to require additional UV reduction strategies. A well planned approach using a combination of protective strategies is required;
- As a general guide, trees with a heavier shade in the visible waveband and canopy closer to the ground provide the better protection from UV exposures;
- The high relative percentages of diffuse UV in tree shade highlight the necessity for the wearing of wrap-around sunglasses or sunglasses with lateral shields.

Further research is required to determine the UV exposures in the shade of trees with thicker density canopies.

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References

CIE (International Commission on Illumination). 1987. A reference action spectrum for ultraviolet induced erythema in human skin. *CIE J.* 6, 17-22.

Department of Architecture, University of Queensland. 1995. Shade for sports fields, Brisbane, Queensland Health.

Department of Architecture, University of Queensland. 1996. Shade for public fields, Brisbane, Queensland Health.

Department of Architecture, University of Queensland. 1997. Shade for young children, Brisbane, Queensland Health.

Grant, R.H., Heisler, G.M. 1999. Modeling UV irradiance in open tree canopies: estimation of pedestrian level exposure. *Proc. Int. Conf. Biometeorol.* 8-12 Nov, 1999, Sydney, Australia.

NHMRC (National Health and Medical Research Council). 1989. Occupational standard for exposure to ultraviolet radiation. Radiation Health Series No.29. NHMRC, Canberra.

Parisi, A.V., Kimlin, M. 1999. Comparison of the spectral biologically effective solar ultraviolet in adjacent tree shade and sun. *Phys. Med. Biol.* 44, 2071-2080.

Parisi, A.V., Kimlin, M.G., Wong, J.C.F., Wilson, M. 2000. Diffuse component of the solar ultraviolet radiation in tree shade. *J. Photochem. Photobiol. B: Biol.* 54(2-3), 116-120.

Parisi, A.V., Wong, J.C.F., Kimlin, M.G., Turnbull, D., Lester, R. 2001. Comparison between seasons of the ultraviolet environment in the shade of Australian trees. *Photodermatol. Photoimmunol. Photomed.* 17, 55-59.

Parsons, P., Neale, R., Wolski, P., Green, A. 1998. The shady side of solar protection. *Med. J. Aust.* 168, 327-330.