UV-B Radiation Effects on New Zealand Grasslands

C. L. Hunt, B. D. Campbell and R. Hofmann

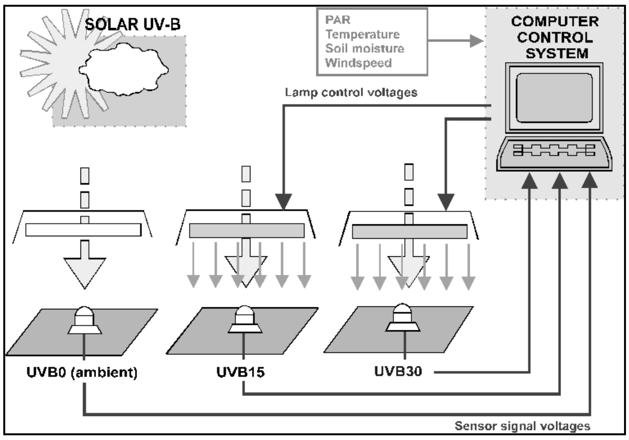
AgResearch, Grasslands Research Centre, Private Bag 11008, Palmerston North, New Zealand

Abstract. A long-term field experiment is being undertaken to investigate the effects of elevated UV-B levels on a typical New Zealand pasture. Results to date are presented illustrating the complexities of working with this system and the need for long-term studies on ecosystems of this type.

Introduction

New Zealand pastures are predominantly ryegrass and white clover, of which white clover comprises up to 20% of total biomass [*Caradus et al.,* 1996]. Pastures are dependent on atmospheric nitrogen input by biological nitrogen fixation in white clover and exhibit high annual production rates in the range 10-20 t DM/ha [*Coop,* 1986]. Pastures are subject to seasonal droughts and have a high economic importance to the country earning $13B exports/year [2001]. Based on past literature, the predicted effects of elevated UV-B on pasture are uncertain but may involve reduced clover content, reduced nitrogen inputs and reduced long-term ecosystem productivity, as well as compounded effects associated with water stress.

There is considerable uncertainty associated with these predictions, making it necessary to test these predicted effects in the field. Accordingly a field-based experiment was established in June 1998 in Palmerston North to test the effects of elevated UV-B on an established ryegrass-white clover pasture.



UV B Field experiment

Figure 1.UV-B supplementation control system.

In the experiment, additional UV-B is supplied to the pasture from UV-B fluorescent lamps suspended on frames above experimental pasture plots. The enrichment system, shown in Figure 1, is a modulated system, in which the amount of added UV-B varies in proportion to varying ambient levels. Three supplementation levels are used: UVB0, UVB15 and UVB30 corresponding to 0, 15 and 30% reductions in stratospheric ozone. The UVB0 treatment has no UV-B added above ambient levels and acts as an experimental control.

A computer control system is used to maintain a constant percentage increase in UV-B received by the two active treatments above the ambient level. This is achieved by continuously monitoring the UV-B level received by UV sensors located on the plots and by adjusting the lamp control voltage to the dimming ballasts associated with each of the lamps.

The percentage increases in UV-B for each treatment are recalculated on a daily basis from model data supplied by NIWA. For the Palmerston North site, in mid summer, the percentage increase in plant-weighted UV-B is about 70% for the 30% (UVB30) ozone reduction treatment. In winter this percentage increases to about 120%.

The experiment is a factorial design consisting of 5 UV treatments, split with two water treatments (+H_2O and –H_2O) and with four levels of replication. The water treatments are used to test the interactive effect that elevated UV-B might have with drought. Pasture plots receiving the +H_2O treatment are automatically spray irrigated with the equivalent of 25mm of rain when the volumetric soil moisture level drops below 25%. The -H_2O treated pasture does not receive additional water and can become severely droughted over the summer/autumn period. In addition to the three UV treatments there are a "No Frame" control and a "UVA" control.

Sheep graze the pasture when the sward height reaches 15cm. At this time measurements are made of herbage growth and vegetation composition. Measurements undertaken include total yield, individual species yields, nitrogen dynamics and flavonoid analysis in white clover.

Results and Discussion

As expected, a significant reduction in clover was measured in the non-irrigated pasture for the whole of the four-year period to date (Figure 2). This was a result of the annual summer/autumn drought at which time volumetric soil moisture levels dropped to between 10-15%.

