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The Biocontrol of Gorse, *Ulex europaeus*, in Chile: A Progress Report

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Abstract

Gorse, *Ulex europaeus*, has become the most important weed of silvicultural and rangeland industries in Chile. The earliest attempt to control it biologically was made in 1976 when the seed predator *Apion ulicis* was introduced into the country. This bioagent established successfully throughout the gorse infested areas but has not been able to regulate the weed on a national bases by itself. The program was renewed in 1996 which resulted in the introduction, quarantine, host-testing, rearing and release of two additional bioagents; the gorse spider mite, *Tetranychus lintearius* (Acari: Tetranychidae) and the gorse shoot-tip moth, *Agonopterix ulicetella* (Lepidoptera: Oecophoridae).

Two gorse spider mite populations introduced from Hawaii and Portugal were released in 1997. They are now colonizing gorse stands and increasing their densities at over 50 sites between the 37° and 40° parallels of southern latitude, especially at the Chilean most important silvicultural areas. The gorse shoot-tip moth, introduced from Hawaii and the UK was first released in Chile in 1997. This bioagent successfully overwintered at nine sites between the 38° and 40° parallels of southern latitude. The best colonization of the population collected at Hawaii occurred at gorse stands located in warmer, drier areas of Chile, whereas the UK population performed better in humid areas.

Keywords: Biological Control, weeds, gorse, *Agonopterix ulicetella, Tetranychus lintearius, Apion ulicis*

Gorse, Ulex europaeus, (Fabaceae), was introduced into Chile at the beginning of the nineteenth century for use as a hedge plant to contain livestock, and as a fodder source (Opazo 1930, Matthei 1995). By the 1930's the plant had become a naturalized weed in the Chiloé and Valdivia Provinces of southern Chile (Opazo 1930). At present gorse is one of the most damaging exotic weeds between the 33° and 43° parallels of southern latitude and has become a serious threat to Chilean agricultural and silvicultural industries. Gorse infests pine and eucalipt plantations, where it hinders the establishment and efficient management of exotic forest trees, and constitutes a serious fire risk. The forest industry estimates that about 100.000 ha of plantations with exotic timber species are under rapidly increasing infestation by gorse. The weed also infests highly productive beef farms and many farmers have resorted to sheep grazing where they would have otherwise grazed cattle.

Mechanical and chemical controls are expensive and difficult to undertake, particularly on step terrain and, as a consequence, biological control appears to be both economic and environmentally the most desirable alternative for the long term management of this weed.

This paper summarises earlier work with the gorse seed weevil, *Apion ulicis* Forster, and reports on recent progress towards biological control of gorse in Chile.

Earlier biological control attempts.

Studies toward biological control were first undertaken in 1976 with the introduction from the UK via New Zealand of *A. ulicis* (Coleoptera: Apionidae), by the Universidad Austral de Chile. From a starter colony of 4,000 adult weevil shiped by Dr. Richard Hill many insect releases were made throughout gorse infested areas in Chile. After several years of successful establishment the weevil was reported to attack up to 98% of the pods (Norambuena *et al.* 1986). Further investigations conducted during the 90's indicated that biomass, seed production, and seedling colonization of gorse were significantly reduced by the insect under field conditions of plant intra- and inter-specific competition (Norambuena 1995, Norambuena and Piper 1996).

Current investigations in Chile.

In spite of the significant effect of the seed predator upon gorse invasiveness it was realized that additional herbivores attacking vegetative structures were needed in order to improve gorse control in Chile. Consequently, the biocontrol program was renewed in 1996 with the introduction, quarantine, host testing, rearing, release and monitoring of two additional bioagents; the gorse spider mite *Tetranychus lintearius* Dufour (Acari: Tetranychidae) which feeds on the cell contents of gorse spines and stems (Hill *et al.* 1991), and the gorse shoot-tip moth *Agonopterix ulicetella* (Stainton) (Lepidoptera: Oecophoridae) whose developing larvae feed on new gorse shoots and spines (Hill *et al.* 1995).

