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AGMARDT GRANT No 20514
Economic and Production Impacts of Clover Root Weevil on New Zealand Farming

MILESTONE REPORT 7

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Report prepared by:

Pip Gerard, Duncan Smeaton,
Han Eerens and Sally Howlett.

2020 SCIENCE

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EXECUTIVE SUMMARY

A review of published experimental and observational studies of the impact of clover root weevil damage on white clover dry matter production showed that losses were generally in the range from 18-35% and were likely to be greatest when clover was grown in the presence of companion grasses. High level economic impact assessments indicated that if a “do nothing” approach was adopted, the weevil could potentially cost the pastoral economy around $400 m/year and that using N fertiliser to boost pasture production to per-CRW levels would the cost to $305 m . Economic assessments at farm system level using farm decision support models (StockPol® and UDDER) showed that farm gross margins would decrease by 10-15%, again if a “do nothing” approach was adopted. However, under current costings and excluding environmental and trade issues, the use of N fertiliser can be used to mitigate damage. Provided pasture N response is in excess of 15 kg DM/kg N, 150 kg N/ha/year was predicted to restore margins. Replacement of only the observed losses in N fixation by fertiliser N was predicted to have no benefit in the short term on farm but over a 30 year period would assist soil fertility such that farm profitability would be restored.

ABBREVIATION USED:

Throughout this report, clover root weevil is abbreviated to CRW

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1 PROJECT BACKGROUND

This AGMARDT Grant (No 20514) obtained by Dr Han Eerens is closely tied to the SFF project 05/085. The goal of the SFF project is to compare a range of pasture establishment and management regimes in order to develop scientifically-based recommendations of how to best manage pasture in the presence of the weevil. It includes nitrogen fertiliser strategies that will give affected farmers a breathing space until longer term controls, such as biological controls and tolerant clover cultivars, become widely available.

The AGMARDT linkage enables an increased level of farmer input, additional field trials covering a wider variety of environments, and most importantly, will provide the cost benefit analyses of the different management strategies.

CHANGES ARISING SINCE PREVIOUS REPORT

None

TASKS PREVIOUSLY REPORTED AS COMPLETED

(Italics denote SFF contract milestones and brackets AGMARDT milestones)

1.1 Collate information on the impact and life cycle of CRW
1.2 Identify and upskill key people in regions
2.1 Identify trial sites and collaborating farmers and establish background information on sites
2.2 Establish field trials
    2.2.1 – plot trials
    2.2.2 – (AGMARDT 3) Paddock evaluations

TASKS IN PROGRESS

2.3 *N fertiliser trials* (AGMARDT 6) – collect data, maintain trials, and discuss trial progress in local farmer discussion groups/field days
3.1 *Clover re-establishment in CRW infested areas* – collect data on pest populations, pasture production and composition.
3.2 Cost/benefit analysis of clover re-establishment option
    (AGMARDT 7) Quantify the economic impact of CRW from the trials and other related CRW research (1/4/07)
4.1 Identify CRW management scenarios, apply costs, prepare templates (Dec 07)

2 THE ECONOMIC IMPACT OF CLOVER ROOT WEEVIL

2.1 Introduction

The clover root weevil (*Sitona lepidus* Gyllenhal (Coleoptera: Curculionidae) was first discovered on a Waikato dairy farm in 1996 (Barratt et al. 1996) and has subsequently become one of New Zealand's worst white clover pests (Eerens et al. 2005). It has spread throughout the North Island and has been confirmed in Nelson and Canterbury in the South Island.

The adult weevils generally emerge in late spring and again in autumn (Gerard et al. 1999). The adults feed on clover foliage, favouring newly germinated seedlings (Hardwick & Harens 2000), and making characteristic notches that are the most obvious symptom of weevil infestation. Adults live several months and female weevils can lay many hundreds of eggs during their lifetime. The soil-dwelling larvae are the most damaging stage, especially during winter when numbers commonly exceed 400 larvae/m^2 in Waikato dairy pastures. The first instar larvae feed on nodules, then as they mature, the lateral roots and finally the nodal roots and stolons (Gerard 2001; Gerard et al. 2004). The larvae are present throughout the year putting continual pressure on clover roots.

