The clover root weevil invasion: Impact and response of the New Zealand pastoral industry 1996-2012

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Abstract. Clover root weevil, *Sitona lepidus* Gyllenhall (Curculionidae: Coleoptera), was first reported in New Zealand in 1996. With few natural enemies or competitors, it rapidly became a major pest of white clover. Its strong flight capability, tendency to be transported in agricultural machinery and vehicles, and wide climatic tolerance enabled it to spread the length of the country (1,600 km) by 2010. The most damaging stage is the larva, which attacks the roots, root nodules and stolons of clovers, reducing herbage production (particularly in spring), pasture clover content, and nitrogen fixation. From the time of the initial invasion, the pastoral industry supported research into management as insecticides were not a viable option. Nitrogen fertiliser applications after grazing were recommended to maintain production. Field evaluations showed that white clovers with good general agronomic adaptation survived better under weevil pressure than less-adapted clovers. In 2006, a parasitic wasp, *Microctonus aethiopoides* Loan (Braconidae: Hymenoptera), was introduced from Ireland for biological control of *S. lepidus*. It has also established and dispersed very rapidly, and often suppresses weevil populations within 2 – 3 years of its establishment in a new locality. Involvement of industry field consultants was an essential aspect of the biological control release programme in the North Island where the weevil was already widespread before *M. aethiopoides* was introduced.

Keywords: White clover, biological control, pasture pests, *Sitona lepidus, Microctonus aethiopoides*

Introduction

Clover root weevil, *Sitona lepidus*, was first detected in the North Island of New Zealand (NZ) near Hamilton in March 1996 (Barratt *et al.* 1996). A delineation survey was undertaken immediately, but the weevil was deemed ineradicable as it was already widely established through the upper North Island regions of Waikato, Auckland and western Bay of Plenty (Barker *et al.*1996).

It was anticipated that the parasitoid *Microctonus aethiopoides*, introduced to control *Sitona discoideus* Gyllenhal, would also provide some control of the new species. However, this did not eventuate. By 1997, dairy farmers were reporting loss of clovers from pasture and had started to increase N fertiliser use to maintain production (Eerens *et al.* 1998). White clover is regarded as a high value component of most pastures in NZ (Caradus *et al.* 1996). With the potential annual direct cost of the pest estimated at $300 million a year (Barlow and Goldson 2002), the pastoral industry looked to the research community for solutions. An integrated research programme was established, funded through reprioritised pasture pest research, and new funding from the major pastoral industry sectors and agrichemical companies.

Impact on pasture

Sitona lepidus adults feed on the foliage of *Trifolium* species. Their strong preference for seedlings over mature plants (Hardwick and Harens 2000) reduces regeneration of clovers from the seed bank and eliminates oversowing as an option for re-establishing clovers in infested pastures. The adults are long-lived and each female can lay over 1000 eggs. Newly hatched larvae feed inside root nodules; as they mature they move onto the roots and into stolons on the soil surface (Gerard 2001).

Unlike in most northern hemisphere countries, *S. lepidus* is bivoltine in NZ (Gerard *et al.* 2010a), and this allows populations to build up rapidly. During the initial "boom" phase following its introduction to NZ, *S. lepidus* reached densities of over 1800 larvae/m^2 in North Island pastures (Gerard *et al.* 2010a). At monitored sites in Waikato, populations of both weevil and clovers collapsed and then recovered to lower, relatively stable levels, with peak larval populations ranging between 450–750/m^2 and pasture clover content around 10%. It was a reciprocal relationship: weevil populations were kept in check by the availability of nodules, and the larval populations limited the amount of clover.