Material and Methods

Populations of the bioagents were collected in Portugal, Spain, USA and the UK. Bioagent importation, quarantine and release procedures followed current chilean plant protection guidelines for using foreign organisms against weeds. To confirm the host specificities of the bioagents, critical plants were exposed in choice and non-choice tests (Zwölfer and Harris 1971, Cullen 1989). Test plants were chosen according to the criteria proposed by Wapshere (1974). Releases were made during the spring of 1997 and the summer of 1998 at several sites throughout the climatic range of gorse including relatively dry (600-1400 mm annual rainfall) and humid areas (1500-3000 mm) between the 37° and 40° parallels of southern latitude. A colony of approximately 50,000 gorse spider mites of mixed ages was released on each experimental plot. Releases of the shoot-tip moth were made on gorse plants into a 2x2x2 m gauze field cage. At each release site three hundred laboratory-reared third instar larvae of the *A. ulicetella* population introduced from Hawaii were placed on new gorse shoots during the spring. At two selected sites (Valdivia and Collipulli) 40 laboratory-reared *A. ulicetella* adults of each population introduced from Plymouth, United Kingdom, and Hawaii, were released during the summer.

Survival of these bioagents was assessed every month during summer, fall and spring of 1998. During winter, release sites were examined at irregular intervals. Visual inspection of mite colony size, webbing, spread, presence of mite predators and damages to gorse plants was assessed *in situ*. The gorse shoot-tip moth survival and damage to the gorse plants was examined by counting the number of larvae, pupae and adults, and attacked gorse shoots during 30 min in each plot.

Table 1.
Phytophagous organisms introduced to Chile for biocontrol of *Ulex europaeus* L.

Organism	Date of Intro.	Origin	Date of release	Status
Apion ulicis Forster	1976	New Zealand ex UK	1976-1987	Established
Tetranychus lintearius	1996	USA		
Dufour		Oregon UK/ Spain		Not released
		Hawaii UK/ Spain	1997	Recovered the following year
		Portugal	1997	Recovered the following year
		Spain	1997	Not released
		UK		Not released
Agonopterix	1996	Hawaii ex UK/Portugal	1997-1998	Recovered the following year
ulicetella	1997	UK		
Stainton		Plymouth	1998	Recovered the following year
		Norwich		Not released

Results and Discussion

Importation.

Five gorse spider mite populations were introduced to Chile in 1996 but only Hawaiian and Portuguese (San Pedro de Muel) gorse spider mite "strains"survived the quarantine. The Hawaiian population was obtained from Oregon (USA) where it established in 1994. This Oregon mites had been brought from New Zealand (Markin *et al.* 1996). One gorse shoot-tip moth population field collected in the Island of Hawaii was introduced into Chile in 1996. This population originated from laboratory crosses between moths introduced from London and the coast of Portugal, about 100 km north of Lisbon (Markin 1996; personal communication). Other two shoot-tip moth populations were collected in Norwich and Plymouth in the UK, and introduced into Chile in 1997. The Norwich population was very small and did not reproduce in the quarantine (Table 1).

Host Specificity.

Both bioagents confirmed to be highly specific to gorse in choice and non-choice tests conducted in the Chilean quarantine (Martinez 1998). Previous safety tests conducted in large field cages in Hawaii had shown that none of the most common lupins species grown in Chile would be suitable hosts for *A. ulicetella* (G. P. M., unpublished data).

Releases.

First releases of the mite "strains" collected in Hawaii and San Pedro de Muel, were made during the spring of 1997 at over 50 gorse infested sites between the 37° and 40° parallels of southern latitude. *A. ulicetella* introduced from Hawaii was released as larvae in the summer of 1998 at nine sites between this range. In addition, adults releases of *A.*

Table 2.
Number and dispersal of *Tetranychus lintearius* colonies in Chile 1997-1998, one year after release.

Location	Latitude S	Number of colonies		Dispersal (m)	
		Hawaii	San Pedro	Hawaii	San Pedro
Arauco	37° 14’	59		75	
Lebu	37° 35’		166		35
Collipulli	37° 57’		>250		1.000
Ercilla	37° 58’	>250		500	
Lautaro	38° 32’	16		45	
Lautaro	38° 32’		87		300
Carillanca	38° 41’	40	50	30	70
Valdivia	39° 48’	3	6	8	6

ulicetella collected in Hawaii and Plymouth were made in two selected localities, Collipulli and Valdivia, representing dry and humid areas of the gorse range, respectively (Table 1).

Establishment.