Assessing the impact of CRW on white clover is very difficult. In contrast to monocultural annual crops where plants are relatively discrete, uniform and have limited ability to “repair” damage, white clover is a very adaptable and “plastic” perennial grown in association with grasses. It is able to grow new roots along stolons away from localised infections/infestations and can shift resources within the plant to where demand is greatest (eg to repair root damage). Plant physiology and phenology varies considerably with surrounding biotic and abiotic factors. It is vulnerable to competition from companion grasses and in New Zealand it is attacked by a complex of other common pests, including nematodes, grass grub, whitefringed weevil, slugs and clover flea. Therefore conventional research tools for measuring pest impact (eg using insecticides) cannot be used here to obtain the base pest assessment data necessary for economic analyses specifically for CRW.

This report summarises previously reported assessments of damage that have provided the basis of past and current estimations of the economic impact of clover root weevil to the pastoral industries.

2.2 Published experimental data and observations

2.2.1 Adult impact studies

Leaf damage by CRW adults is generally regarded as unimportant, since pasture plant species are well adapted for periodic removal of foliage. However, selective loss of foliage is likely to reduce the ability of clover to compete with companion grasses. Lewis & Thomas (1991) surveyed pasture at 16 sites in England and Wales over a two year period and found the mean number of clover leaves damaged by *Sitona* spp. ranged from 3% to 62%. A subsequent similar study by Clements & Murray (1993) showed that an average of 12% of clover leaf area was lost to the combined effects of pests and diseases, with over half of that attributable to *Sitona* spp. This was most noticeable in late winter when up to 30% of the photosynthetic area of the plant was removed. In white clover variety trials at Crossnacreevy, Northern Ireland, the mean percentage of leaves damaged by *Sitona* spp. (mainly CRW) throughout the growing season ranged from 40 – 63% depending on the cultivar.

Leaf consumption estimates for individual weevils have ranged from a high of 7 mg dry matter (DM)/day (Wiech and Clements 1992) to 0.75-1.2 mg DM/day (Gerard & Hackell 2005) depending on clover cultivar and weevil sex. Clover DM loss through direct CRW adult feeding in a typical Waikato pasture (peaking around 75 adults/m^2 in spring and 44/m^2 in autumn) has been estimated at just over 50 kg/ha/year and therefore, apart from affecting clover competitiveness, is not a significant problem in most circumstances (Gerard & Hackell 2005).

Observations during field trials conducted in 1998 and 1999 testing the feasibility of protecting clover seedlings (P. Addison and S. Hardwick, unpubl. client data) suggested, however, that white clover is particularly vulnerable to attack during its establishment phase. This has been supported by laboratory tests which have shown adult CRW will each completely defoliate several seedlings each per day (Hardwick 1998) and that there are olfactory cues that enable them to find seedlings in the presence of mature clover plants (Hardwick & Harens 2000). This behaviour reduces the re-establishment of white clover from seed in existing pastures, and has caused particular problems to farmers wishing to undersow productive cultivars into pasture where the clover has run out under pest pressure.

2.2.2 Larval impact studies

a) Overseas field studies

Trials in Northern Ireland in the 1980s using insecticide to control CRW larval populations during pasture establishment showed an increase in clover content at the end of the second year from 16% (untreated) to 54% and clover DM from around 300 kg/ha to over 1100 kg/ha (Mowat & Shakeel 1988a). The effect was mirrored in established pasture where control of populations of around 250 larvae/m^2 was associated with a trebling in clover production in spring and autumn and an overall increase of 34% (Mowat & Shakeel 1989). However, the insecticide used was chlorpyrifos which is active against some plant nematode species at high rates. Although the authors make no reference to nematodes, it is possible that they contributed to treatment effects.

