ESTABLISHMENT OF THE LEAF-MINING MOTH, *DIALECTICA SCALARIELLA*, ON PATERSON'S CURSE IN WESTERN AUSTRALIA

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Summary. After being released at 220 sites in Western Australia between May and August 1989, *D. scalariella* had established at 35% of sites when surveyed in October 1989. Low temperatures and grazing by sheep appeared to be major causes of failure to persist in winter. Little or no spread occurred from these sites, although an earlier experimental release resulted in 30 km spread within 8 months. Because of the virtual absence of live host plant material during summer over most of the weed's range in W.A., *D. scalariella* - apparently a non-aestivating species - is not expected to persist widely. Other agents, capable of aestivation, offer better prospects for controlling Paterson's curse in W.A.

INTRODUCTION

Paterson's curse, *Echium plantagineum*, is a widespread, long-established weed of pastures and roadsides in W.A. In many parts of its distribution in W.A. it is a declared plant (noxious weed) against which landholders are obliged to conduct eradication, control or containment measures, which must be repeated annually because of the persistent seed bank produced by this weed. It is not regarded highly as a pasture plant, particularly in view of its toxicity (7), and its significance as a nectar source is less than in other States. The benefit:cost ratio for the biological control of Paterson's curse in W.A. was calculated to be 3.5:1 (6). This paper reports the progress of the leaf-mining moth, *Dialectica scalariella* (9), the first agent to be released in W.A. for the biological control of this weed (4).

METHODS

A breeding colony of *D. scalariella* was obtained in early September 1988 from the Department of Conservation, Forests and Lands, Victoria. The colony was derived from a population collected from Italian bugloss, *E. italicum*, in southern France. After breeding the moths on Paterson's curse in the South Perth insectary for several weeks at 25°C (4), there were sufficient infested plants and newly-emerged adults available for release. Eight experimental release sites, four of which received irrigation, were established between October and December 1988 to allow monitoring of the progress of the moth during summer. The total number of moths released at each site varied between 300 and c.3700 (4). The sites were visited at least monthly to monitor the progress and spread of *D. scalariella*. At Jane Brook, in the Swan Valley 20 km NE of Perth, spread was measured along eight radii running N, NE, E, etc. from the site, by sampling Paterson's curse plants at 500 m intervals from the point of release.

Results from the experimental releases (4) were sufficiently encouraging to justify a full-scale release programme. Between May and August 1989, newly-emerged moths were released on Paterson's curse infestations throughout the south-west of W.A. Nearly all releases were made by staff of the Agriculture Protection Board of W.A. (APB) who had been requested to select sites, such as seepage areas, drainage lines and around dams, that were judged to be most favourable for the survival of Paterson's curse over summer. Single releases of 300 or 600 moths were made at most sites, although larger quantities were released at some sites and additional releases were made at others. A detailed survey of sites was conducted by APB staff in early October 1989 to enable documentation of the extent of establishment and spread of *D. scalariella* and the amount of damage caused to Paterson's curse during winter and spring. Site characteristics and the type of land use and disturbance occurring since release were also recorded. A second survey in late March 1990 recorded the survival of both Paterson's curse and *D. scalariella* over summer (results not presented).

RESULTS AND DISCUSSION

The performance of *D. scalariella* at the experimental sites varied considerably (4). By late January 1989, the moth had established at five of the eight sites. The most successful was Jane Brook, where a total of 60 infested plants and 790 moths (the equivalent of 2300 to 3700 moths) were released on seven occasions between 4 October and 1 December, 1988 (4). Irrigation of this site began in late December and immediately caused a massive germination of Paterson's curse. The seedlings grew rapidly and soon supported a large population of *D. scalariella*. The moth spread beyond the irrigated area to rosettes derived from spring germinations that grew in firebreaks, road verges and horse paddocks. The moth had spread up to 1.6 km by late January 1989. Occasional heavy rain which began in February resulted in widespread germination of Paterson's curse throughout the Swan Valley, enabling *D. scalariella* to spread further. By late April, plants at the release site were heavily damaged and numerous moths were visible. In mid May, newly infested plants were found 12 km N and 7 km W of the release site, indicating that *D. scalariella* had spread over c.70 km^2 (4). The greatest amount of spread from Jane Brook was recorded in late June 1989 when newly infested plants were found in the Avon Valley, 30 km NE of the site. At the four other sites where establishment occurred, the amount of spread during the corresponding period varied from 0 to 300 m (4).