San Pedro and Hawaiian gorse spider mites successfully overwintered and were recovered at all of the agricultural and silvicultural sites where they were released (Table 2). These mite “strains” increased rapidly their population during the summer and fall of 1998. During winter and early spring mite colonies declined and then increased up to 250-fold during the summer and early fall of 1999 causing evident damage to gorse plants. Gorse damage attributed to mites has varied greatly from site to site. Mite feeding destroyed gorse tissue and some heavily attacked plant became brownish to yellowish. Altough death of plants caused by gorse spider mite attacks was not evident, reduced regrowth and flowering due to the mite feeding and extensive webbing were common, especially in dry areas. Gorse mite dispersal ranged from 6 to 1000 m from the release points in a one year period (Table 2).

We have not found significant differences between San Pedro and Hawaiian “strains” in terms of mite population growth and dispersal, as well as damage to the weed. These “strains” have performed much better in relatively dry areas (i.e., Collipulli; 37° 57’), than in humid areas (i.e.,Valdivia, 39° 48’S) (Table 4).

The most common predator associated to gorse spider mites in Chile has been *Oligota* sp. (Staphylinidae). It has been observed destroying mite colonies at every release site, but without accounting for failure of whole colonies.

The mite population growth pattern recorded in Chile is similar to that observed in Oregon and Hawaii (Coombs 1999; G. P. Markin, personal communication) during the first year after the mite release. In contrast, it is rather different with the situation occurred in New Zealand after the gorse spider mite introduction, particularly in terms of “strains” performance. In New Zealand, a mite strain introduced from the UK (Cornwall) in 1989 established well in most areas but poorly in areas characterized by relatively warm winters and high rainfall. Consequently, five new "strains" were introduced from Spain and Portugal (including one population collected at San Pedro de Muel). These mites improved establishment success in rainy areas of New Zealand, but San Pedro mites were the least successful of the new "strains" (Hill *et al.* 1993). Interestingly, annual rainfall at the original source of the Portuguese "strain" (San Pedro de Muel, 39° 45'N) is intermediate between those of Lisbon (708 mm) and Oporto (1150 mm), and similar to the unusual low rainfall levels registered in dry areas of the gorse distributional range in Chile during 1998 (Table 4).

Nonetheless, this marked population increase of the San Pedro "strain" at relatively drier areas in Chile and its failure to establish in high-rainfall regions in New Zealand strength the statement made by Hill *et al.* (1993) that rainfall is a major deleterious factor on gorse spider mite establishment. It might also reinforce the suggestion of ease establishment when importing the bioagent from the climatic analogue of the release area as emphasized by Wapshere (1982), and Hill *et al.* (1993).

Our results also indicate that in order to improve the likelihood of gorse spider mite establishment and density in coastal humid areas in Chile, further introductions from high-rainfall areas in Europe should be attempted.

The gorse shoot-tip moth introduced from Hawaii and the UK successfully overwintered between the 37° 57' and 38° 4' S. The UK "strain" also overwintered at humid areas 40° S, but no evidence of survival of the Hawaiian "strain" was noticed at this latitude (Table 3). The reasons for this fail on survival of the Hawaiian "strain" at sites north of latitude 38° S and south of latitude 39° S, are uncertain. These are coastal areas characterized by wetter winters than the regions where the moth was recovered in Chile (Table

Table 3.
Releases of *Agonopterix ulicetella* in Chile, 1997-98.

Location	Latitude S	Number released	Strain released per site	Status after 1 year
Arauco	37° 14'	300 L	Hawaii	Not recovered
Lebu	37° 35'	300 L	Hawaii	Not recovered
Collipulli	37° 57'	40 A	Hawaii, U.K.	Recovered
Collipulli	37° 57'	40 A	Hawaii, U.K.	Recovered
Collipulli	37° 57'	40 A	Hawaii, U.K.	Recovered
Ercilla	37° 58'	300 L	Hawaii	Recovered
Lautaro	38° 32'	300 L	Hawaii	Recovered
Carillanca	38° 41'	300 L	Hawaii	Recovered
Valdivia	39° 48'	40 A	Hawaii	Not recovered
		40 A	U.K.	Recovered

L= larvae; A= adults

Table 4.
Climatic data for collection and release areas of gorse bioagents.

Location	Latitude	Rainfall (mm)		Temperature (°C)	
		Average	1998	Average	1998
Oporto	41° 10' N	1150		14,5	
Lisbon	38° 45' N	708		17,0	
Hawaii	19° 50' N	3500		13,8	
London	51° 20' N	799		10,5	
Plymouth	50° 15' N	950		10,5	
Lebu	37° 35' S	1106		12,71	
Collipulli	37° 57' S	1054	771	13,5	13,20
Carillanca	38° 41' S	1394	619	11,5	11,7
Valdivia	38° 48' S	2531	1393	12,8	12,18

4). This, and the fact that in Hawaii the moth is well established above 1, 000 m altitude (Markin *et al.* 1996), suggest that overwintering of the "Hawaiian" population might be enhanced at cooler sites.

