Report to the Stapledon Memorial Trust

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Will climate change cause a surge in UK clover weevil populations?

DETAILS OF THE FELLOWSHIP

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BACKGROUND AND PURPOSE OF THE FELLOWSHIP

There is now a general consensus that global climate change will have important impacts on pasture systems.[1] By 2080, it is predicted that the UK mean temperature will increase by 2.0 -3.5˚C and atmospheric carbon dioxide (CO_2) will be double present levels.[2] Such changes could undermine many environmentally driven management practices in pasture systems, for instance by making minor pest species more prolific.[3]

There is renewed interest in the use of white clover for nitrogen enrichment in production systems, conferring as it does both environmental and economic benefits.[4] Simply replacing inorganic fertilizer (with its associated environmental concerns) with legume-based silage can generate economic gains of £100 ha^{-1}.[4] The clover weevil (*Sitona lepidus*) is currently a moderate pest of white clover in the UK,[5] but increases in temperature and precipitation could cause comparatively small populations to increase and become more destructive. This is illustrated by the situation in New Zealand, where *S. lepidus* was accidentally introduced about 10 years ago and now threatens the New Zealand pastoral industry by inflicting costs of at least £112 million per year.[6] Invasive populations have rapidly adapted to the different climate, and is indicative of what could eventually happen in the UK. It is speculated that changes in the biology of New Zealand populations of *S. lepidus* in response to warmer and wetter conditions have led to population increases of 300-900% compared to the UK[6]. Specific changes include the evolution of 2-3 generations per year and longer seasonal activity.

My overall aim was to build a conceptual model for how climate change will affect *S. lepidus* in the UK, using existing knowledge and a series of experiments in the UK and New Zealand. The fellowship had four specific aims:

1. To collect a population of *S. lepidus* from New Zealand pastures in the Waikato region. The population will be returned to the UK and maintained under license at SCRI for future comparative work with the New Zealand research team.
2. To prepare a review article based on existing information about the pest dynamics of *S.*

lepidus in New Zealand, in collaboration with scientists working in this area.

3. Conduct experimental work to assess the likely impacts of climate change on *S. lepidus* populations.
4. Establish contacts for future collaborations with established climate change facilities in New Zealand; the New Zealand Biotron and the FACE (free air carbon dioxide experimental) facility at Palmerston North.

OVERVIEW

The fellowship was carried out at AgResearch, hosted by **Dr Pip Gerard** at the Ruakura research station in the North Island and by **Professor Stephen Goldson** at the Lincoln research station in the South Island. In addition, shorter visits were made to the research station at Palmerston North (**Dr Paul Newton**) and Lincoln University (**Professor Leo Condron**).

Research into the pest dynamics of *S. lepidus* populations in New Zealand is carried out by two teams of scientists at AgResearch sites (Ruakura and Lincoln). The Ruakura site is based in the Waikato region, the area still most affected by *S. lepidus*. *Sitona lepidus* was first discovered here by the Ruakura team in 1996 (also in Auckland), and by 2004 it had spread throughout the North Island. The Lincoln team first discovered it in the South Island in January 2006, when insects were recovered from traps at Christchurch International Airport. By April 2006, a large population of *S. lepidus* had become established in dairy pasture at Richmond, near Nelson. During the fellowship, the teams were rolling out a biocontrol program based on a parasitic wasp *Microctonus aethiopoides*.

WORK ACCOMPLISHED (RELATED TO AIMS 1-4 ABOVE)

1. Population sampling and training

Over several weeks, and with the assistance and advice of the Ruakura team, I successfully collected substantial *S. lepidus* populations from various sites. The insects were collected both by vortis sampling (Plate 1) and by sledge (Plate 2). The insects were initially maintained in culture at Ruakura and were subsequently shipped to the UK, where we currently maintain the culture at SCRI under special license (PH/25/2007).

▲ **Plate 1.** Vortis sampling

I was trained in the dissection of weevils so that we could standardise scoring techniques to make direct comparisons between populations in the UK and New Zealand. This had previously been difficult to achieve by e-mail, but now provides the opportunity to communicate and compare our findings in a more compatible fashion.

▼ **Plate 2.** Sampling using a slay. Adults would 'bounce' into the sledge as it was dragged across the paddock - in theory!

2. Review article

I studied existing records kept by AgResearch on the population dynamics of *S. lepidus* since its arrival in New Zealand.

We held a number of meetings and I gave a seminar to address how comparative information on UK and New Zealand populations (see Fig. 1) might be used to make predictions about the impacts of climate change on the species. During the fellowship, we started to write the review article, which is now underway and will shortly be submitted to *Agricultural & Forest Entomology*. The working title is '*Biology and management of the clover root weevil* (Sitona lepidus) *in the context of climate change*' and is co-authored by Pip Gerard, Stephen Goldson and Phil Murray.