The explosive spread at Jane Brook is attributed to the combination of the large number of moths released, the abundance of Paterson's curse at the site and adjoining areas, both at the time of release and during the following summer, and the high temperatures which enabled the moth to breed rapidly (9). At two other sites where *D. scalariella* established, there were very few live Paterson's curse plants, while at another site, the few rosettes were destroyed by sheep during February. The most southerly site, Donnybrook, experienced much cooler summer weather which would have limited the moth's population growth.

The moth's potential to spread from Jane Brook was limited by the virtual absence of Paterson's curse in adjoining areas with different soil types, topography and land use. The distances spread by *D. scalariella* within the Swan Valley are equivalent to those reported for New South Wales and Victoria (3, 5, 8) although the spread of 30 km to the Avon Valley is greater than most, but is comparable to the 25 km by which the moth spread in the year following its release on Viper's bugloss, *E. vulgare*, at Cooma, N.S.W. (E.S. Delfosse, pers. comm. 1990).

Between May and August 1989, 145,000 moths were released at 220 sites in 50 shires throughout the south-west of W.A. Although the number of sites treated is greater than in other States, fewer moths were released at most sites (300-600 per site in W.A. cf. 2000 for N.S.W. and 40,000 for each of two CSIRO sites). A further difference in methodology is that adult moths were released in W.A., whereas infested leaves or whole plants were placed in the field in N.S.W. (3, 5, 8; R.C.H. Shepherd, pers. comm. 1989; D.C Hopkins, pers. comm. 1989; E.S. Delfosse, pers. comm. 1989). By October 1989, evidence of *D. scalariella* was found at 35% of the 186 release sites surveyed in W.A. The amount of damage caused to Paterson's curse was generally limited to a few mined leaves on a small proportion of plants within the stand. Little or no spread was reported for most sites (Table 1).

The limited amount of spread reflects the short time between the release and survey dates and the lack of substantial population growth during winter and early spring. Two thirds of the sites with establishment were ungrazed. When grazed heavily by sheep, Paterson's curse leaves did not persist long enough to enable any enclosed larvae to complete their development (Dodd, unpublished), especially as rates of development were slowed by the low seasonal temperatures (9). Of the 13 establishment sites exposed to sheep, 12 experienced only light grazing.

Table 1. Spread from established *D. scalariella* sites in W.A., October 1989.

Distance spread (m)	Sites (n)	(%)
0	18	28
≤20	23	36
50	8	12
100	7	11
>400	1	1.5
'a few metres'	2	3
'could not tell'	6	9

Below-average minimum air temperatures, often with frosts, might have contributed to the failure of *D. scalariella* to establish at many sites. Between June and August 1989, many of the areas where releases were being made had mean minimum temperatures >1°C below average (1) and received four episodes of 10 to 14 days with minimum temperatures <2°C which were conducive to frost (Table 2). Only 15% of the releases made in June and 32% of those in July resulted in establishment (Table 2). Many of the unsuccessful June releases experienced >20 frost-prone nights before the October survey (Table 2). Even so, moths survived in several areas that experienced these cold conditions.

Table 2. Fate of *D. scalariella* in relation to month of release and duration of cold periods.

Month of release	Cold period		Established		Failed	
	Dates	Frost-prone nights[a]	n	(%)[b]	n	(%)
June	16-29	7	10	(15)	56	(85)
July	4-18	5	12	(32)	26	(68)
August	2-16, 21-31	8	26	(79)	7	(21)

[a] Minimum temperature <2°C.

[b] Percentage of monthly total.

The rate of establishment in W.A. was much lower than in N.S.W. (3, 5, 8) where most releases took place in spring and early summer, when seasonal conditions were more favourable for the survival and reproduction of the moth and provided a continuity of Paterson's curse at most sites (3). In the main parts of its distribution in W.A., Paterson's curse plants do not survive through summer, because of the severe seasonal drought characteristic of the extreme Mediterranean-type climate of the State's south-west: by November, most Paterson's curse is either dead or leafless and moribund, while new seedlings capable of surviving to the break-of-season do not usually emerge until early autumn. Consequently, *D. scalariella* could only be released extensively in W.A. in autumn and winter, but then faced the loss of its host plant in summer. The persistence of *D. scalariella* in W.A. is likely to be limited to those exceptional sites where live Paterson's curse is available year-round, such as the Swan Valley.

To be effective under W.A. conditions, biological control agents for Paterson's curse - and other winter annual weeds - should possess mechanisms for surviving summer, when there are no live host plants available. Since most of the other agents being considered for Paterson's curse possess some form of aestivation (2), they offer greater potential to exert effective control of this weed in W.A.

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