b) Overseas laboratory studies

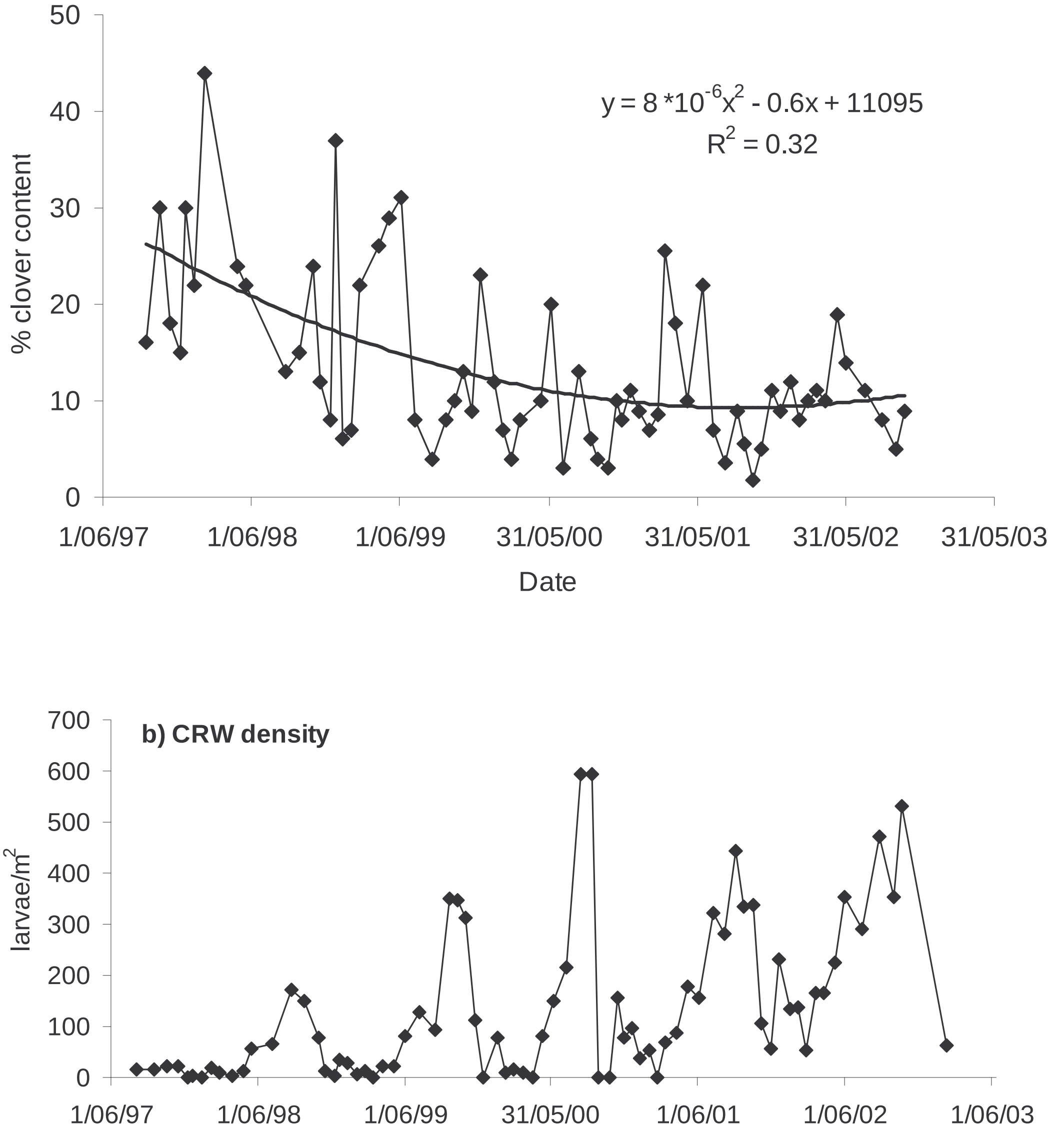
The above researchers from Ireland (Mowat & Shakeel 1988b) found that even infestations averaging as little as 1.2 larvae/plant caused significant damage to established clover plants and that the effect persisted after larval feeding ceased, possible due to disease and vascular decay.