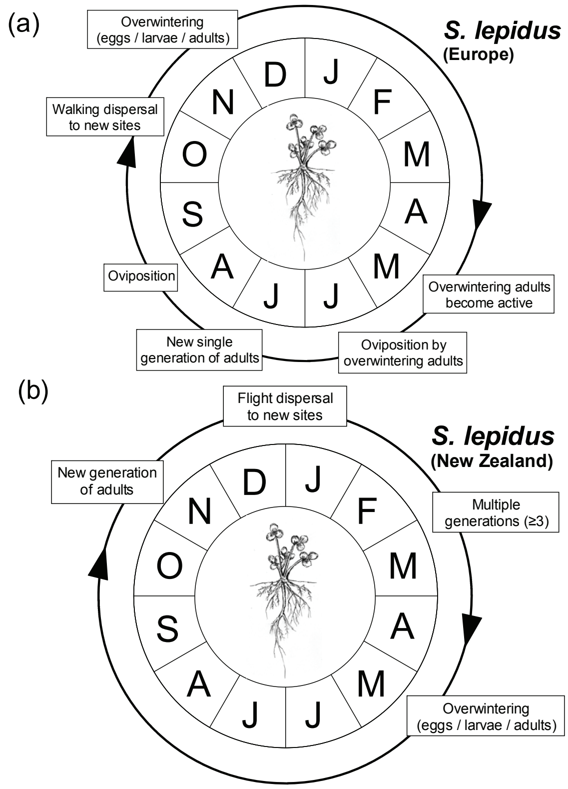


Fig. 1. Comparative life-cycles of *S. lepidus* in Europe (a) and recently introduced populations in New Zealand (b).

3. Experimental work

Experimental work is now underway, with the successful completion of one experiment that investigated how elevated carbon dioxide concentrations affect *S. lepidus*. Full experimental details and results can be supplied on request, but this work is shortly to be submitted to *Global Change Biology* so is summarised here.

- Experiments were conducted in chambers (Fig. 2)[7] that allowed soil temperature gradients to follow a lag function of air temperature. Air temperature followed a sine function, having a midday peak of 25°C decreasing to 15°C at night.
- Twenty nine *T. repens* plants were grown under [CO_2] of 380 and 700 $\mu l\ l^{-1}$. A single ovipositing female *S. lepidus* was caged on 14 *T. repens* plants, with the remaining 15 *T. repens* remaining insect-free. After four weeks, aboveground-belowground insect and plant responses were quantified.

<u>Results</u>

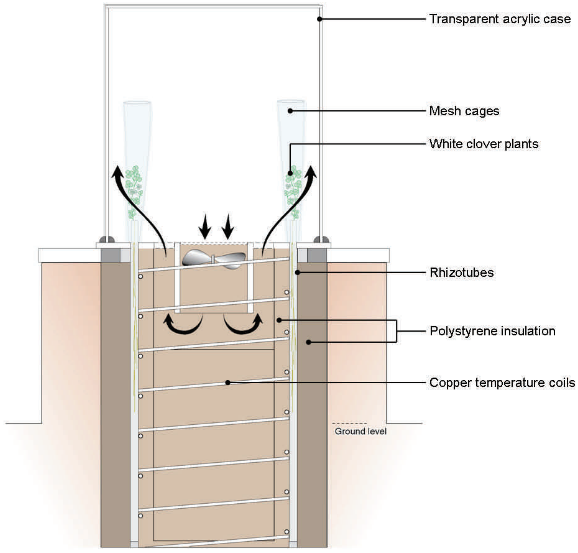
Aboveground

- Leaf area increased significantly with elevated [CO_2] (Fig. 3a) as did foliar C:N ratio (Fig. 3b), due to reduced N and increased C. Insect presence significantly increased the C:N ratio further (Fig. 3b).
- No changes were seen in stem length, fresh mass or leaf number.
- Adults consumed significantly more foliage at elevated [CO_2] but laid significantly fewer eggs (Fig. 3c).