Damaged white clover has plasticity in resource allocation and resources are diverted from above ground foliage production to root and nodule repair. The continual pressure of *S. lepidus* larvae causes the plant to become severely N limited (Murray *et al.* 2002). The subsequent reduction in plant size and vigour contributes to poor persistence and low clover levels in *S. lepidus*-infested pastures. Consequently, farmers reported large post-invasion reductions in animal performance (Eerens *et al*. 1998), though bloat also disappeared. A pre- *S. lepidus* survey of 312 North Island dairy farms showed spring clover contents used to average 31% of total dry matter on bloat-prone farms and 20% on nil-mild bloat farms (Ledgard *et al.* 1990). Small plot trials showed that a typical post-invasion Waikato *S. lepidus* population of just over 300 larvae/m^2 resulted in a 35% reduction in clover yield, with greatest losses in spring, which coincides with high nutrient demand from rapidly growing young animals and lactating cows and ewes (Gerard *et al.* 2007). On an intensive dairy system (4 - 4.25 cows/ha) in Canterbury, 300 larvae/m^2 in the spring of 2010 contributed to the disappearance of almost all white clover compared to an estimated 25% clover content in previous seasons (McNeill *et al.* 2012). An early recommendation was to apply small amounts of N fertiliser to infested pastures after grazing to ensure clover persistence. This gave marked improvements in pasture production and quality, which probably contributed to the increase in average Waikato dairy farm N fertiliser use from 68 kg/ha/yr in 1997/98 to 125 kg/ha/yr in 2002-03 (Waikato Regional Council 2012).

Vulnerability of New Zealand pastoral systems

NZ pastures were particularly vulnerable to invasion by *S. lepidus*. Firstly, 33% of NZ land cover is in high producing exotic grassland (Ministry for the Environment 2009), consisting mainly of ryegrass and white clover. Secondly, our white clover cultivars are highly susceptible: with the absence of specialist clover insects (*e.g. Hypera* and *Sitona* spp.) it is very likely most defence attributes associated with *Trifolium* spp. had been lost during the 70 plus years of intensive breeding to maximise production (Caradus *et al.* 1996). Therefore, *S. lepidus* arrived to a 'land of plenty' with no co-evolved natural enemies or competitors. As well as its high reproductive rate, the adult is an excellent flier and has the physical robustness to be easily transported in agricultural machinery and vehicles. While warnings not to transport hay and baleage from infested to non-infested districts were put out through industry networks, there was little that could be implemented in terms of internal biosecurity to prevent the pest from spreading throughout NZ. By 2006, *S. lepidus* was throughout the North Island and had reached the South Island (Phillips *et al.* 2007). Detailed surveys early in the South Island invasion showed discrete, isolated weevil populations some distance from each other, suggesting that many arose from small founder populations being carried to distant locations by vehicles and machinery (Ferguson *et al.* 2012). This "patchiness" contrasts with the flood-like spread observed in the North Island, and more recently in the South Island, which is more indicative of natural dispersal.

Pasture management with *S. lepidus*

Insecticides were not a viable control option in most situations as foliar applications against adults were usually ineffective in reducing larval damage, seed treatments gave poor control and the soil insecticides were ineffective and/or impractical (*e.g.* withholding times, residues posed risks to export markets). Instead, farmers were advised to adopt clover-friendly management practices to alleviate clover stress, particularly avoiding use of excess nitrogen fertiliser, grazing frequently in spring to minimise grass competition, and leaving higher summer residues to protect stolons. Research highlighted the importance of using a non-host break crop during pasture renovation, and careful selection of companion grasses to get good clover establishment and persistence. For example, spring clover cover in three year old pasture sown in autumn 2004 following either a maize or turnip crop was well over 30%, compared with 15% in ex-grass pasture, and averaged 35% with tetraploid ryegrass (cv. Quartet) compared to 25% for diploid ryegrass (cv. Bronsyn) (Gerard *et al.* 2009).

Tolerant white clovers

While some *Trifolium spp*. do have resistance factors against *S. lepidus* (*e.g.* red clover *T. pratense* (Murray *et al.* 2007) and subterranean clover *T. subterraneum* (Crush *et al.* 2007)), no resistance has been found in white clover (Crush *et al.* 2010). However, vigorous, well-adapted white clovers are more tolerant of larval damage than less vigorous or poorly adapted clovers. Glasshouse trials of progenies bred from plants performing well under pest pressure in the field indicate there is heritable tolerance in at least some populations (Crush *et al.* 2010).