What may be of greater importance is the statistically significant increase in clover content that is observed with increased UV-B in the droughted pasture for the first two years (1998/1999 and 1999/2000). The significant increase in white clover content at the UVB30 treatment was found in the droughted treatment when a persistent and long-term effect of elevated UV-B was observed from summer 1998. At this time soil moisture in the droughted pasture dropped to around 12%. Significant increases in percentage clover were observed in subsequent autumns (2000 and 2001).

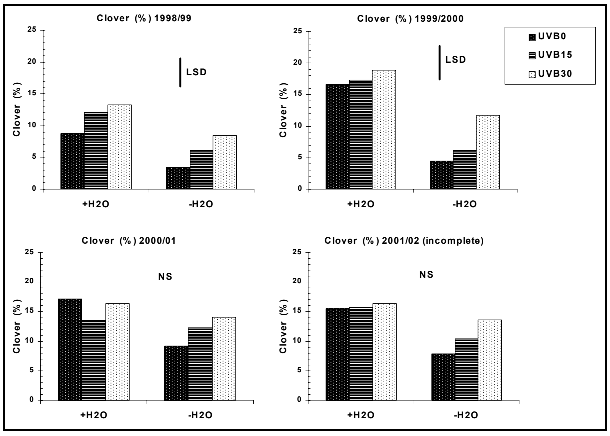


Figure 2. Clover content of pasture (%) with different UV-B and water treatments for the first 4 years of the experiment.

White clover is very important to pasture due to its ability to biologically fix nitrogen from the atmosphere. The percentage clover-fixed-nitrogen CFN (%) is an estimate of the percentage of total nitrogen found in clover that has been biologically fixed from the atmosphere (as opposed to mineral nitrogen which is absorbed into the plant through the roots). Significant increases in CFN (%) were discovered in response to elevated levels of UV-B in both years in which the measurements were made.

The CFN yield (kg N/ha) was calculated by taking into account clover yield and shows that elevated UV-B significantly increases the amount of biologically fixed nitrogen entering the system for droughted pasture.

In terms of the overall pasture production level, the total annual yields of dry matter (kg DM/ha) were not significantly affected by elevated UV-B although there was evidence of reduced total annual yield in the droughted pasture in one particular year. In the same year there was a significant increase in total yield in response to an increased level of UV-B in the irrigated treatment.

Measurements have been made to determine how levels of flavonoids in white clover vary in response to elevated UV-B. Flavonoids are compounds that can protect against stress in plants. Measurements made in June (winter) 2001 found a subtle but significant increase in kaempherol in clover in the droughted pasture in response to the highest level of supplemented UV-B.

A possible mechanism could be that elevated UV-B in winter causes greater production of protective flavonoids in clover at a time when levels of these compounds are normally low. At the onset of the summer drought these plants may be better adapted to stress. This may explain the significantly higher percentage clover content in the high UV-B treated, droughted pasture plots over the autumn period.

Conclusions

- We observed both positive and negative effects of UV-B on pasture depending on season. These may act against each other to dampen long-term changes.
- There is some evidence of effects on N_2 fixation and hence N dynamics. This could have long-term implications for ecosystem productivity.
- Long-term study (>10 years) is required to determine potential UV-B effects on the ecosystem.

Acknowledgements

Thanks to Bruce Campbell, Chris Hunt, Rainer Hofmann, Derryn Hunt, Yvonne Gray, Shona Brock, David Hume, Philip Williamson, Ewald Swinny (IRL), Stephen Bloor (IRL), Ken Markham (IRL), Ken Ryan (IRL), Richard McKenzie (NIWA), Chris Thorpe (NERC), Nigel Paul (NERC). This research was funded by the New Zealand Foundation for Research, Science and Technology under contract C10X0007.

References

Caradus, J.R., D. R. Woodfield, and A. V. Stewart, Overview and vision for white clover. *White clover: New Zealand's competitive edge*. (ed. by D.R.Woodfield) Agronomy Society of New Zealand Special Publication No. 11, Christchurch, 1996.

Coop, I. E., (Pasture and crop production. *Sheep production , Volume II, Feeding growth and health* (ed. By S. N. McCrutcheon, M. F. McDonald & G.A. Wickham), New Zealand Institute of Agricultural Science, Wellington, 1986.

The Economic Service (2001).