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The host range of *Tetranychus lintearius* (Acarina: Tetranychidae)

R.L. Hill[a] and D.J. O'Donnell[b]
[a]*DSIR Plant Protection, Private Bag, Christchurch, New Zealand*
[b]*CABI Institute of Biological Control, Silwood Park, Ascot, SL5 7TA, UK*

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ABSTRACT

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The host range of *Tetranychus lintearius* was examined experimentally to determine if the mite could be safely introduced into New Zealand for the biological control of gorse, *Ulex europaeus* (Leguminosae: Genisteae). The rationale for choosing test plants was the same as that employed for testing insect species as biological control agents. Outdoors, mite colonies could be transferred successfully from gorse plant to gorse plant, but could not re-establish on any of 39 other plant species tested. In the laboratory, the ability of adult mites to settle on plants and to lay eggs, and for resulting progeny to develop, was measured on 58 plant species other than gorse. Apart from *Ulex europaeus* and *U. minor*, development was completed only on *Phaseolus vulgaris* and *Glycine max*. Further experiments using 22 bean cultivars showed that mites could not complete a second generation on detached leaf cultures, could not form permanent colonies on potted plants in the glasshouse, and remained only a short time when transferred to bean plants in the field.

Tetranychus lintearius has never been recorded from any plant but *Ulex* species. This fact, coupled with the results of host-range testing, suggests that the mite is sufficiently host-specific to be safely used as a biological control agent for gorse in New Zealand.

INTRODUCTION

Gorse, *Ulex europaeus* L. (Leguminosae: Genisteae) has become a serious weed in many countries including New Zealand, U.S.A., Chile and Australia. It is a tall thorny shrub which forms dense thickets on grazing land and forest plantations (MacCarter and Gaynor, 1980). Chemical control of gorse has become uneconomic in many instances, and so biological control is now being considered.

A survey of the phytophagous insects which attack gorse was carried out by Zwölfer (1963), who found that a mite, later identified as '*Tetranychus telarius*', caused more damage than any other single species. He observed that this might be a race which fed only on gorse, and suggested that it be consid-

ered more closely as a potential biological control agent for this plant. Since then this mite has been restored to specific status as *T. lintearius* Dufour (Van Eyndhoven, 1967). It is morphologically distinct from closely related members of the *T. urticae* complex of species (Stone, 1982, 1986), and is reproductively isolated from at least two species of that complex (Hill and O'Donnell, 1991). *Tetranychus lintearius* also varies from other tetranychids in its colonial behaviour. Mites of all stages gather closely together in groups which can number many thousands inside a heavy communal web (Van Eyndhoven, 1967).

Tetranychid mites have never been introduced into any country for the purpose of weed control. Hill and Stone (1985) have suggested that the methods employed to test the suitability of insect species as biological control agents are valid for mites as well. This paper describes laboratory and field experiments to find the potential host-range of *T. lintearius* in order to determine its suitability as a biological control agent for gorse in New Zealand.

MATERIALS AND METHODS

Colonies of *T. lintearius* for these tests were obtained from Porthtowan, Cornwall and Chobham Common, Berkshire, Great Britain. The species of plants used in the tests which were chosen using the principles described by Wapshere (1974), are listed in Appendix I.

A) Oviposition and survival tests on a range of plant species

Three series of tests were carried out. The initial test (an establishment test) used either potted plants in field cages or mature plants growing in the field. Small portions of infested gorse shoots bearing at least 100 mites were tied onto the test plants with cotton thread. Colonies were also transferred into gorse plants as controls. Plants were examined every two days. A colony was judged to be dead when no living mites could be seen in or around the colony. Thirty-two plant species were tested.

Further tests were carried out in the laboratory. For test plants with large leaves, single leaves were placed dorsal-side-down on a large wad of wet cotton wool in a 10-cm diameter plastic dish with 5-cm-deep sides and perforated base. Dishes were placed in a tray of water to keep the cotton wool wet. Controls contained five small gorse spines with their bases pushed into the cotton wool. For plants with small leaves or woody stems, an 8-cm length of shoot was cut, inserted through a small hole in a sponge plastic stopper and into a small 5-cm-tall vial of water. Each shoot survived long enough to support one complete generation of the mite.

Oviposition and survival tests were carried out as follows. Ten mated adult female mites were placed on each leaf or stem. They were immediately trans-

ferred to 15°C for 12–18 h. This caused all mites to aggregate and settle on all test plants. They were then transferred to 20°C for two further days. The number of mites that remained and the number of eggs laid were then counted. It was not possible to distinguish whether absent mites had died or dispersed from test plants. In most cases, few females remained and few eggs were laid. Eggs and any remaining mites were transferred to 23°C and counted again on the 10th day.

