THE POTENTIAL ABILITY OF *Stethorus bifidus* (Kapur) TO REGULATE POPULATIONS OF *Tetranychus lintearius* (Dufour)

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of the requirements for the degree of
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PLATE 1: Gorse as a problem in forestry

KOPURIKI NEAR TE PUKE

Silviculture practices are restricted or prevented by gorse.

ABSTRACT

Tetranychus lintearius Dufour (Acari; Tetranychidae) was released in New Zealand, in 1989, to assist in the regulation of gorse (*Ulex europaeus*). The present study was initiated to determine why colonies of GSM are consistently failing to establish above parallel 39°S and the possibility that *Stethorus bifidus* may be regulating populations of *T.lintearius* (GSM).

Predation by *S.bifidus* was investigated by examining both numerical and functional responses to prey density.

- Development of *S.bifidus* is described by a linear relationship with temperature between 8.5°C and 27.5°C (numerical response). Oviposition and temperature are linearly related and independent of GSM density. Measurements of temperature under GSM webbing showed an elevation of 1-2°C above ambient.
- The feeding rate of *S.bifidus* increased in a non-linear fashion between 6.5°C and 32.5°C (functional response).
- Handling time decreased with increasing prey density demonstrating that *S.bifidus* is an effective predator at high mite densities.

This investigation suggests that the role of *S.bifidus* in regulating GSM is more important in northern regions of New Zealand.

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CHAPTER ONE: INTRODUCTION

Part one: Regulation of gorse in New Zealand - The plant, the biocontrol agents, the policies/procedures and the complications.

Gorse - The options for regulation of a noxious plant:

Gorse (*Ulex europaeus* L.) is a fast growing woody legume capable of establishing rapidly from seeds or stumps. It thrives particularly in low fertility soils where the competitive ability of other 'more favoured' plants is reduced. Although gorse is found throughout Europe, it is only considered a major weed of agriculture and forestry in North America, South Australia, Tasmania, New Zealand and at high altitudes in Hawaii. A warm, moist climate free of temperature extremes and exposure to cold winds appears to suit gorse. Control is difficult and expensive. In 1977, chemical control of gorse in New Zealand cost approximately $7 million and this did not include the cost of lost production (MacCarter & Gaynor 1980). According to Miller (1970; cited in Hill & Gourlay 1990), gorse plants can be found on over 3.5% of the land area of New Zealand, however long-lived seed is buried in the soil over a larger area.

The first attempts to control gorse biologically began in the 1920's when the only agent introduced was the seed-feeding weevil, *Apion ulicis* Forst. Because of the importance of gorse as a hedging material damaging plant foliage was not desirable. *A.ulicis* did not control the spread of gorse, but it did establish successfully (MacCarter & Gaynor 1980). MacCarter (loc cit.) considered that the good establishment of *A.ulicis* argued well for introductions of further biocontrol control agents for gorse. Consequently, DSIR's Entomology Division began to investigate several agents for biological control of gorse, including the stem boring weevil *Apion scutellare* Kirby and a leaf feeding moth, *Agonopterix ulicetella* Stnt. (MacCarter loc cit.). This research recognized that even if many introductions of biocontrol agents were to be made, eradication of gorse would be unlikely, instead, the probable effect would be to reduce its vigour to a situation where gorse is merely part of the natural succession, and no longer a serious weed (MacCarter loc cit.).

In 1984 the value of lost production on gorse infested lands exceeded $150 million per annum (Monsanto 1984). Current gorse regulation practices are largely ineffective because of the extreme vigour and competitive ability of the weed. According to Monsanto (loc cit.) the herbicide applied to gorse infested land each year is enough to kill 25% of the gorse in New Zealand, yet the problem remains as severe as it was 30 years ago.

A report by Monsanto in 1984 clearly identified gorse as a major weed. Hackwell (1980) however, pointed out that gorse also has beneficial effects, including a role as a soil improving species and as a nurse plant for regenerating native forest.