The effect of nodule damage due to first instar larvae has been shown to impact immediately on plant growth with leaf DM reduced by 37% in the first two weeks after egg hatch (Murray et al. 2002). The combined effect of both nodule and root feeding for the duration of the larval stage has been found to cause an overall reduction of 19% in leaf DM and 45% reduction in N fixation (Murray et al. 1996). A further study in which clover was grown with wheat as a companion plant showed CRW larval infestations resulted in a 32% reduction in clover shoot DM (Murray & Clements 1998).

c) New Zealand field observations

In 1997/98 when CRW was becoming established in the Waikato, a questionnaire to gather on-farm observations of CRW presence and impact was distributed to farmers in the northern North Island. Overall, farms infested with CRW reported lower clover levels than those free of the weevil, and around half of the infested paddocks had less than 10% visual clover cover (Gerard et al. 2004). This aligns well with data from three sites where CRW populations and pasture clover content were monitored between 1996 – 2003 (Gerard 2004). Two of the sites had been infested prior to commencement of monitoring and the mean annual clover content in herbage dissections averaged 9.4% (Ruakura No 5 dairy site 1996-2001) and 10.1% (near Morrinsville 1997-2003). However, monitoring of >5 year old pasture at the third site near Otorohanga commenced prior to CRW arrival and showed that following CRW infestation a decline of clover content from above 20% to an annual average of around 10% even though pasture management remained unchanged (Fig. 1).

Fig. 1: Change in a) percent clover in herbage dissections (a)(ex. Gerard et al. 2004) and b) CRW density at Otorohanga 1997-2003



A small plot trial investigating the impact of CRW on first year pure white clover swards showed that even at densities of 600/m^2, CRW adults had no effect on flowering or seed production (Gerard et al. 1999). In the second year, increasing levels of CRW larvae had a beneficial effect on seed production in the cultivar Grasslands Prestige (Gerard 2001b). This was because larvae feeding stimulated a shift from vegetative to reproductive plant growth. High larval numbers increased nodule damage and reduced foliar nitrogen content, which in turn significantly reduced clover DM production by around 50% (Gerard 2002).

A subsequent similar small plot trial assessing CRW larval impacts on newly established perennial ryegrass/white clover pasture showed that overall mean larval density of 320 larvae/m^2 reduced clover yield in second year pasture by around 35%, with the greatest losses in spring (Gerard et al. 2007).

d) New Zealand glasshouse studies

The impact of CRW on clovers in a range of simulated management options showed that a mean larval density of 444 larvae/m^2 reduced DM production of clover plants by 18% (Eerens & Hardwick 2003).

A pot trial comparing the effect of CRW larval feeding on different clover cultivars and breeding lines indicated that an average of 12 larvae/plant reduced DM production of the cultivar Kopu II by 26% (Crush et al. 2005).

e) Summary of larval impact studies

Table 1 summarises the results of the reported experimental assessments of the impact of CRW on white clover DM production. Generally clover grown with grasses had greater reductions in DM production than when grown alone, presumably because of the added effect of plant competition. There appears to be little relationship between larval density and %DM reduction, probably because of the diversity of experiments and because larval establishment is highly dependent on nodule availability (Gerard 2001a).

Table 1: Summary of published assessments of the impact of CRW larval feeding on clover dry matter production

Authors	System	Larval density	% DM reduction
(Mowat and Shakeel 1988a)	pasture	159/m^2	72
(Mowat and Shakeel 1989)	pasture	250/m^2	34
(Mowat and Shakeel 1988b)	Potted clover	1.2/plant	29*
(Murray and others 2002)	Potted clover	5 eggs/plant	37
Murray and others 1996	Potted clover	30 eggs/plant	19
(Murray and Clements 1998)	Potted wheat & clover	15 eggs/plant	32
Gerard PJ 2007	Pasture in plots	320/m^2	35
Eerens and Hardwick 2003	Clover in crates	444/m^2	18
(Crush 2005)	Potted clover	12/plant	26
Overall mean			**33**

* At 70 days after exposure

2.3 CRW economic impact assessments

This section summarises previous economic impact assessments that have been undertaken. The reason each was undertaken varied from cost/benefit analysis in a business plan associated with a funding application to assessing how a new pest through our biosecurity borders impacts on the New Zealand economy. The final assessment has been undertaken not only to fulfil AGMARDT Milestone 7 requirements but to enable the subsequent cost: benefit analyses of the clover re-establishment and CRW management options to be undertaken.

2.3.1 Clover root weevil: The problem and pasture management options. 1997 Farmer handout sponsored by New Zealand Dairy Board.