Eggs laid during the oviposition test began to hatch on day 9. Surviving larvae were counted on day 10 and then every two days. The age and developmental stage of the longest-surviving mite were recorded. Mites laid very few eggs on some host plants. To test the survival of larvae on these species, a series of egg transfer tests was carried out. Approximately 20 eggs which were about to hatch were transferred onto leaves or shoots at 23°C. The larvae were counted immediately after hatching and their survival was monitored every two days, as described above.

B) Oviposition and survival tests on beans

The survival of *T. lintearius* on three bean species was examined more closely using three methods. Twenty-two varieties of *Phaseolus vulgaris* L. cultivars in experimental or commercial use in New Zealand were tested. Two varieties of *Vicia faba* L. and one of *Glycine max* (L.) Merrill also were used. Three series of tests were carried out using excised leaves, whole plants in a glasshouse, and whole plants in the field.

In the first series of tests, mite colonies were maintained on excised bean leaves on damp cotton wool. The control colonies were maintained on cut gorse shoots in bottles of water by the methods described above, and all treatments were kept at 25°C (±1°C). Ten female *T. lintearius* were placed on each leaf at the beginning of the experiment. The colonies were monitored daily and mite survival recorded. Where possible, four replicates were set up for each bean variety.

In the second series of tests, potted plants in a heated glasshouse were infested between October 1985 and March 1986. The experiment was set up in four phases (as test plants became available), and a new gorse plant was infested at the beginning of each phase to act as a control. Plants were infested by transferring a portion of a *T. lintearius* colony estimated to contain approximately 50 mixed-age mites.

The plants were checked daily and the vigour of the mite colony was subjectively scored 0–7 according to number of mites, as follows:
Score 0, number of mites=0; 1=1–20; 2=21–25; 3=26–50; 4=51–75; 5=76–100; 6=101–500; and 7=500+.

The third series of tests was conducted in the field at Silwood Park, Berkshire. Potted plants were each inoculated with a *T. lintearius* colony esti-

mated to contain approximately 50-mixed age mites. The plants were widely spaced in rows and did not touch each other, so that each plant could be examined with minimum disturbance. Each plant was randomly assigned its position in the row. For the first few days of each test plants were covered with tarpaulin to shelter the mite colonies and so help them to establish themselves on the plants. Three tests were set up between mid-June and mid-September 1986. The plants in all tests were examined every one to two days, and the vigour of the mite colony subjectively scored as in the glasshouse tests.

RESULTS

A) Oviposition and survival tests on a range of plant species

In the establishment tests, *T. lintearius* transferred very easily onto whole plants of both *Ulex europaeus* and *U. minor* Roth. (Table 1), but did not form viable colonies on any of the other 32 plant species tested. Other than *Ulex* spp., colonies survived longest on plants of *Genista hispanica* L. and *Spartium junceum* L., both of which belong to the same legume tribe, Genisteae, as *Ulex* spp. These results indicated that *T. lintearius* could only form colonies on a narrow range of hosts.

Female mites also established well on excised gorse shoots and laid 1.5 eggs female^{-1} day^{-1} (Tables 2 and 3). Females laid so many eggs on gorse during these experiments that hatching larvae destroyed the controls. Female mites were therefore removed from control shoots after only three days.

Adult mites also settled successfully on *Genista hispanica*, *G. tinctoria* L. and *Spartium junceum*, three species which belong to the same tribe as gorse (Table 2). Fewer adults remained on these test plants after three days than on controls, but mites survived for up to ten days and laid many eggs. Other members of the tribe were less acceptable hosts for oviposition. Mites settled successfully on *Carmichaelia enysii* Kirk, although none remained after ten days. Females laid 0.38 eggs female^{-1} day^{-1} on *C. ensyii* compared with 1.5 eggs on gorse plants. Few eggs were laid on the other legume shrubs (Table 3). A high proportion of mites settled successfully on *Lotus pedunculatus* Cav. and *Ononis spinosa*, but laid few eggs. Some mites established on *Medicago sativa* L. and *Vicia sativa* L., but were gone by day 10. Eggs and larvae were present on day 10, which suggests that adults were still laying eggs on *M. sativa* and *V. sativa* as late as day 7. Adult mites settled poorly on leaves of *Phaseolus vulgaris* and did not survive beyond day 10. In the meantime, however, they laid a large number of eggs.