Nevertheless, the evidence of survival of *A. ulicetella* in Chile after one year from its release and the extensive establishment of the moth on the Island of Hawaii indicate that new introductions and releases of this bioagent should be considered for the Chilean bio-control program, particularly for gorse growing at sites with relatively cooler winter. Given the similarity of rainfall distribution between areas in the United Kingdom (i.e., Plymouth) and coastal gorse infested areas in Chile (i.e., Valdivia), a sound program of gorse shoot-tip moth introductions from the UK is also highly recommended.

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References

Cullen, J.M. 1989. Current problems in host-specificity screening, pp. 27-36. *In* E.S. Delfosse [ed.], Proceedings. VII International Symposium on Biological Control of Weeds, 6-11 March 1988, Ist. Sper. Patol. Veg. (MAF) Rome, Italy.

Hill, R.L., J.M. Grindell, C.J. Winks, J.J. Sheat, and L.M. Hayes. 1991. Establishment of gorse spider mite as a control agent for gorse, pp 31-34. *In* Proceedings 44th N.Z. Weed and Pest Control Conference, 1991.

Hill, R.L., A.H. Gourlay, and C.J. Winks. 1993. Choosing gorse spider mite strains to improve establishment in different climates**.** pp 337-383. *In* Prestidge [ed.]. Proceedings. VI Australian Conference on Grassland Invertebrate Ecology, 17-19 February 1993, Hamilton, New Zealand.

Hill, R.L., D.J. O'Donnell, A.H. Gourlay, and C.B. Speed. 1995. Suitability of *Agonopterix ulicetella* (Lepidoptera: Oecophoridae) as a control for *Ulex europaeus* (Fabaceae: Genisteae) in New Zealand. Biocontrol Science and Technology 5: 3-10.

Matthei, O. 1995. Manual de las malezas que crecen en Chile. Alfabeta Impresores, Santiago de Chile.

Markin, G.P., E.R. Yoshioka, and P. Conant. 1996. Biological control of gorse in Hawaii, pp 371-375. *In* V.C. Moran and J.H. Hoffmann [eds.], Proceedings of the IX International Symposium on Biological Control of Weeds, 19-26 January 1996, University of Cape Town, Stellenbosch, South Africa.

Martinez, G. 1998. Estudio de especificidad de los bioagentes *Tetranychus lintearius* Dufour y *Agonopterix ulicetella* (Stainton), introducidos para el control biológico de la maleza *Ulex europaeus* L. thesis, Universidad Austral de Chile, Valdivia.

Norambuena, H. 1995. Impact of *Apion ulicis* Forster (Coleoptera: Apionidae) on gorse *Ulex europaeus* L. (Fabaceae) in agricultural and silvicultural habitats in southern Chile. Ph.D. dissertation, Washington State University, Pullman.

Norambuena, H., R. Carrillo, and M. Neira. 1986. Introducción, establecimiento y potencial de *Apion ulicis* como antagonista de *Ulex europaeus* en el sur de Chile. Entomophaga 31: 3-10.

Norambuena, H., and G.L. Piper. 1996. Impact of *Apion ulicis* Forster (Coleoptera: Apionidae) on gorse *Ulex europaeus* L. (Fabaceae) in an agricultural habitats in southern Chile, pp. 336-337. *In* V.C. Moran and J.H. Hoffmann [eds.], Proceedings of the IX International Symposium on Biological Control of Weeds, 19-26 January 1996, University of Cape Town, Stellenbosch, South Africa.

Opazo, R.G. 1930. Monografía cultural de las diversas plantas agrícolas. MINAGRI, Santiago, Chile.

Wapshere, A.J. 1974. A strategy for evaluating the safety of organisms for biological weed control Ann. Appl. Biol. 77: 201-211.

Wapshere, A.J. 1982. Discovery and testing of a climatically adapted strain of *Longitarsus jacobaeae* [Col.: Chrysomelidae] for Australia. Entomophaga 28: 27-32.

Zwölfer H., and P. Harris. 1971. Host specificity determination of insects for biological control of weeds. Annu. Rev. Entomol. 16: 159-178.