Sandry's (1985) economic analysis considered both detrimental and beneficial effects, and concluded that current benefits of gorse were unimportant apart from beekeeping. Sandry also suggested that control of gorse may undermine the unrealized potential of goat farming. A subsequent review by Longworth (1986) also concluded that the benefits of biological control of gorse outweighed the costs.

Hill (1986) summarized opinions expressed in 49 submissions on a proposal for biological control of gorse. Thirty submissions supported the proposal to use biological control agents to control gorse, nine opposed the proposal and ten did not express a strong opinion. Responses from the various organisations contacted allowed a balanced assessment of some non-economic questions which were beyond the scope of Sandry's (1985) report. Strongest opposition to the proposal came from those concerned about the possible impact of successful control on regeneration of native forests in New Zealand. Hill (loc cit.) considered that biological control of gorse, even at its most effective level, would probably have no adverse effect on the rate of succession of native forest species. He pointed out that effective biological control might be beneficial in other respects for native plant communities. Other major concerns expressed included those to do with the use of gorse as fodder and the fear of increased erosion. Hill (loc cit.) concluded that both concerns were unlikely to eventuate in practice.

Clearly public debate was necessary to uncover all arguments for and against biological control of gorse. This debate was summarised and analyzed in a subsequent cost-benefit analysis (Hill & Sandry 1986). Key points of this report include, firstly that it is not possible to predict the amount of damage that biological control agents could do to gorse in New Zealand; and secondly that beekeepers were the major group which could suffer economically, but only if gorse vigour was reduced by more than 50%.

These reports by Sandry (1985), Hill (1986), and Hill & Sandry (1986), together conclude from an overall perspective that a biological control programme against gorse in New Zealand is desirable.

Ninety four species of invertebrates attack gorse in Europe; of these only 16 appear sufficiently host specific to show promise for introduction into New Zealand as biological control agents (Hill 1983). Five of these attack reproductive structures and 11 feed on green shoots. There are no suitable agents which attack roots, crowns or woody stems. The four species with the greatest potential to damage gorse are *Tetranychus lintearius* Dufour (Acari; Tetranychidae), *Agonopterix ulicetella* Stat. (Lepidoptera; Oecophoridae), *Dictyonota strichnocera* Fieber (Lepidoptera; Tingidae) and *Apion scutellare* Kirby (Coleoptera; Curculionidae) (Hill loc cit.). Of these *T.lintearius* the gorse spider mite (GSM), can severely damage gorse in Europe, and offers the only prospect of causing lethal damage to gorse by itself. This species was the first to be selected for introduction during the 1980s, **see plate 2**. Subsequent introductions of other species aim to increase the biotic pressures on gorse. The net effect should be to reduce gorse vigour, improve the susceptibility of gorse to existing control measures, and reduce the extent of regrowth. Some agents may further reduce gorse seed production throughout the year (Hill 1983).