On the following species all mites were dead by day 3 and had not laid eggs: *Carmichaelia astonii* Simpson; *Citrus* sp.; *Convolvulus arvensis* L.; *Fagus sylvatica* L.; *Hordeum murinum* L.; *Lactuca sativa.*; *Olearia* sp.; *Pisum sati-*

TABLE 1

Establishment of *Tetranychus lintearius* colonies transferred onto various species of test plants

	Species	Replicates	Survival of colonies	
			(Days)	(%)
1)	*Ulex europaeus*	20	>30	90
	U. minor	10	>30	100
	Cytisus scoparius	4	3.5	0
	Genista hispanica	5	12.2	0
	G. tinctoria	2	3.5	0
	Lupinus polyphyllus	7	2.6	0
	Spartium junceum	6	11.2	0
2)	*Carmichaelia arborea*	7	4.4	0
	C. compacta	5	2.6	0
	C. corrugata	2	5.5	0
	C. cunninghamii	3	3.7	0
	C. enysii	2	5.0	0
	C. kirkii	1	1.0	0
	C. monroi	2	4.0	0
	C. petriei	4	3.7	0
	Corallospartium crassicaule	2	2.5	0
	Notospartium glabrescens	4	2.1	0
	H. torulosum	3	3.5	0
	Sophora microphylla	2	1.5	0
3)	*Coronilla varia*	1	4.0	0
	Lotus pedunculatus	7	4.4	0
	L. tenuis	2	3.0	0
	Medicago sativa	8	3.6	0
	Trifolium fragiferum	2	0.5	0
	T. hybridum	3	3.5	0
	T. pratense	1	4.0	0
	T. repens	5	1.6	0
4)	*Citrus mitis**	10	9.5	0
	Eucalyptus gunnii	3	1.0	0
	Hebe rakaiensis	3	3.5	0
	*Malus sylvestris** (4 varieties)	18	9.6	0
	Olearia haastii	1	1.0	0
	Solidago sp.	3	3.0	0

*Tests carried out on trees outdoors.

vum L.; and *Sophora prostrata* Buchan. Although all mites were dead by day 3 on *Corallospartium crassicaule* (Hook.) J.B. Armst., *Coronilla varia* L., *Robinia pseudacacia* L. and *Vicia faba*, some eggs were laid. On five other plant species tested, although mites survived past day 3 no eggs were laid; these

TABLE 2

Survival of ten *Tetranychus lintearius* females on various species of test plants in laboratory tests

Species	Mean no. (±SE) Day 3	Remaining Day 10
1) *Ulex europaeus*	8.8±0.4	*
Cytisus scoparius	2.0±1.3	0
Chamaecytisus palmensis	4.6±1.0	0
Genista hispanica	8.8±0.8	8.0±0.6
G. tinctoria	5.4±1.1	5.0±1.1
Lupinus arboreus	0.4±0.2	0
Spartium junceum	3.6±2.2	3.0±2.4
2) *Carmichaelia arborea*	1.3±1.3	0
C. compacta	1.0±1.0	0
C. cunninghamii	2.0±1.1	0
C. enysii	5.3±1.5	0
C. petriei	2.0	0
C. williamsii	0.4±0.4	0
Chordospartium stevensonii	0.7±0.7	0
Notospartium torulosum	0.5±0.4	0
Sophora microphylla	0.7±0.3	0
S. tetraptera	0.4±0.2	0
3) *Clianthus puniceus*	0.3±0.3	0
Colutea arborescens	0.3±0.3	0
Laburnum anagyroides	2.7±1.7	0
Lotus pedunculatus	9.3±1.9	0
Medicago sativa	4.0±1.5	0
Ononis spinosa	9.3±0.9	0
Phaseolus coccinea	5.8±1.0	—
P. vulgaris (A)	3.2±1.1	—
P. vulgaris (B)	4.3±1.6	0
Trifolium pratense	2.0	0
T. repens	2.3±1.3	0
Vicia sativa	5.7±0.3	0
Wistaria sinensis	0.3±0.3	0
4) *Achillea millefolia*	7.7±1.5	0
Actinidia chinensis	3.8±1.6	0.3
Brassica oleracea	0.5	0
Calluna vulgaris	3.5	0
Fragaria×ananassa	1.3±0.6	0
Hebe stricta	4.3±0.3	0
Helianthus annuus	2.5	0
Holcus mollis	4.5	0
Malus sylvestris	5.3±0.9	0
Pinus sylvestris	2.0±1.2	0
Rosa multiflora	0.3±0.3	0
Rubus fruticosus	2.3±0.3	0
Solanum tuberosum	7.0±2.0	0
Vitis vinifera	0.3±0.3	0

*Adults removed after three days to prevent large numbers of larvae killing shoots.
13 other species were tested but all ten mites were gone by Day 3 (see text).