CRW damage was at its extreme in 1997 in the Waikato while populations went through the invasive boom and bust cycle. Many farmers lost all pasture clover. In this handout written for farmers at this time, Chris Glassey, Livestock Improvement stated that if the weevil removed clover from pastures, a “do nothing” approach would cost dairy farmers $560/ha. If clover nitrogen (N) was replaced with fertiliser N, and the loss of feed value that clover provides is taken into account, the impact would be at most $250/ha using 1997 prices.

2.3.2 Funding applications to Meat & Wool NZ for research on the long term management of clover root weevil.

J Crush 1998: The annual financial contribution of white clover to the New Zealand (NZ) economy in 1995 was estimated by as over $3 billion (Caradus et al. 1995). If CRW was assumed to reduce white clover by 16.6% throughout NZ, it would result in a $0.5 billion cost to the pastoral industry if farmers adopted a “do nothing” approach.

PJ Gerard 2003: Using 2003 MAF primary industry statistics, the financial contribution of white clover was revised upwards to around $4 billion. Based on the assumption that at any one time only 20% of NZ pastures are affected, that the clover content decreased on average from 20% to 10% and that farmers took no remedial action, it was calculated that once CRW was spread throughout NZ it would cost the pastoral industry $400 million/year in lost production.

2.3.2.1.1 Clover root weevil: Economic impact assessment NZ Institute of Economic Research 2005

This assessment was based on several impact scenarios in which rate of spread of CRW through New Zealand and damage severity varied. The medium impact scenario assumes that CRW will have nationwide distribution by 2010 and meat and dairy production will decline by 10% with 8 years of an infestation occurring if farmers took no remedial response. Under this scenario CRW would cost the pastoral industry $7.2 billion over a 35 year period commencing 2004/05. The model estimated this “no response scenario” would currently cost New Zealand $419 m/year which would be expected to reach $1bn by 2017. As the largest sector and a nitrogen-intensive activity, dairy accounted for 52% of the costs. The Waikato and Bay of Plenty would be the most seriously affected accounting for 30 and 13% of total national costs, as these regions are already experiencing the impacts of CRW and both have significant dairy, beef and sheep sectors.

If all farmers maintained current production by adding the correct volume of nitrogen fertiliser to offset the losses from CRW damage, the estimate of economic impact would reduce to a cost of $305 m/year.

2.3.2.2 Clover root weevil: Impact on farm systems in contrasting NZ farm environments. Report to Meat & Wool NZ by PJ Gerard & JPJ Eerens 2005

This report modelled the impact of CRW damage on four contrasting sheep farm scenarios (Dryland ±N and Moist (or irrigated) ±N) with three CRW pressures (zero, low and moderate). The seasonal reductions in clover DM as a result of these three CRW scenarios were based on small plot trial data using the cultivar Grassland Prestige (Gerard et al. 2007). The model predicted that on dryland country, chronic infestation by moderate CRW levels would severely affect the ability of farmers to achieve desired lamb killing weight (e.g. 45 kg) unless stocking rate is reduced or animals are given supplementary feed (Table 2). This was driven predominantly by the large drop in clover production in the spring. Irrigated pastures were much less sensitive to CRW damage and the increase in pasture production resulting from application of N in moist condition greatly exceeded all other scenarios in terms of animal production, even in the presence of CRW. However, the model predicted that using 150 kg N/ha/annum would not compensate farmers in terms of revenue/ha for the losses in clover due to CRW unless the pasture N response is in excess of 15 kg DM/kg N.

2.3.5 MODELLING THE FARM SCALE IMPACTS OF CLOVER ROOT WEEVIL HERBIVORY (White & Gerard 2006)

This study used the model EcoMod to simulate CRW weevil damage on clover plants and the flow-on implications for long-term pasture growth and quality. EcoMod is a mechanistic biophysical simulation model of a plant, soil and grazing animal pastoral ecosystem operating on a daily time-step (IR Johnson unpubl. data). The consequences and financial implications to a typical sheep and beef farmer over a 30 year period were then investigated using StockPol®, a sheep/beef/deer farm decision support tool (Marshall & Johns 1991) and results are summarised in Table 3 . Three farm scenarios were explored, the absence of CRW and the presence of CRW with and without additional nitrogen (N). For a hypothetical 325 ha Waikato sheep and beef farm, CRW decreased mean clover abundance from 21 to 13%, pasture production from 9200 to 7900 kg DM/ha/year, pasture quality from 10.5 to 10.2 MJME/kg DM and N fixation from 60 to 42 kg N/ha/year. This resulted in a 16% reduction in the annual gross margin. However, assuming current prices and costs, and appropriate timing of N applications, the model predicted that over the 30 year term, replacing the N lost through less nitrogen fixation would restore pasture production and gross margins to pre-CRW levels. This is because continual small N applications over a long period of time will increase N in soil organic matter and eventually will make more N available for growth (through SOM mineralisation).