Biocontrol of *S. lepidus*

After an extensive search and safety testing in quarantine (Goldson *et al.* 2004), an effective strain of the parasitoid *M. aethiopoides* was introduced into NZ from Ireland and released in early 2006 (Gerard *et al.* 2006). This biocontrol agent established extremely rapidly, showed excellent dispersal attributes and the ability to suppress *S. lepidus* to below damaging levels (Gerard *et al.* 2010b). The parasitoid is asexual so small numbers can initiate new populations. Thirteen mass releases were carried out in the North Island, and over 2000 mini-releases, consisting of 10-20 parasitoid-exposed weevils, were distributed to infested farms by DairyNZ, Beef+Lamb NZ and fertiliser company advisory and field networks (Gerard *et al.* 2010b). Different strategies were needed in the South Island where *S. lepidus* is still spreading. A release in the original infestation near Nelson has seen the parasitoid spread with the weevil through the upper South Island (Phillips *et al.* 2007; Phillips *et al.* 2010; Ferguson *et al.* 2012). Extensive coverage of the South Island from this release alone, however, may have required several decades to eventuate, so additional biocontrol agent releases were made as isolated weevil populations were detected in Canterbury, Otago and Southland (Ferguson *et al.* 2012). A GIS mapping system has been used to track new weevil infestations in the South Island and prioritise locations both for sampling and for making additional biocontrol agent releases (Phillips *et al.* 2010) with the aim of optimising coverage of weevil infested areas. It is anticipated that the combination of the biocontrol agent and clover-friendly pasture management practices will enable New Zealand farmers to once more rely on white clover as a cheap source of high quality feed and fixed nitrogen.

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References

Barker GM, Addison PJ, Firth AC, Barratt BIP (1996) *Sitona lepidus* Gyllenhal newly established in New Zealand: assessment of distribution in the North Island. *Proceedings of the forty ninth New Zealand Plant Protection Conference* pp. 226-269.

Barlow ND, Goldson SL (2002) Alien invertebrates in New Zealand. In 'Biological Invasions: economic and environmental costs of alien plant, animal, and microbe species.' (Ed. D Pimental.) pp. 195-216. (CRC Press: New York, USA)

Barratt BIP, Barker GM, Addison PJ (1996) *Sitona lepidus* Gyllenhal (Coleoptera: Curculionidae), a potential clover pest new to New Zealand. *New Zealand Entomologist* **19** 23-30.

Caradus JR, Woodfield DR, Stewart AV (Eds.) (1996) 'Overview and vision for white clover, White clover: New Zealand's competitive edge.' (Agronomy Society of New Zealand, Christchurch, New Zealand Special publication No 11, Grassland Research and Practice Series No. 6: 1-6.

Crush JR, Gerard PJ, Ouyang L, Cooper BM, Cousins G (2010) Effect of clover root weevil larval feeding on growth of clover progenies from parents selected for tolerance in field trials. *New Zealand Journal of Agricultural Research* **53**, 227-234.

Crush JR, Ouyang L, Gerard PJ, Rasmussen S (2007) Effect of clover root weevil larvae on four annual forage legumes. *Proceedings of the New Zealand Grassland Association* **69**, 213-217.

Eerens JPJ, Willoughby B, Kettlewell F, Hardwick S, Bay S (1998) The clover root weevil in northern pastures: on-farm observations of its impact on white clover. *Proceedings of the New Zealand Grassland Association* **60**, 287-290.

Ferguson CM, McNeill MR, Phillips CB, Hardwick S, Barton DM, Kean JM (2012) Status of clover root weevil and its biocontrol agent in the South Island after six years. *Proceedings of the New Zealand Grassland Association* **74**, 171-176.