TABLE 3

Oviposition response of ten *Tetranychus lintearius* females and survival of their progeny (beyond one day) on various species of test plants in laboratory tests

Species	Mean oviposition rate*	Larvae surviving	Adults produced
1) *Ulex europaeus*	1.50	X	X
Cytisus scoparius	0.06	0	0
Chamaecytisus palmensis	0.24	0	0
Genista hispanica	1.03	X	X
G. tinctoria	0.68	X	X
Lupinus arboreus	0.32	0	0
Spartium junceum	0.39	X	0
2) *Carmichaelia arborea*	0.16	0	0
C. compacta	0.18	0	0
C. cunninghamii	0.11	X	0
C. enysii	0.38	0	0
C. petriei	0.06	0	0
Corallospartium crassicaule	0.07	0	0
Notospartium torulosum	0.4	0	0
Sophora microphylla	0.04	0	0
S. tetraptera	0.13	0	0
3) *Clianthus puniceus*	0.09	0	0
Colutea arborescens	0.02	0	0
Coronilla varia	0.18	0	0
Laburnum anagyroides	0.22	0	0
Lotus pedunculatus	0.18	0	0
Medicago sativa	0.62	X	0
Ononis spinosa	0.21	0	0
Phaseolus coccinea	—	0	0
P. vulgaris (A)	—	X	0
P. vulgaris (B)	0.38	X	X
Robinia pseudacacia	0.13	0	0
Trifolium pratense	0.19	0	0
T. repens	0.11	0	0
Vicia faba	0.16	0	0
V. sativa	0.18	0	0
Wistaria sinensis	0.06	0	0
4) *Achillea millefolia*	0.10	0	0
Actinidia chinensis	0.18	0	0
Calluna vulgaris	0.15	0	0
Hebe stricta	0.09	0	0
Holcus mollis	0.14	0	0
Malus sylvestris	0.26	0	0
Pinus sylvestris	0.57	0	0
Rosa multiflora	0.04	0	0
Rubus fruticosus	0.12	0	0
Solanum tuberosum	0.08	0	0
Vitis vinifera	0.06	0	0

*eggs per surviving female per day after three days; X indicates affirmative.
14 other species were tested but no eggs were laid (see text).

TABLE 4

Survival of mite larvae hatching from eggs transferred onto a range of test plants

Species	Mean no. of larvae		Est. age, oldest survivor (days)
	Hatched	Surviving 1 day	
1) *Ulex europaeus*	16.7	12.7	<16
Colutea arborescens	7.0	0	<1
Cytisus scoparius	10.0	1.0	4
Spartium junceum	11.0	0	<1
Laburnum anagyroides	10.0	2.0	<1
Wistaria chinensis	9.0	0	<1
Robinia pseudacacia	17.5	0	<1
2) *Carmichaelia arborea*	14.0	0	<1
C. astonii	14.5	0	<1
C. compacta	9.0	1.3	2
C. cunninghamii	10.7	2.7	6
C. petriei	8.5	0	<1
Chordospartium stevensonii	9.7	2.0	4
Notospartium sp.	9.5	2.5	2
Sophora microphylla	11.5	1.5	2
3) *Lotus pedunculatus*	9.0	0	<1
Trifolium repens	10.0	0	<1
Coronilla varia	8.5	1.0	2
Pisum sativum	14.0	3.3	4
Vicia faba	10.5	3.0	2
4) *Achillea millefolia*	10.0	0	<1
Actinidia chinensis	11.0	1.0	2
Brassica oleracea	19.0	8.0	2
Calluna vulgaris	12.0	2.0	2
Hebe stricta	10.0	0	<1
Helianthus annuus	14.3	2.0	2
Holcus mollis	10.0	1.0	2
Hordeum murinum	11.5	1.0	2
Rosa multiflora	9.0	0	<1
Solanum tuberosum	13.0	2.0	2
Vitis vinifera	12.5	1.0	2

species were *Brassica oleracea* L., *Carmichaelia williamsii* Kirk, *Chordospartium stevensonii* Cheesem., *Fragaria*×*ananassa*, and *Helianthus annuus* L.

