

## GUEST EDITORIAL: DENNIS GREER AND IAN WARRINGTON



**Dennis Greer** was born in Central Otago, schooled in Alexandra and went on to attend the University of Otago, completing a B.Sc. (Hons) and Ph.D. at the Department of Botany on ecophysiology of snow tussocks in the mountains of Central Otago. Appointment as a research scientist at Plant Physiology Division, DSIR, Palmerston North, enabled a career in environmental physiology, with a special interest in low temperature stress effects on plants to be pursued, using facilities at the National Climate Laboratory. He received a DSIR fellowship in 1984 to study at the Department of Plant Biology, Carnegie Institute of Washington where his long standing interests in low temperature-high light stress effects on photosynthesis were initiated. He is past President of the New Zealand Society of Plant Physiologists, has published over 50 refereed papers and been invited to numerous international conferences in Australia, Japan, Finland, Sweden and the USA.



**Ian Warrington** was born in Timaru, received his primary and secondary education in Hastings, and completed B. Hort. Sci., M. Hort. Sci and D.Sc. degrees at Massey University. He has spent his research career in Palmerston North, being employed initially as a scientist in the Plant Physiology Division of DSIR, and more laterly as a Science Manager in the Horticulture and Food Research Institute of NZ Ltd. Throughout that period he has played a central role in the development of the National Climate Laboratory - a controlled environment facility that has been used by research scientists from all universities and many CRI's around New Zealand. His primary research interests have been focussed on the environmental physiology of horticultural, agronomic and forestry species of relevance to New Zealand. He is a Fellow of the Royal Society of New Zealand, of the New Zealand Society for Horticultural Science, and of the American Society for Horticultural Science. He has over 100 refereed publications, including a book (co-edited with Graeme Weston) on the science and management of kiwifruit.

## THE NATIONAL CLIMATE LABORATORY: AN UNAPPRECIATED TOOL FOR ECOLOGICAL RESEARCH

“A freezing chamber offers an easy place for such [frost] experiments... and ... valuable data as to the cold-resisting powers of our plants might be arrived at” (Cockayne, 1897).

The National Climate Laboratory was opened in 1970 and has been operating for the past 25 years (recently celebrating its anniversary) for both

national and international scientists carrying out environmental research on plants and animals (Halligan, 1995). The facilities have been used by a wide range of plant and animal based researchers from the pastoral, horticultural, and forestry sectors involving a range of disciplines from agronomy, pathology, entomology, physiology, plant breeding and zoology. New Zealand ecologists have been

conspicuously absent (in spite of the potential in controlled environment research seen by pioneering ecologists - see above quotation) and yet there has been a range of activities that are complementary to this discipline.

The rationale for using the National Climate Laboratory facility is to overcome the difficulty in field-orientated plant and animal research of separating out the confounding influences of temperature with light, photoperiod with light quantity and quality, and temperature with water vapour pressure deficit, on a range of biological processes. The main capability of this facility is to control virtually all climatic factors with high precision. These factors include temperatures ranging from  $-25$  to  $+50^{\circ}\text{C}$ , water vapour pressure deficits from  $0.0$ - $3.0$  kPa, photon flux densities from  $0$ - $2000$   $\mu\text{mol m}^{-2} \text{s}^{-1}$  and carbon dioxide concentrations from  $300$  -  $1000$   $\mu\text{mol mol}^{-1}$ . In addition, light quality can simulate shade light through to the open sky spectrum and photoperiods can be held fixed or varied at constant rates. Plants growing in this facility are routinely supplied with one of two complete mineral nutrient solutions or water on demand. There are 24 rooms with individual microprocessor based controllers and all can be selectively programmed to simulate a wide range of climates, particularly to programme a wide temperature range yet keep all other environmental factors constant. Similarly, there is scope to simulate changes in specific environmental factors, such as the diurnal temperature patterns or matching the change in photoperiod with that occurring outdoors. Changes in light quality, notably the red/far red ratio (R/FR), while maintaining a constant photon flux density, are possible.

The capabilities of the National Climate Laboratory and its potential as a tool for ecological research are largely unappreciated. However, some research carried out by National Climate Laboratory physiologists does highlight the ecological opportunities provided by this facility.

The New Zealand timberline is characterised by a sharp transition from beech forest to either scrub or grassland. Greer, Wardle and Buxton (1989) examined the possibility that a contributing factor to this sharp transition was the failure of seedlings to survive the temperature extremes in the zone beyond the timberline. By regular transport of mountain beech (*Nothofagus solandri* var. *cliffortioides* (Hook. f.) Poole) seedlings from the Craigieburn timberline to the National Climate Laboratory and exposing of these to a range of precision controlled frosts, the seasonal changes in frost hardiness were determined. This study showed that these seedlings were incapable of tolerating frosts in excess of

$-11^{\circ}\text{C}$ ; yet these were regular events at timberline, suggesting frosts were the cause of seedling mortality above timberline. A further result of this study was to show that low-altitude grown seedlings were incapable of frost hardening beyond a few degrees of frost, suggesting an altitudinal gradient in capacity to frost harden in beech. Field frosts are notoriously unreliable in frequency and severity, making studies such as these difficult without controlled frosts.

Although this study could not reveal ecotypic variation in frost hardening capacity in beech, a related study with the widely distributed *Leptospermum scoparium* J.R. et G. Forst was successful in this context. Greer, Muir and Harris (1991) collected seeds from a range of locations and these were grown in a common environment. Again using the specialised frost facilities at the National Climate Laboratory, these seedlings were exposed to a range of precision frosts and the seasonal changes in frost hardiness of each population were measured. This study revealed that manuka populations from the northerly locations were virtually incapable of frost hardening during the transition from summer to winter while southerly and high altitudinal populations had a relatively high capacity to frost harden. Because these differences were expressed in spite of all seedlings being raised in a common environment, there was *prima facie* evidence of ecotypic selection for the capacity to frost harden within this genus.