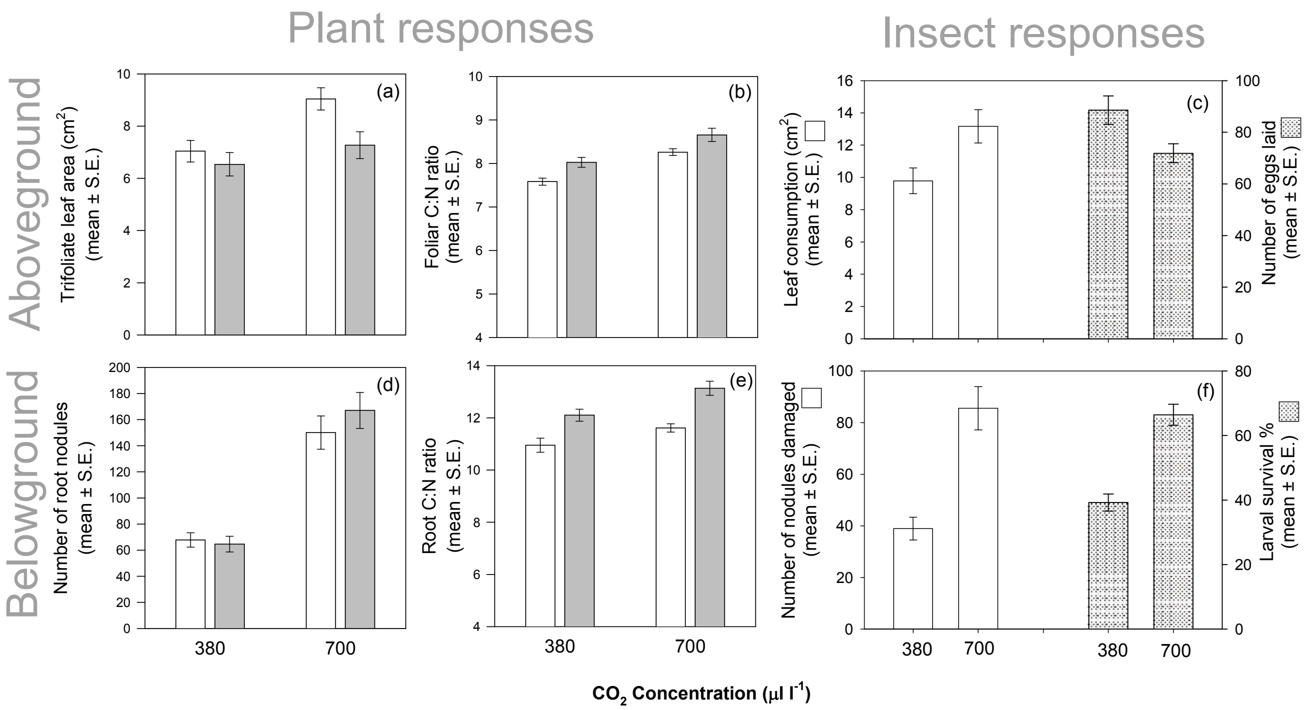
Belowground

- Elevated [CO_2] increased the number of root nodules (Fig. 3d), with accompanying significant increases in root depth, root mass and nodule size.
- C:N ratios also increased with elevated [CO_2]. The presence of *S. lepidus* was associated with even greater increases in this ratio due a substantial decrease in root N levels.
- The number of nodules damaged by *S. lepidus* larvae increased significantly in elevated [CO_2], which was associated with significantly enhanced survival (Fig. 3f) and faster rates of development.

► Fig. 2. Schematic diagram (in longitudinal section) of one of the chambers used in this study which permit air and soil temperatures to be regulated independently of each other.



▼ **Fig. 3.** Examples of plant and insect responses (above and belowground) to elevated [CO_2]. (For plant responses: □ insect-free, ■ *S. lepidus* treatments. Insect responses as indicated on axis label)



▼ Plate 3. The New Zealand Biotron (Lincoln University)

▼ Plate 4. Large experimental column used in the New Zealand Biotron (Lincoln University)

Conclusions

- Elevated [CO_2] affected *T. repens* in several ways, most notably in the root system which had 230% more nodules than plants grown at ambient [CO_2]. When reared on less nutritious foliage (e.g. higher C:N) at elevated [CO_2], adult *S. lepidus* consumed more foliage (probably due to compensatory feeding) but laid fewer eggs.
- Even though fewer eggs were laid into the soil, *S. lepidus* larvae survived and performed much better at elevated [CO_2], possibly due to the increased levels of nodulation.[2] Increased nodule herbivory, however, exacerbated C:N root increases due to an even greater reduction in root N.
- Climate change may increase nodulation in *T. repens* under certain conditions, but potential benefits (e.g. provision of N without chemical fertilization), could be undermined by larger *S. lepidus* populations belowground.

4. Climate change facilities - contacts made

New Zealand has two climate change experimental facilities that were particularly pertinent to addressing how climate change might affect *S. lepidus*.