Eggs laid on gorse stems and spines during these oviposition tests hatched successfully, and completed development after 16 days. Complete development was also achieved on *Genista hispanica* and *G. tinctoria*. A large number of eggs were laid on *Spartium junceum* which hatched successfully, but larvae

could not complete their development feeding on this host. None of the other species in the tribe supported complete development.

Mites did not complete development on any of the New Zealand native legume shrubs. One mite survived for three days on *Carmichaelia cunninghamii* Raoul, but most larvae disappeared after only one or two days.

Mites did not complete development on any of the non-leguminous species tested (Table 3).

Some of the larvae that hatched on *Medicago sativa* survived beyond the first day, but the oldest surviving mite died aged five days while still a larva. Some of the mites that hatched on *Phaseolus vulgaris* survived to become adults and to lay eggs. This is the only species in this experiment outside the Tribe Genisteae on which *T. lintearius* could complete its development. The closely related species *Phaseolus coccineus* L. was not a suitable host.

Well-fed larvae and protonymphs of *T. lintearius* are dark green because of the colour of the gut contents. Well-fed deutonymphs and adults are brick red (Stone, 1986). Mites which fed on *Ulex* spp. and *Genista* spp. took on these colours. On all other plant species, mites appeared pink or rust-brown because the gut was not full of green material. Mites therefore fed poorly on all plants outside the Tribe Genisteae.

Larvae that hatched from eggs transferred onto gorse shoots survived well and completed their development after 16 days (Table 4). Survival on all other plant species tested was poor, and no larvae survived past the sixth day.

B) Oviposition and survival tests on beans

In all the tests on excised leaves the original ten females placed on the leaves laid eggs and, in most cases, these eggs hatched and the progeny survived to produce F1 adults (Table 5). This confirmed the findings of the previous series of tests described above. However, the performance of F1 adults varied greatly depending on the cultivar on which they had been fed. Mites reared on the *P. vulgaris* varieties Carioca, Green Pak, Shibori Cranberry, T. Kintoki and Yates Crop, and the *Vicia faba* varieties Sutton and Collossal, failed to lay eggs in any replicate. Mites reared on the *P. vulgaris* varieties Otebo and Peru 69 laid eggs, but all were infertile. Mites reared on the remainder of test varieties (including *Glycine max*) laid fertile eggs which hatched, but none of the progeny survived beyond the teliochrysalid stage. Only mites that had been fed on gorse were able to complete two generations (Table 5). In the two cases where those mites which fed on gorse did not complete a second generation, the mite population had expanded so much that it was no longer possible to keep them on cut shoots (Table 5). This situation never arose with any of the bean varieties under test. All mites reared in the tests, except those on controls, were pale red and resembled the starved *T. lintearius* described by Stone (1986).

TABLE 5

Oviposition and survival of *Tetranychus lintearius* on excised bean leaves in 1st and 2nd generation

Species/Variety	Tests (n)	No. of tests which produced:				
		1st gen. adults	Eggs, 2nd gen.		Teliochrysalids 2nd gen.	Adults 2nd gen.
			Fertile	Infert.		
Ulex europaeus						
	4	4	4	0	4	2
Phaseolus vulgaris						
A43 Sunred	4	4	2	1	1	0
A57	4	3	2	0	2	0
A154	4	4	4	0	3	0
Carioca	4	3	0	0	0	0
Gt. Northern	4	2	1	1	0	0
Green Pak	4	2	0	0	0	0
GV50	4	2	1	0	0	0
ICA 10103	4	4	1	1	1	0
Mangere Pole	4	3	2	0	2	0
Market Wonder	4	3	2	0	0	0
Otebo	4	2	0	1	0	0
Pinto UI III	4	4	2	1	1	0
Peru 69	4	4	0	1	0	0
Purple King	4	4	4	0	2	0
Sanilac Navy	4	3	3	0	3	0
Shibori Cranberry	4	2	0	0	0	0
T. Kintoki	4	3	0	0	0	0
Top Crop	4	3	2	0	2	0
Uzura Cranberry	4	2	1	0	0	0
Yates Crop	4	2	0	0	0	0
Glycine max						
	4	2	2	0	1	0
Vicia faba						
Sutton	2	1	0	0	0	0
Collossal	3	0	0	0	0	0