2.3.6 5 Economic impact of clover root weevil on a typical Waikato dairy farm. D. Smeaton

The two previous analyses of on-farm impacts of CRW in New Zealand were on sheep and beef farms. However, as indicated by the NZ Institute of Economic Research analysis, it is the Waikato dairy farmer who is most likely to bear the greatest impacts of CRW. Therefore the following analysis was undertaken.

The impact of CRW on a typical Waikato dairy production system (Dexcel survey data) running 291 cows at close to optimum stocking rate, and using 124 kg N/ha/year was evaluated using UDDER. This is a commercially available computer simulation model developed by Dr Michael Larcombe of Maffra Herd Improvement Co-op, Victoria, Australia. UDDER predicts the expected milk production of a herd under specified conditions of management and pasture growth which enables the user to "test" the likely effects of changes in management or pasture growth for a given farm.

The CRW damage parameter used in the model was the seasonal dry matter loss data (Fig 2) from a small plot trial conducted at Ruakura by Gerard et al (2007). Greatest losses in DM production are during spring. This, however, underestimates CRW impact as the model does not take account of the change in pasture quality through loss of clover.

The key outcomes are presented in Table 4. In summary, CRW depressed pasture growth by 15%. This in turn depressed milksolids production by 11%, gross margins by 10% and stocking rate by 18%. When N fertiliser rates were increased to compensate for the impact of CRW on N fixation, the impact on stocking rate and milksolids production was lessened but the gross margins remained at -10% of the No CRW scenario.

Table 2: Comparison of lamb production from dryland and moist scenarios with no or moderate CRW infestations, and conservative (N^c), moderate (N^m) or high (N^H) urea application responses (Gerard & Eerens 2005).

	No CRW	+ CRW	+ N^c, +CRW	+ N^m, +CRW	+ N^H, +CRW
Scenario	Dryland				
ME/ha	83416	66032	77065	83767	
Carcase kg/ha	939	267	694	953	
Nitrogen cost ($)			209	139	
GM/ha($)	563	160	208	363	
Scenario	Moist (or irrigated)				
ME/ha	119706	100333	123339	128047	142169
Carcase kg/ha	1199	450	1340	1522	2069
Nitrogen cost ($)			209	209	417
GM/ha($)	719	270	595	705	824

Table 3: Revenue, expenditure and gross margins ($/ha) without CRW and with CRW, either without or with nitrogen fertiliser (White & Gerard 2006).

		No CRW	+CRW	+CRW +N
Sheep revenue	Sales-Purchases	536	450	545
	Wool	102	92	103
	Capital value change	6	5	6
Beef revenue	Sales-Purchases	218	180	222
	Capital value change	4	3	4
Total Revenue		866	731	882
Crop & feed costs	Hay and silage	90	78	78
	Nitrogen	0	0	24
Stock costs	Animal health	51	43	52
	Shearing	38	34	38
Interest on capital		118	99	120
Total expenditure		297	253	312
Gross margin		569	478	570

Fig 2: DM production with and without CRW from dairy pasture in the Waikato.

