# Population studies of ultraviolet-B radiation responses in white clover (*Trifolium repens* L.)

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To Angelika and Stephan

# Abstract

White clover growing in New Zealand is experiencing increasing levels of ultraviolet-B (UV-B) radiation as a result of ozone depletion. This thesis reports a series of investigations on morphological and physiological responses to UV-B in various white clover populations. In addition, these studies examined UV-B responsiveness in combination with drought and consequences for insect herbivores. Plants were grown in controlled environment rooms with and without supplemental UV-B radiation at a dose of 13.3 kJ $m^{-2}$ $d^{-1}$, corresponding to a 25% mid-summer ozone depletion above Palmerston North, New Zealand. Morphological measurements included numerous attributes of plant growth and morphogenesis as well as several aspects of leaf structure. Physiological studies investigated both primary and secondary metabolic functions. In general, UV-B reduced components of white clover growth. The white clover populations showed a number of constitutive and UV-B-induced differences in many morphological and physiological attributes. UV-B sensitivity was mitigated by drought and was less pronounced with increasing duration of UV-B exposure. Bioassays revealed differential dietary effects of UV-B-treated foliage on the performance of lepidopteran insects. UV-B effects were also apparent under frequent defoliation. Comparisons of morphological and physiological features showed that white clover UV-B responsiveness was mainly linked to inherent differences in morphology and growth among the populations, while on a physiological level it was more the UV-B-induced differences that conferred UV-B tolerance. In particular, UV-B tolerance of the white clover populations was related to lower constitutive productivity. This was further linked to several constitutive leaf attributes, including small leaf size, small and lens-shaped epidermal cells as well as low leaf water potential. UV-B-induced features linked to UV-B tolerance included high percentage of leaf dry mass, accumulation of UV-absorbing compounds and of total flavonols (particularly quercetin glycosides) as well as increases in leaf water potential. UV-B tolerance was greatest in white clover populations adapted to multiple and severe stresses in the habitat of origin. This series of investigations was used to propose a functional framework, linking UV-B responsiveness to underlying specialisation of the white clover populations.

This thesis has been written with a view to publish much of the presented material. Accordingly, each Chapter represents a self-contained unit, forming the basis of papers published, submitted or prepared for submission.

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# Abbreviations

| | |
|---|---|
| AC | Available carbohydrates |
| ACR | Average consumption rate |
| AD | Approximate digestibility |
| AGR | Average growth rate |
| $\Delta F/F'_m$ | Photochemical yield |
| DM | Dry mass, dry matter |
| ECI | Efficiency of conversion of ingested food |
| $F_v/F_m$ | Intrinsic efficiency of PSII |
| HCN | Hydrogen cyanide |
| LAR | Leaf appearance rate |
| LM | Light microscopy |
| LWR | Leaf weight ratio |
| NDF | Neutral detergent fibre |
| NGP | Number of growing points |
| NPQ | Non-photochemical quenching |
| PC | Principal component |
| PCA | Principal components analysis |
| PDM | Percent leaf dry mass |
| PPF | Photosynthetic photon flux |
| PSII | Photosystem II |
| $q_P$ | Photochemical quenching |
| RGR | Relative growth rate |
| RSR | Root:shoot ratio |
| SER | Stolon elongation rate |
| SLM | Specific leaf mass |
| TEM | Transmission electron microscopy |
| UV-A | Ultraviolet-A radiation |
| UV-B | Ultraviolet-B radiation |
| UV-C | Ultraviolet-C radiation |
| $\psi_L$ | Leaf water potential |