In the glasshouse tests, with whole plants, mite colonies on all four gorse plants thrived and survived to the end of the test (143 days) with a score of 7 (Table 6). These colonies were still doing well and expanding when the last colony on the test plants expired. The performance of mites on whole test plants varied with cultivar, but was noticeably poorer than on excised leaves. The longest-surviving mite colonies on plant species other than gorse were on *Glycine max* ($\bar{x}=120\pm16.3$ days; Table 6), but these colonies were not as vigorous as those on gorse and achieved a highest score of 6. All mite colonies on *Phaseolus vulgaris* plants, regardless of variety, died before the end of the test. Colonies of ten of the 22 cultivars tested scored 3 or less, indicating that

TABLE 6

Oviposition and survival of *Tetranychus lintearius* on whole bean plants grown in a glasshouse

Species/Variety	Replicates (n)	Days colony survived ($\bar{x} \pm$ SE)	Highest colony vigour score achieved	No. replicates with highest score
Ulex europaeus				
	4	*	7	4
Phaseolus vulgaris				
A43 Sunred	1	69.0	4	—
A57	6	53.3 ± 9.3	4	3
A154	1	> 4.0	3	—
Carioca	5	36.8 ± 6.8	5	1
Gt. Northern	2	57.5 ± 12.4	4	1
Green Pak	3	55.3 ± 15.9	5	1
GV50	5	86.6 ± 10.4	6	3
ICA10103	2	53.5 ± 8.1	3	1
Mangere Pole	2	46.0 ± 2.1	4	1
Market Wonder	1	40.0	3	—
Masterpiece	2	40.0 ± 7.1	3	2
Otebo	3	39.3 ± 8.3	3	1
Peru 69	1	73.0	3	—
Pinto IU III	1	76.0	3	—
Purple King	1	52.0	3	—
Royal Burgundy	3	49.7 ± 5.4	4	1
Sanilac Navy	3	33.0 ± 5.0	3	2
Shibori Cranberry	3	54.7 ± 9.2	4	2
Top Crop	4	59.8 ± 7.9	5	1
T. Kintoki	2	70.5 ± 7.4	5	2
Uzura Cranberry	2	64.5 ± 4.6	3	1
Yates Crop	3	36.3 ± 7.1	5	1
Glycine max				
	2	120.0 ± 16.3	6	2

*Colonies raised on *U. europaeus* plants survived to the end of all tests (max. time 143 days).

these colonies did not increase in size at any time during the test. Colonies on six of the cultivars tested achieved a highest score of 4, indicating a slight initial expansion of the colonies before they declined. This slight increase in colony size is probably due to the mites having fed on gorse prior to the test. Mite colonies on five cultivars (Carioca, Green Pak, Top Crop, T. Kintoki and Yates Crop) managed, in some replicates, to grow to twice the size of the initial colony before declining. Only on one cultivar, GV50, did mite colonies grow to more than twice the initial colony size before declining. GV50 was also the cultivar that managed to sustain mite colonies for the longest period ($\bar{x} = 86.6 \pm 10.4$ days; Table 6). Fifteen of the remaining 21 cultivars tested failed to sustain mite colonies for longer than 60 days. *Tetranychus lintearius* reared on all cultivars of *P. vulgaris* and *G. max* in this test were pale red in

colour, indicating that they were poorly nourished. Adults and deutonymphs reared on gorse were the typical dark-red colour of healthy mites.

The survival of *T. lintearius* colonies on beans grown outdoors was noticeably shorter than on beans grown in the glasshouse (Table 7). The longest mean survival time for a *T. lintearius* colony was 14 days on Shibori Cranberry. The only cultivars on which colonies survived for more than 20 days were the *Phaseolus vulgaris* varieties Top Crop (one replicate out of ten), GV50 (one replicate out of eleven), Shibori Cranberry (two replicates out of five), Otebo (one replicate out of two), and Gorse (eight replicates out of eight). Mean colony survival time on *Glycine max* was very short (six days). *Tetranychus lintearius* survived on all the gorse control plants for the complete duration of each test. Two gorse plants from the first test were left in the field to determine how long the colonies could survive on potted gorse plants

TABLE 7

Oviposition and survival of *Tetranychus lintearius* on whole bean plants kept outdoors (summary of three consecutive tests)