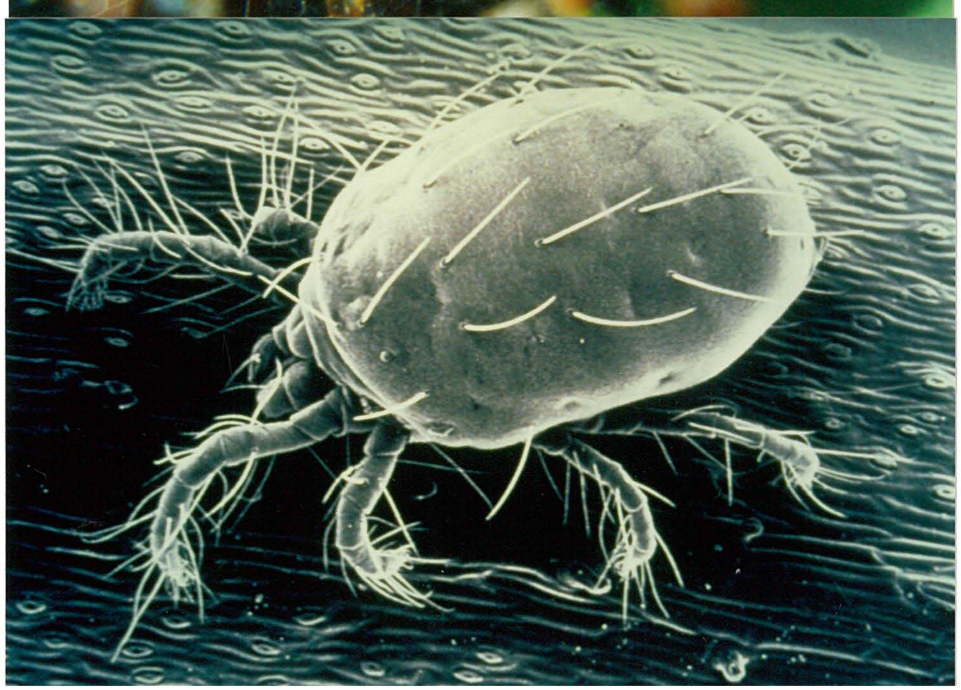
Hill (1987) prepared an Environmental Impact Assessment (EIA) which considered the potential for biological control of gorse, the suitability of GSM as a control agent for gorse, and the possible impact of biological control of gorse to the environment and primary production in NZ. This EIA ties together Sandry's (1985) ex-ante evaluation of biological control of gorse, Hill's (1986) implications for the natural environment report, media response, goat farming considerations by Sandry (1987) & farming organisations in general including the beekeepers association submissions. It also includes draft papers describing the host range of GSM and the inability of GSM to

PLATE 2: *Tetranychus lintearius* - the biocontrol agent

a- *T.lintearius* the gorse spider mite (a colonial tetranychid mite)
(Magnification X 1)

b- *T.lintearius* feeding on a gorse (*Ulex europaeus*) spine
(Magnification X 25)

c- Electronmicrograph of *T.lintearius* Photo: Lynley Hayes
(Magnification X 150)



breed with other species. These draft papers, which were eventually published elsewhere (Hill & O'Donnell 1988), showed that *T.lintearius* is a distinct species incapable of crossing with either *T.urticae* or *T.turkestani* and that it is entirely host specific to *Ulex* species. *T.lintearius* does not feed and reproduce on native legumes.

T.lintearius was finally introduced into New Zealand from Porthowan, Cornwall, England in 1988 (Hill et al. 1989). The first four shipments of mites arrived at Christchurch on 22 July. The mites were reared in strict quarantine at DSIR, Lincoln, for two generations. *T.lintearius* was first released near Christchurch on 22nd February, 1989. Mites successfully transferred from shoots onto gorse plants (30 April, 1989) (Hill loc cit.).

By 1990 *T.lintearius* had been released at over 100 sites (Hill 1990). It overwintered successfully and is regarded as established. Its effect on gorse is currently being evaluated in Otago, Canterbury and Southern Hawkes Bay (P.McGregor & R.Hill pers comm.). Hill et al. (1991) recorded the establishment success of *T.lintearius* at over 170 sites. The mite established poorly above latitude 39 degrees south where only 22% of colonies released became successfully established on gorse. Conversely 87% of colonies successfully established below this latitude (poor establishment success on the west coast of the South Island was also noted). This pattern of establishment demonstrates the difficulty in predicting the outcome of an introduction for biological control, even when great effort is directed at forecasting the result. Analysing the outcome of an introduction therefore depends on post hoc. research. My research contributes to this analysis by examining the potential effects of predation by an endemic insect *Stethorus bifidus* (Kapur) (Coleoptera; Coccinellidae) on *Tetranychus lintearius* populations. The importance of predation in regulating gorse spider mite populations is not known.

New Zealand has two families of common predatory invertebrates that may significantly affect *T.lintearius* populations. *Phytoseiulus persimilis* (Acari; Phytoseiidae) Athias-Henriot and three species of *Stethorus* (Coleoptera; Coccinellidae) which have been recorded in the literature as regulating tetranychid mite populations. Successful establishment of GSM colonies in the field has been recorded despite the presence of *P.persimilis* (Hill et al. 1991). This suggests that *P.persimilis* alone is unlikely to cause widespread establishment failure of GSM. This information on *P.persimilis* coupled with a lack of knowledge on *Stethorus* predation in New Zealand, indicated that research needed to focus on GSM predation by coccinellids. In line with 'major factor analysis', as opposed to a study of the predator complex, the potential regulatory ability of *Stethorus* species alone is addressed in this thesis. *Stethorus bifidus*, the most common endemic *Stethorus* species in New Zealand, was taken as the study predator in association with *T.lintearius*.