Gerard PJ (2001) Dependence of *Sitona lepidus* (Coleoptera: Curculionidae) larvae on abundance of white clover *Rhizobium* nodules. *Bulletin of Entomological Research* **91**, 149-152.

Gerard PJ, Cooper BM, Eden TM, Howlett SA, Lane PMS, Panckhurst KA, Willoughby BE, Wilson DJ (2009) Impact of ryegrass selection and paddock history on clover establishment in new dairy pasture. *Proceedings of the New Zealand Grassland Association* **71**, 133-137.

Gerard PJ, Goldson SL, Hardwick S, Addison PJ, Willoughby BE (2010a) The bionomics of an invasive species *Sitona lepidus* during its establishment in New Zealand. *Bulletin of Entomological Research* **100**, 339-346.

Gerard PJ, Hackell DL, Bell NL (2007) Impact of clover root weevil *Sitona lepidus* (Coleoptera: Curculionidae) larvae on herbage yield and species composition in a ryegrass-white clover sward. *New Zealand Journal of Agricultural Research* **50**, 381-392.

Gerard PJ, McNeill MR, Barratt BIP, Whiteman SA (2006) Rationale for release of the Irish strain of *Microctonus aethiopoides* for biocontrol of clover root weevil. *New Zealand Plant Protection* **59**, 285-289.

Gerard PJ, Wilson DJ, Eden TM (2010b) Clover root weevil biocontrol distribution in the North Island - release tactics and outcomes. *Preceedings of the New Zealand Grassland Asssociation* **72**, 85-89.

Goldson SL, McNeill MR, Gerard PJ, Proffitt JR, Phillips CB, Cane RC, Murray PJ (2004) British-based search for natural enemies of the clover root weevil, *Sitona lepidus*, in Northwest Europe. *New Zealand Journal of Zoology* **31**, 233–240.

Hardwick S, Harens B (2000) The behaviour of adult *Sitona lepidus* Gyllenhål (Coleoptera: Curculionidae) in response to white clover. *New Zealand Plant Protection* **53**, 415-419.

Ledgard SF, O'Connor MB, Carruthers VR, Brier GJ (1990) Variability in pasture nitrogen fractions and the relationship to bloat. *New Zealand Journal of Agricultural Research* **33**, 237-242.

McNeill M, Lee S, Pellow R, Moir J (2012) Maintaining milk production in the presence of clover root weevil on an intensive pasture based dairy system in Canterbury, New Zealand. *Proceedings of the Australasian Dairy Science Symposium* (13-15 Nov 2012), pp.195-196.

Ministry for the Environment (2009) The New Zealand Land Cover Database 1 July 2009 www.mfe.govt.nz/ issues/ land/land-cover-dbase/ Accessed 31 Jan 2013

Murray PJ, Cheung AKM, Abberton MT (2007) Intraspecific variation in *Trifolium pratense*: impact on feeding and host location by *Sitona lepidus* (Coleoptera, Curculionidae). *Journal of Pest Science* **80**, 51-57.

Murray PJ, Dawson LA, Grayston SJ (2002) Influence of root herbivory on growth response and carbon assimilation by white clover plants. *Applied Soil Ecology* **20**, 97-105.

Phillips CB, McNeill MR, Hardwick, S, Ferguson C, Kean JM (2010) South Island distributions of clover root weevil and its biocontrol agent. *Proceedings of the New Zealand Grassland Association* **72**, 227-232.

Phillips CB, McNeill MR, Hardwick S, Vink CJ, Kean JM, Bewsell D, Ferguson CM, Winder LM, Iline II, Barron MC, Stuart B (2007) Clover root weevil in the South Island: detection, response and current distribution. *New Zealand Plant Protection* **60**. 209-216.

Waikato Regional Council (2012) Fertiliser use on farms report card 22 June 2012 www.waikatoregion.govt.nz /Environment/Environmental-information/ Accessed 31 Jan 2013