To further understand this, Greer and Robinson (1995) took two of these populations and grew the plants under constant controlled hardening conditions in the National Climate Laboratory, using results determined from an intensive study with *Pinus radiata* D. Don that showed frost hardiness was a (low) temperature dependent process (Greer, 1983; Greer and Stanley, 1985). In the manuka study, seedlings were grown at temperatures from  $-3$  to  $+6^{\circ}\text{C}$  and frost hardiness determined by exposing seedlings to a range of controlled frosts. From time courses of hardiness development at each temperature, the rate of hardening was measured and the temperature response of each population determined. This analysis showed that the low-hardening population had a small response to temperature while the high-hardening population had a relatively steeper temperature response. Thus for the first time, ecotypic variation in hardening capacity could be accounted for in physiological terms. Intrageneric and interspecific studies of the frost hardiness of several native species have contributed to understanding the ecology of other natives (Warrington and Stanley, 1987; Hawkins *et al.*, 1991).

Climate changes that are induced by increases in CO<sub>2</sub>, the so-called greenhouse effect, are an important issue facing the global biosphere. For plants, however, there is an additional issue, that of the direct effect of elevated CO<sub>2</sub> on their photosynthetic processes. To predict the consequences and impacts of climate change requires not only the knowledge of the direct CO<sub>2</sub> effect but also the indirect CO<sub>2</sub>-induced temperature effect. The National Climate Laboratory is uniquely set up to seek answers to these questions, particularly with the capability to precisely control temperatures. Study of the impacts of this interaction between CO<sub>2</sub> and temperature on a wide selection of common pasture species was carried out in the National Climate Laboratory by Campbell and co-workers (Campbell, Laing and Newton, 1993; Greer, Laing and Campbell, *in press*). No relationship between morphology, life history or ecology and their response to elevated CO<sub>2</sub> could be discerned among the various species. Instead continuous variation in response to CO<sub>2</sub> was observed at all temperatures. A most surprising result was that the response of these pasture species to elevated CO<sub>2</sub> was independent of temperature, at least between 12 and 28°C. Sustainability of natural ecosystems must be at risk from increasing CO<sub>2</sub> concentrations and potential changes in temperature. The results from this detailed pastoral study show there is no simple prediction of the response from ecological characteristics of the species.

Changes in light quality through the canopy are a characteristic feature of stratified plant communities from pastures to forests and these changes can have a marked effect on the growth of understory species. Such effects are almost impossible to simulate in the field, particularly in eliminating the confounding influence of light quality with quantity. Warrington and co-workers (Warrington *et al.*, 1988) grew *Agathis australis* (D. Don) Lindl. and *Dacrydium cupressinum* Lamb. seedlings and both juvenile and mature *Pinus radiata* D. Don trees under a simulated range of red/far red ratios at two photon fluxes in the National Climate Laboratory. Their results showed the shade intolerant pine was very responsive to decreasing R/FR with stem height, dry weight and apical dominance markedly increasing. In contrast, the shade tolerant rimu was largely unresponsive to R/FR ratio with kauri intermediate. These differences in response to changing light quality in the understory have important implications for understanding competition between species in forest understories and the role of canopy gaps in providing opportunities for shade intolerant species on the development of forest stands.

Temperature is a major determinant of the productivity of ecosystems through its effect on plant growth and development. Methodologies to describe responses of plants to temperature have been well established in the National Climate Laboratory, as exemplified by the extensive studies by Warrington and Kanemasu (1983) of leaf initiation and leaf appearance rates in maize. Using a combination of day and night temperatures to achieve 17 different mean temperatures ranging from 6 to 38°C, the quantitative relationships with temperature were measured and an underlying temperature response for each process derived. Analysis of these data lead to the development of analytical tools, such as the discrete rate method (McNaughton, Gander and McPherson, 1985), enabling controlled environment-determined temperature responses to be transportable to the field. This has provided a method of predicting productivity of field-grown maize. Similar methodologies were used by Seager (1993) to derive an underlying temperature response curve that allows commercial kiwifruit maturation to be predicted from meteorological data. Application of these controlled environment methods and analytical techniques to ecological examples could help to resolve the importance of climatic limitations to sustainability of native ecosystems.

The capabilities of the National Climate Laboratory have been employed for animal research in a variety of cases but is best exemplified by the study of Williams and Turnbull (1983) on variation in seasonal nutrition, thermoregulation and water balance in Westland and Wanganui populations of the brushtail possum (*Trichosurus vulpecula* Kerr). Their study examined acclimation to simulated winter and summer temperature conditions and provided information on how the two possum populations compared during abstinence from feeding during low temperature and prolonged drought conditions.

These selected examples show how the capabilities of the National Climate Laboratory have been used as a tool in studies of climatic effects on plants and animals. To understand how any environmental variable is affecting biological processes, studies must be directed at understanding the *response* of that process to the environmental factor. Only in a controlled environment facility, such as the National Climate Laboratory is there an opportunity to achieve that understanding by growing plants or animals over a range of conditions of the chosen variable while holding all other climatic variables constant. From there, quantitative relationships can be derived and analytical tools developed to allow interpretation of field responses.

Advances in understanding the ecology of some aspects of a selected range of native plant species has accrued from studies in these facilities. Controlled environments are a powerful tool to achieve spectacular gains in wider understanding of the ecology of our native flora and fauna. Now is the time for ecologists to seize the opportunity that the agronomists, foresters, horticulturists, physiologists and zoologists have done for almost the past three decades.

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