S.bifidus an endemic predatory insect:

There are three New Zealand species of *Stethorus*. *S.bifidus* (Kapur), *S.griseus* (Chazeau) and *S.histrio* (Chazeau). *S.griseus* and *S.bifidus* are endemic to N.Z. (both with an earliest record of February 1912) and their closest relatives are in Australia, *S.nigripes* and *S.vagans*, respectively. *S.histrio* is native to Australia, New Caledonia, Chile and Mexico. It has been present in NZ since at least 1932, while the earliest Australian record is 1892 (Houston 1990).

The importance of coccinellid predators in New Zealand orchards has long been recognized. This is indicated by Collyer (1964) who sees *S.bifidus* as the only important predacious insect in New Zealand. This statement, while not to be taken literally, does indicate the importance of *Stethorus* species as predators (especially of phytophagous mites).

Chapter three provides information relating to predatory performance of *Stethorus* species in general as well as specific information on the taxonomy and biology of *S.bifidus*.

Part two: Objectives, hypotheses and how the problem was investigated

Previous research:

Debach (1950) working on population fluctuation in *Paratetranychus citri* (citrus red mite) comments on the controversial nature of published work regarding the relative importance of regulatory factors, especially predatory and climatic variables. Debach (1950) reviewed a variety of methods to evaluate the effectiveness of predators feeding on citrus red mite populations. These methods involved the correlation of quantitative data on mite and predator population changes and the effect of predator exclusion on mite development rate. The possible influence of climate variables on mite population regulation were also considered by following two procedures; attempting to correlate climatic extremes in temperature and humidity with mite population fluctuations and secondly mite population fluctuations with prior climatic extremes (Debach loc cit.). This type of data can be very useful if consistent trends are uncovered though collection of data is labour intensive and often unpractical.

Looking at variables within the predation process Tanigoshi loc cit. (1977b) considers predation pressure as the compilation of many predatory species. The importance of this is stressed by the study done by Tanigoshi loc cit. (1977b) on the dynamics of predation of *S.picipes* and *Typhlodromus flordanus* on the prey *Oligonychidae punicae*. It was noted here that 'phytoseiid mites were the most effective predators in maintaining *O.punicae* populations at low levels and that *S.picipes* was the most effective predator in suppressing high spider mite populations and that the impact of the two predators together resulted in a numerical suppression of the prey which was 3.0 and 6.7 times greater than that for *T.floridanus* and *S.picipes*, respectively, acting alone.' Finally Putman (1955) noted that 'although *S.punctillum* alone cannot alone control severe infestations of mites it is an important member of the biological complex that limits mite populations.'

It is clear that *Stethorus* species have the ability to exert considerable predation pressure on prey populations under certain conditions. However *Stethorus* species are consistently referred to as merely one of the components of the overall predation pressure shaping pest population dynamics. *Stethorus* is often considered as having a reduced regulatory potential if present in isolation from other predators. This point stresses the importance of adopting a 'multi-factor' approach to this type of problem in order to uncover the underlying importance of various interactions. In other words caution is needed when interpreting results dealing with a predator taken from it's surroundings.

The objective of this study is to determine the potential ability of *Stethorus bifidus* to regulate populations of *Tetranychus lintearius*. To do this it is necessary to learn about the predators Phenology (activity cycle) and consumption rate. Phenology and consumption rate are therefore used as starting points for the examination of wider interactions.

Objective A: What is determining *S.bifidus* phenology?

- Physiological State in relation to temperature
- Development rate in relation to temperature
- Prey quantity (density) measured by development speed/fecundity of *S.bifidus*
- Prey quality (colony age structure) measured by the fecundity of *S.bifidus*
- Substrate

(NB: A high fecundity is the ability to produce offspring frequently and in large numbers)

Objective B: What are the primary influences on consumption rate?