The first is the New Zealand Biotron (http://www.bioprotection.org.nz/biotron.html) (Plate 3) which was opened in 2004 and is housed at Lincoln University. The facility is managed by **Stuart Larson** and **Professor Leo Condron**. The significance of the facility is that it allows soil temperature gradients to be manipulated to realistically represent field conditions. The large columns (Plate 4) permit plant community experiments, which would be ideal for looking at mixed swards. During a two day visit we discussed how we might collaborate on future research. We will be following this up when Leo visits SCRI in September 2007

The FACE (free-air carbon dioxide experimental) facility at Palmerston North is run by **Dr Paul Newton**, and is among one of the only permanent grassland FACE facilities (Plate 5). I visited the experimental facility and spent two days discussing potential collaboration with Paul and colleagues. We followed up on this when Paul visited SCRI in July 2007 and hope to submit a grant application to the Royal Society of New Zealand in 2008.

Plate 5. One of the rings that make up the FACE facility at Palmerston North. CO_2 concentrations are kept constant by emissions of CO_2 from stakes

Experience gained

- A better understanding of *S. lepidus* population dynamics in New Zealand, based on unpublished but highly detailed information I was given access to.
- Dissection skills used by the group to assess physiological condition of the insects.
- Practical experience in collection and maintenance of insect cultures, which has now been passed on to staff at SCRI.
- An appreciation of the experimental facilities that may be used for investigating the impacts of climate change on *S. lepidus*, and how we might work together on further research.
- An understanding of how control strategies might be applied to manage *S. lepidus* which on the New Zealand biocontrol release program.

OUTPUTS FROM THE FELLOWSHIP

1. **Oral paper at the Ecological Society of America Annual Meeting** (August 2007). I delivered an invited talk at the ESA meeting in San Jose, presenting the results of the experiment described above.
2. **Poster at the British Ecological Society Annual Meeting** (September 2007). I have prepared a poster of the experimental results for the BES meeting in Glasgow, which I will present on 10 September 2007.
3. **Review paper**. We aim to submit the review article to *Agricultural & Forest Entomology* early in 2008. One of the editors has already expressed interest on behalf of the journal in publishing this article.
4. **Experimental paper**. A paper is now in final stages of preparation and will be submitted to *Global Change Biology* next month.
5. **Press coverage**. The fellowship attracted some press coverage from the *Waikato Times* (see Plate 6), although they regrettably didn't mention any of my three funding sources despite being provided with this information.

UK scientist joins weevil fight

By Chris Gardner

UK research scientist Scott Johnson has spent six weeks with AgResearch in the fight against clover root weevil.

With UK temperatures predicted to rise Dr Johnson, who returned to the Scottish Crop Research Institute in Dundee at the weekend, believed some of the New Zealand techniques could be useful in the UK as global warming begins to take effect.

"Back home we only have one generation of these weevils breeding each year but in New Zealand you have two to three annually."

"While it is not a serious pest in the UK at present it is predicted that it could become a real problem for pastoral farmers as the climate in the UK changes."

Dr Johnson spent five weeks at AgResearch's Ruakura campus in Hamilton and a week at Lincoln near Christchurch.

Clover root weevil was discovered in the Waikato in 1996 and could cost the pastoral sector $300 million a year.

The adult weevil feeds on clover leaves which would otherwise be consumed by dairy cows, and the larval stages feed on clover roots. Young larvae tend to feed in clover root nodules (which capture atmospheric nitrogen), while bigger larvae will feed anywhere on the root system.

AgResearch, funded by Dairy InSight and Meat and Wool New Zealand, is leading the crusade against clover root weevil through a biocontrol programme which introduced a weevil-eating parasitic wasp to the Waikato last year.

While New Zealand temperatures were not as warm as Dr Johnson expected, he said he learned much about controlling the pest.

Dr Johnson was impressed with AgResearch's connection to the farmer.

"It's in their interest to know that the farming community know about these things," he said.

Dr Johnson hopes to return to New Zealand in October for more research.

GAINING CONTROL: Scott Johnson collects clover root weevils in a Waikato paddock.

► **Plate 6**. Article from the *Waikato Times* during the fellowship.

FUTURE PLANS

As mentioned above, I have already had a follow up meeting with Paul Newton and will soon meet again with Leo Condron. Paul and I plan to write a grant application for further work which includes the FACE facility and the climate change cabinets (Fig. 2). Potential funding sources include the Royal Society of New Zealand and NERC. Leo and I have held discussions about a joint PhD studentship and are currently exploring possibilities with the British Council and OECD.

CONCLUDING REMARKS

The question of whether climate change will cause a surge in UK clover weevil populations, is still being investigated but from these results it suggests that the clover root weevil problem is likely to get worse in the UK, largely through promotion of the belowground root-feeding stages. How climate change will affect the composition of grass and clover in mixed swards, and the extent to which this will interact with clover root weevil populations will clearly be important in addressing this question.

On a personal note, I would like to give the warmest of thanks to the Trustees for their generous support for this research. I feel that I have gained a great deal from the fellowship, in terms of my own research but also in forging new links with several research groups in New Zealand.

References

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