Species/Variety	Replicates (n)	Days colony survived ($\bar{x} \pm SE$)
Ulex europaeus		
	8	*
Phaseolus vulgaris		
A43 Sunred	10	8.1±1.3
A57	5	6.2±1.7
A154 Pink	8	7.0±1.4
Brown Lentil	2	4.0±0.0
Carioca	8	10.3±2.1
Gt. Northern	2	9.0±1.4
Green Pak	7	10.0±1.6
GV50	11	10.6±2.2
ICA 10103	5	9.4±2.7
Market Wonder	3	11.0±3.3
Otebo	2	12.0±6.4
Peru 69	1	2.0±0.0
Pinto IU III	5	8.6±1.9
Red Lentil	2	4.0±0.0
Sanilac Navy	7	6.3±0.9
Shibori Cranberry	5	14.0±3.0
Top Crop	10	7.7±1.9
T. Kintoki	4	10.3±1.3
Uzura Cranberry	7	8.4±2.6
Yates Crop	5	4.8±1.2
Glycine max		
	4	6.0±3.2

*Colonies raised on *U. europaeus* plants survived to the end of all tests (i.e. 25–26 days, max. time 105 days).

in the field. These colonies continued for 100 and 105 days until the plants had deteriorated to the stage where they could no longer support mite colonies.

In almost all tests carried out, the *T. lintearius* colonies did not expand. The exceptions were all the gorse plants used and one Carioca plant in Test 1.

Very little webbing was produced by the mite colonies on any of the bean plants tested. Normal webs were formed on the gorse control plants.

DISCUSSION

The best-known tetranychid mites, such as *Tetranychus urticae* Koch and *T. turkestani* Ugarov and Nikolski, are serious pests of a wide range of crops throughout the world. It is less well known that a large number of species within this family can feed on only one or two host plant species (Hill and Stone , 1985); *T. lintearius* is one of these.

The results presented here showed that *T. lintearius* colonies were easily transferred from one gorse plant to another but that mites chose to emigrate from unacceptable plants rather than to settle and form a colony. When confined on various host plants, *T. lintearius* adults survived badly and laid fewer eggs on test plants than on gorse. In most cases, hatching larvae died without feeding. None of the non-leguminous species tested was a suitable host for the mite. Even apple and strawberry, which are susceptible to attack by closely related tetranychid mites such as *T. urticae*, were unsatisfactory.

It is widely accepted that starvation tests can overestimate the true host-range of a phytophagous species (Dunn, 1976). This was clearly shown in these experiments. Mites could be reared from egg to adult on *G. hispanica* and *G. tinctoria* under laboratory conditions, but colonies transferred to these species in outdoor tests did not establish. Clearly, the laboratory tests did not measure all of the host-selection mechanisms used by the mite under field conditions.

Apart from *Ulex* spp. and *Genista* spp., *T. lintearius* completed its development only on dwarf bean, *P. vulgaris*, and *Glycine max*. The ability of *P. vulgaris* to support the development of many species of tetranychid mites in the laboratory is well known. It is often used as a surrogate host to temporarily maintain cultures of host-specific mites when the true host plant is not available (W. Helle, personal communication, 1984).

Our initial findings, that *T. lintearius* could survive to maturity and produce fertile eggs when reared on excised leaves of *P. vulgaris* and *G. max*, were confirmed by the more detailed study using a range of New Zealand cultivars. However, none of these cultivars was able to support mite development for more than one generation. No second-generation adults were produced in any of the tests. It may be, therefore, that survival for one generation on excised bean leaves may be only a residual effect of feeding on gorse by the mites used to inoculate the tests prior to the experiment.

When transferred to potted bean and soybean plants in a glasshouse, *T. lintearius* formed colonies successfully only on soybean. Performance on *P. vulgaris* varied greatly between cultivars but, in general, the numbers of surviving mites slowly dwindled and no viable colonies were formed. In the field, under less-favourable conditions, mites performed much worse on all bean plants, particularly on soybeans. Under field conditions, mite colonies have greater opportunities for dispersal and are less sheltered from the weather than in a glasshouse. *Tetranychus lintearius* webbing is less dense on *P. vulgaris* than on gorse, so perhaps the mites are less able to protect themselves from adverse weather when not on their natural host. Mites on beans were very pale, which suggests that they were unable to feed satisfactorily. Together, these experiments strongly suggest that, despite the ability of *T. lintearius* to complete its life-cycle on excised bean leaves under laboratory conditions, it poses no threat to commercial crops of either *P. vulgaris* or *G. max*.

It is interesting to note that, under laboratory conditions, *T. lintearius* performed better on species that have been domesticated than on naturally occurring plants. Perhaps heavy selection for agronomic characteristics has removed some of the negative cues used for host selection by *T. lintearius*.

Further evidence of the host specificity of *T. lintearius* comes from the literature. Despite a long history of entomology and crop-protection records in Europe (including bean and soybean crops), and the striking appearance of mite colonies, *T. lintearius* has never been recorded from any plant other than gorse (D. MacFarlane, CABI Institute of Entomology, personal communication, 1984).