- Activity tempo (or speed) in relation to temperature
- Prey density measured by search distance
- Interference measured by webbing & competition

The approach to addressing each of these 'variables' associated with *S.bifidus* phenology and consumption rate is given below. Abbreviations are used in each case to describe the way in which each question was investigated.

Obs= observations

Ref= key reference(s)

Exp= experiment

Objective A: What is determining *S.bifidus* phenology?

Temperature

aim - PHYSIOLOGICAL OR ACTIVITY STATE: At what times of the year/season is *S.bifidus* an active predator having the potential to regulate *T.lintearius*?

obs. - To address this question *S.bifidus* populations in the field will be observed. A review of the literature will also be used.

ref. - (Collyer, 1964)

Temperature

aim - DEVELOPMENT RATE: The rate of development will depend on temperature. Experimental work and a literature review will be used here.

ref. - Putman (1955)

exp. Experiments will be run to determine the duration of development at different temperatures when excess food is available. An estimate of threshold temperatures will be made. Incorporating this information with work done by Stone (1986; looking at development rates of *T.lintearius*) will allow development rates of both predator and prey to be plotted and compared as temperature changes, **see Chapter four: part one.**

Prey quantity

aim - DEVELOPMENT SPEED/FECUNDITY: How is development time/fecundity affected by prey density. Past evidence will be used here in conjunction with oviposition testing.

ref. - (Bailey 1986; Collyer 1964; Houck 1991; Putman 1955; Smith 1965).

exp. - Measure oviposition in relation to prey density **see Chapter four**.

Prey quality

aim - FECUNDITY: How is the availability of mite stages influencing *S.bifidus* fecundity. A literature review will be used.

ref. - (McMurtry et al. 1974; Scriven & Fleshner 1960; Putman 1955; Orr & Obrycki 1990)

Substrate

aim - SUBSTRATE: Can *S.bifidus* carry out it's life cycle on gorse? Evidence and observation will be incorporated here.

ref. - (McMurtry et al. 1970a; Collyer 1964).

obs. - Observation of eggs being laid on gorse in the field or laboratory by *S.bifidus* will be made. Development while feeding on GSM alone will be followed and the laying of viable eggs on gorse will be used as a final check.

Objective B: What are the primary influences on consumption rate?

Temperature

aim - ACTIVITY TEMPO OR SPEED: How is temperature affecting consumption of GSM by *S.bifidus*. Evidence and experimentation will be used here.

ref. - (Hull 1974; Hull et al. 1976; Hull et al. 1977a)

exp. - Experiments will determine the number of mites consumed by *S.bifidus* feeding at different temperatures. GSM distribution in relation to temperature will be important (if the mites clump as temperature drops prey consumption may be maintained or even increase). However this will not be determined (as the tests will be carried out in artificial arenas) but this point must be kept in mind.

Prey density

aim - SEARCH DISTANCE: Determine how prey density will affect predation. Literature and experimental findings will be incorporated here.

ref. - (Putman 1955; Hull et al. 1977b; Putman 1950; Chant 1961; Readshaw 1973,74; Charles et al. 1985).

exp. - Testing individuals under varying prey densities will be used to determine if

S.bifidus' functional response has characteristics necessary for effective regulation of GSM populations. This will be done by measuring the handling time variation as prey density is altered, **see chapter four: part 2, section 2.**

Interference

aim - WEBBING: Does the presence of webbing affect consumption rate? Evidence and observation will be relied on here.

ref. - (Tanigoshi & McMurtry 1977a; Putman 1955; Davis 1952)

obs. - check for obstruction to feeding in GSM web throughout experimentation.

aim - INTRASPECIFIC COMPETITION: Is intraspecific competition likely to be occurring? Use evidence here.

ref. - (Hattingh & Samways 1990; Putman 1955; Raros & Haramoto 1974)

The above information will be integrated to predict the potential ability of *Stethorus bifidus* to regulate *Tetranychus lintearius* in various regions of New Zealand, **see Figure 8 for a summary of the above considerations.**