

## UV effects in plants - case studies from New Zealand with a northern hemisphere twist

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**Abstract.** This paper highlights recent work done in New Zealand on the regulatory role of UV radiation, showcasing the significance of protective UV responses in plants. It is demonstrated here how knowledge gained from such studies can be expanded to other areas of plant science, with sometimes surprising consequences.

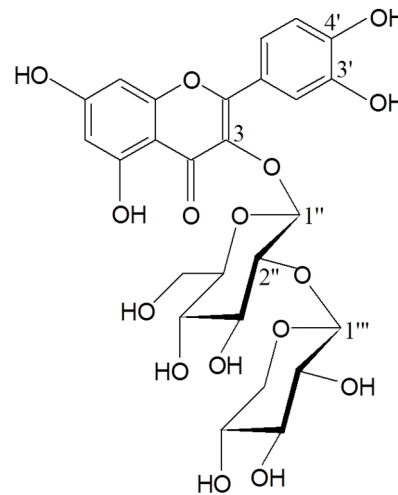
### Introduction

Research on UV effects in plants is entering its fifth decade. Initial studies were triggered by the realisation that the stratospheric ozone layer was becoming depleted. Consequently, most studies in plants focussed on the damaging effects of UV, and particularly of UV-B radiation. The large majority of these studies were conducted under indoor conditions, and often paired with low levels of accompanying photosynthetic photon flux (PPF, ~400-700nm). The latter has photo-protective effects, e.g. strongly contributing to photorepair of UV damage in plants. The frequently applied high and unrealistic UV-B/PPF ratios in those earlier studies exaggerated UV effects in plants.



**Figure 1.** Exposure of plants to UV-B radiation under controlled environment conditions.

More recently, it has become clear that UV radiation (both UV-A and UV-B) is not just a stress factor, but that it constitutes an important environmental factor that performs crucial regulatory roles in plants. At the forefront of this role are plant pigments that act as sunscreens, antioxidants and energy-dissipating agents in plants. Many of these pigments are phenolic compounds, particularly flavonoids. The flavonol quercetin (Figure 2) is a key flavonoid compound that performs ubiquitous and important protective roles in plants, including UV protection (Hofmann et al. 2000). What's more, this compound has now also been established as a key protective link in studies examining plant responses to other environmental variables (Ballizany et al. 2012).

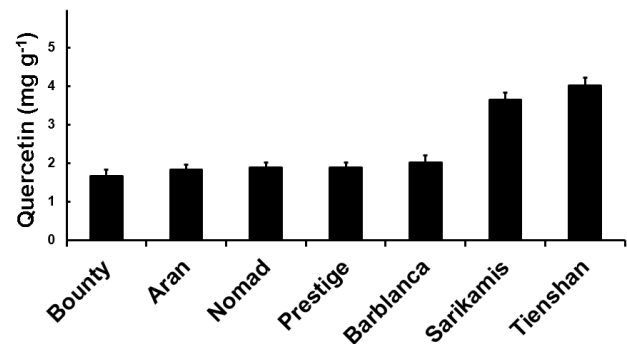


**Figure 2.** Structure of the main quercetin glycoside elicited by UV-B radiation in white clover (Hofmann et al. 2000).

A key objective of our studies was to examine the protective role of quercetin and of other flavonoids in plants of economic importance to New Zealand. New Zealand's primary industries are based on a number of crop plant species imported from the northern hemisphere, be it legume species of utmost importance to New Zealand pastures, or key horticultural crops such as grapevines.

### Results and Discussion

Our studies in the key New Zealand pasture legume species white clover revealed that quercetin glycoside levels were particularly high in plant populations derived from stress-prone habitats, such as wild ecotypes from high altitudes, UV-, cold- and drought-exposed regions (Figure 3, Hofmann and Jahufer 2011).



**Figure 3.** Accumulation of quercetin glycosides in five white clover cultivars bred for agricultural productivity (Bounty, Aran, Nomad, Prestige and Barblanca), and two ecotypes from the wild (Sarikamis and Tienshan).

Not surprisingly, these wild white clover ecotypes were tolerant against exposure to elevated UV radiation. In contrast, white clover cultivars bred for agronomic performance were UV-sensitive and had low levels of these stress-protective compounds (Figure 3). In subsequent studies we found that wild white clover ecotypes with high quercetin levels were also more resistant against other abiotic environmental factors such as drought (Hofmann and Campbell 2011). Of further interest was that the concentration of quercetin compounds in white clover populations peaked when UV and drought stress were applied in conjunction, thus showing synergistic stress-protective effects for plants (Hofmann et al. 2003).

The relevance of these findings in white clover is that the UV screen quercetin is now also used as a marker for drought stress resistance in this and in other plant species. We have built on this knowledge using hybridisation techniques. For example, we created new intraspecific hybrids between a highly productive (but sensitive to UV-B, drought and other stress factors) white clover cultivar and a stress-tolerant quercetin-rich (but less productive) white clover ecotype (Ballizany et al. 2012). This hybrid performed well under drought conditions in the field, strongly increasing its quercetin levels and maintaining higher levels of plant yield under drought when compared to its parents. We are now developing this approach further to create hybrids between different clover species, with promising results for the development of novel stress-resistant pasture cultivars (Nichols et al. 2014).

Using UV filtration in the vineyard, we found that near-ambient New Zealand UV levels strongly increased the accumulation of phenolic compounds such as quercetin glycosides in grapes of the cultivar Sauvignon Blanc. This was particularly observed in the skins of the grape berries and was strongly driven by UV-B, rather than UV-A radiation (Gregan et al. 2012). We are now expanding this research to examine the UV responses of other compounds of interest for wine quality. Preliminary findings indicate similar UV-B-elicited specificity for the accumulation and activities of antioxidants that are of importance to plant stress protection and also contribute to wine flavour and aroma.

Viticulturists can now utilise these findings by applying specific techniques to alter the UV environment in the vineyard. This can be achieved e.g. with UV-reflective mulches, as well as with targeted leaf removal around the fruiting zone of grapevines. The resulting increases in the levels of UV-driven phenolic compounds, as well as enhanced antioxidant accumulation and activity, can be used to optimize the characteristic flavour and aroma profile of iconic New Zealand wine varieties such as Marlborough Sauvignon Blanc.

## Conclusions

It has become clear that plants are well adapted to ambient levels of UV radiation and that we can utilize specific UV-driven processes for practical applications to enhance the quality of crops and of food products.

## References

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