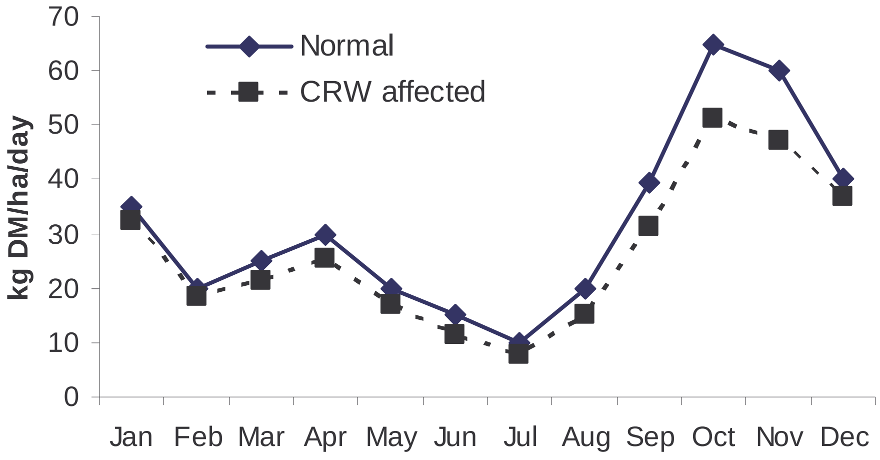


Table 4: Predicted impact of CRW (± N to compensate for lost fixation) on carrying capacity, milk solid (ms) production and total farm gross margin (GM) on a model Waikato dairy farm.

Inputs and outputs	No CRW	+ CRW	% change	+CRW +N	% change
Cows wintered	291	240	-18	255	-12
Cows milked	285	235	-18	250	-12
Total ms	94128	83587	-11	87033	-8
ms/ha	970	862	-11	897	-8
Total farm GM $	165468	149154	-10	148985	-10
GM $/ha	1706	1538	-10	1536	-10

2.4 Discussion

While there is considerable variation in experimental design, all investigations into the effects of CRW have shown that damage to roots by CRW causes a significant reduction in clover herbage production. Generally the reduction ranged between 18-35%. Of course, these experiments were designed to ensure pest pressure. In the field both insect and white clover populations have a patchy distribution and both species interact with each other and the environment, particularly climate. Therefore as Fig. 1 shows, even though the overall trend will be that infested pastures have less clover than un-infested pastures, there will be times and seasons that are highly favourable to clover whereas others may favour the weevil. In addition, farm management practises have a tremendous influence on the stresses placed on clover in pastures, and therefore susceptibility to negative impacts from root damage. It is the aim of this combined SFF/ AGMARDT project to develop scientifically-based cost-effective recommendations of how best to manage pasture in the presence of the weevil.

The economic impact assessments, whether based on high level “best guesses”, or using experimental data and standard industry models, were moderately consistent. The high level “NZ economy” impact assessments both estimated CRW would cost the pastoral industry around $400 m/year if a “do nothing” approach was adopted. The sheep & beef system (White 2006) and current Smeaton dairy system impacts are very similar (10-15% decrease in gross margin) whereas the Gerard & Eerens lamb production system predicted a much greater financial impact. Partially this reflects the vital role spring clover plays in lamb growth. However, as the latter researchers had to extrapolate from Waikato field data, there would be greater confidence in the assessment if damage parameters could be obtained based on seasonal CRW populations and damage in dryland systems.

In two scenarios, the use of nitrogen fertiliser was shown to mitigate or eliminate the negative impact of CRW on pasture production. However, environmental and trade implications have not been considered, and the dairying scenario showed that just replacing lost N fixation did not lift productivity sufficiently to return farm gross margins to previous levels. Whilst CRW is only one of the drivers behind the use of N, it is probable that farmers might not have to use so much if CRW was absent. CRW larval damage, like that of nematodes, is chronic and invisible; many farmers are likely to be unaware that the pasture responses they are achieving through N application are a symptom of poor clover root health.

3 PROGRESS TOWARDS REMAINING 2007 MILESTONES.

SFF

3.2 Cost/benefit analysis of clover re-establishment options (Dec 07)
4.1 Identify CRW management scenarios, apply costs, prepare templates (Dec 07)

AGMARDT

7 Quantify the economic impact of CRW from the trials and other related CRW research (1/4/07)
8 Prepare final report at conclusion of the field trials (1/7/07)
9 Prepare a cost benefit analysis based on the economic impact data and potential alternative management practices (1/7/07)

There appears to be poor alignment in timing between SFF and AGMARDT milestones with regard to cost/benefit analyses, especially as the field trials are on-going till June 2008. However, the 2007 analyses will be undertaken using data to date with the understanding that later data will be incorporated prior to public release in 2008.

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