Stone (1986) and Hill and O'Donnell (1991) have shown that *T. lintearius* is a distinct, recognisable species which is reproductively isolated from its closest relatives within the Tetranychidae. This study has used accepted methodology (Wapshere, 1974) to show that *T. lintearius* has a very narrow host range, and in the field is almost certainly restricted to *Ulex* spp. In fact, the host range determined under laboratory conditions is narrower than that of some insects which have been successfully and safely used for biological control of weeds in the past. On the basis of the host-range tests reported here, *T. lintearius* is safe to introduce into New Zealand as a biological control agent.

Since completion of this study, *T. lintearius* has been released widely in New Zealand for the biological control of *U. europaeus* (Hill et al., 1989).

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APPENDIX 1

Plant species tested, and number of replicates conducted in each test (—, not tested)

	Family or Tribe	Replicates (*n*) Establishment tests	Oviposition + survival tests	Egg transfer tests
1) Genisteae				
Ulex europaeus	Genisteae	20	19	3
U. minor		10	—	—
Cytisus scoparius		4	5	4
Chamaecytisus palmensis		—	5	—
Genista hispanica		5	4	—
G. tinctoria		2	5	—
Lupinus arboreus		—	5	—
L. polyphyllus		7	—	—
Spartium junceum		6	5	1
Laburnum anagyroides		—	3	1
2) Legumes native to New Zealand				
Carmichaelia arborea	Carmichaelieae	7	3	2
C. astonii		—	2	2
C. compacta		5	5	3
C. corrugata		2	—	3
C. cunninghamii		3	5	—
C. enysii		2	3	—
C. kirkii		1	—	—
C. monroi		2	—	—
C. petriei		3	2	2
C. williamsii		—	5	—
Chordospartium stevensonii		—	3	3
Corallospartium crassicaule		2	1	—
Notospartium glabrescens		4	—	—
N. torulosum		3	8	—
Notospartium sp.		2	—	4
Clianthus puniceus	Galegeae	—	10	—
Sophora microphylla	Sophoreae	2	3	2
S. tetraptera		—	5	—
S. prostrata		—	5	—
3) Economic and other legumes				
Colutea arborescens	Galegeae	—	3	1
Coronilla varia	Hedysareae	1	3	2
Lotus pedunculatus	Loteae	7	3	1
L. tenuis	Loteae	2	—	—
Medicago sativa	Trifolieae	8	4	—

APPENDIX 1 (continued)

	Replicates (n)			
	Family or Tribe	Establishment tests	Oviposition + survival tests	Egg transfer tests
Ononis spinosa	Trifolieae	—	3	—
Phaseolus coccinea	Phaseoleae	—	5	—
P. vulgaris	Phaseoleae	—	11	—
Pisum sativum	Vicieae	—	3	3
Robinia pseudacacia	Robinieae	—	3	2
Trifolium fragiferum	Trifolieae	2	—	—
T. hybridum		3	—	—
T. pratense		1	2	—
T. repens		5	4	2
Vicia faba	Vicieae	—	3	—
V. sativa		—	3	2
Wistaria sinensis	Tephrosieae	—	3	2
4) Other plant species				
Achillea millefolia	Compositae	—	3	1
Actinidia chinensis	Actinidiaceae	—	5	3
Brassica oleraceae	Brassicaceae	—	2	1
Calluna vulgaris	Ericaceae	—	2	1
Citrus mitis	Rutaceae	10	3	—
Convolvulus arvensis	Convolvulaceae	—	3	—
Eucalyptus gunnii	Myrtaceae	3	—	—
Fagus sylvatica	Fagaceae	—	3	—
Fragaria×ananassa	Rosaceae	—	6	—
Hebe rakaiensis	Scrophulariaceae	3	—	—
H. stricta	Scrophulariaceae	—	3	2
Helianthus annuus	Compositae	—	2	3
Holcus mollis	Gramineae	—	2	1
Hordeum murinum	Gramineae	—	3	2
Lactuca sativa	Compositae	—	3	—
Malus sylvestris	Rosaceae	18	3	—
Olearia haastii	Compositae	1	1	—
Pinus sylvestris	Pinaceae	—	3	—
Rosa multiflora	Rosaceae	—	3	2
Rubus fruticosus	Rosaceae	—	3	—
Solanum tuberosum	Solanaceae	—	3	1
Solidago sp.	Compositae	3	—	—
Vitis vinifera	Vitaceae	—	3	2

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