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BIOLOGICAL CONTROL OF ALLIGATOR WEED: UNSUCCESSFUL ATTEMPTS TO CONTROL TERRESTRIAL GROWTH USING THE FLEA BEETLE *DISONYCHA ARGENTINENSIS* [*COL.: CHRYSOMELIDAE*]

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Biological control of alligator weed growing in aquatic habitats in Australia is successful but the agents, a flea beetle *Agasicles hygrophila* and a moth *Vogtia malloi,* do not control terrestrial growth. Consequently another flea beetle *Disonycha argentinensis* was introduced into Australia specifically to control the terrestrial growth. Progeny of adults collected in Brazil from areas similar in climate and habitat to areas infested with alligator weed in Australia, were released but failed to become established. Eggs were laid by females released into a large field cage and some completed development, but the new adults failed to reproduce.

Tentative conclusions are that microclimate or predation may have prevented establishment of *D. argentinensis* but the results should not preclude attempts to establish this insect in North America, China or elsewhere.

KEY-WORDS: *Disonycha argentinensis,* alligator weed, terrestrial growth, biological control.

Alligator weed, *Alternanthera philoxeroides* (Martius) Grisebach (*Amaranthaceae*), grows in habitats ranging from mesophytic terrestrial to aquatic in its native range, South America (**Vogt** *et al.*, 1979). It has invaded a similar range of exotic habitats in USA, Australia, China and New Zealand, where it is considered an important weed.

The importance of *A. philoxeroides* results from excessive aquatic growth which covers waterways and affects navigation, prevents access, disrupts flow and adversely affects the aquatic fauna and flora (**Julien & Broadhent,** 1980; **Spencer & Coulson,** 1976). On land, alligator weed invades and competes with pastures and provides a source for its further spread (**Julien & Bourne,** 1988). Spread of this weed is especially important in Australia where we believe its current distribution is a fraction of its potential distribution. There it is known to be spreading particularly from terrestrial infestations in turf and soil and on machinery (**Julien & Bourne,** 1988).

Although cattle graze alligator weed in Australia it is not considered a desirable pasture species and recent studies indicate that pasture grasses and clovers are being competitively displaced by the weed (**Julien & Bourne,** 1988). In addition farmers have supplemented their incomes by selling pasture grasses for turf. This is no longer legal since legislation restricts transportation of produce or soil infested with alligator weed (**Anon,** 1988).

Biological control of alligator weed was achieved in Australia when the aquatic flea beetle *Agasicles hygrophila* Selman and Vogt (*Col.* : *Chrysomelidae*) and the moth, *Vogtia malloi* Pastrana (*Lep.* : *Pyralidae*), were released in 1976 and 1977 respectively (**Julien**, 1981). Most damage to the weed was caused by the flea beetle but it was unable to survive in terrestrial infestations. Although the moth attacks the weed where it grows on land it has no significant effect (**Julien**, unpubl. data).

The flea beetle *Disonycha argentinensis* Jacoby (*Col.* : *Chrysomelidae*) was first recognised as a potential biological control agent for alligator weed by **Vogt** *et al.* (1979). They considered that this flea beetle might complement the biological control of aquatic alligator weed achieved by *A. hygrophila* and *V. malloi* by attacking terrestrial growth of the need. However, *D. argentinensis* was not liberated in USA due in part to objections raised by cattle graziers and the Louisiana Fish and Game Commission (**G. B. Vogt**, pers. comm. 1984).

Disonycha argentinensis was introduced into and subsequently released on alligator weed in Australia (**Julien**, 1981 ; **Sands** *et al.*, 1982). Descriptions of this insect were presented in **Jacoby** (1901) and **Blake** (1955), illustrations and morphological comparisons with related species in **Vogt** *et al.* (1979), and biology, host range studies and results of host specificity tests in **Cordo** *et al.* (1984) and **Sands** *et al.* (1982).

This paper describes the releases of *D. argentinensis* and discusses its failure to become established in the field.

BRAZILIAN COLLECTION SITES

In 1979 collections of *D. argentinensis* were made in southern and eastern Brazil, where it attacks terrestrial alligator weed (**I. W. Forno**, pers. comm. 1989), and sent to Australia.

Host-specificity and biology studies (**Sands** *et al.*, 1982) were conducted using a colony of *D. argentinensis* originating from Maruim, near Salvador, Brazil (lat. 10°44′, long. 37°06′). The collection site was a flat area with high water table in a warm coastal region of eastern Brasil. There, alligator weed grew around natural swampy lagoons and was flooded annually (**I. W. Forno**, pers. comm. 1989).

Disonycha argentinensis was also collected at Curitiba (lat. 25°25′, long. 49°16′) and Taim, near Porto Alegre (lat. 32°29′, long. 52°32′) in Brazil. The collection sites at Curitiba were suburban vacant lots and roadsides. These areas were 900 m ASL, never flooded, often dry and severely frosted in winter. At Taim, in a low, flat coastal area of southern Brazil, a drainage canal had been cut in a natural waterway and alligator weed grew on the canal banks above the water level but was subject to flooding and to frosts that killed the erect stems and leaves (**I. W. Forno**, pers. comm. 1989). Checks were made to ensure that the host-specificities of these colonies were not different to that of the Maruim colony (**D. P. A. Sands**, pers. comm. 1989).

RELEASES IN AUSTRALIA

Field releases were made during the period from February 1980 to December 1981, in a range of habitats and using varying numbers of adults (table 1). Only progeny of the originally introduced adults were released into the field. Mass rearing was carried out using potted alligator weed collected from the release areas.

A comparison of general climatic features indicated that of the 3 collection sites in Brazil, Taim was most similar to Parramatta, near Sydney, and to Newcastle areas were

D. argentinensis was to be released in Australia (table 2). Consequently most releases were of progeny of the Taim colony on the assumption that individuals from that colony would be better adapted to Australian conditions. Conversely, it was decided that the Curitiba colony was probably not well adapted to environmental conditions at the release areas in Australia where winter conditions were less severe than in Curitiba, and the entire colony, 179 adults and an unknown number of larvae, was released in early 1981 (table 1).

TABLE 1

Sites in Australia where D. argentinensis *was released, number of releases per site and number of adults from each colony, Taim (T), Maruim (M) and Curitiba (C), that were released, 1980-81*

Site		Number of releases	Total number of adults released T	M	C
Sydney area					
Duck River	steam bank[b]	5	300	1,250	
Haslams Creek	damp pasture[a]	1	750		
Moorebank	swampy river bank[a]	6	2,546	500	
Chipping Norton	river bank[a]	4	400	586	
Casula	swampy river bank[c]	1	700		
Newcastle area					
Williamtown	swampy river bank[c]	1	500		
	ungrazed pasture[a]	9	2,058	800	
	pasture drain[a]	4	112	326	179*
	road drain[a]	3	400	317	
	swampy pasture[a]	1	1,100		
	treed drain bank[a,c]	5	150	800	
	road side flats[a]	1	900		
Salt Ash	pasture[b]	1	300		
Tomago	treed pasture[b]	1	600		
Shortland	swamp[a]	1	500		
Raymond Terrace	treed swamp[a]	2	200	400	
Totals		46	11,516	4,979	179*

[a] Open, no trees, no canopy above the alligator weed.
[b] Open treed area.
[c] Filtered sunlight through tree canopy.
* An unknown number, hundreds, of larvae of the Curitiba colony were released in addition to the 179 adults.

Sixteen release sites were chosen to provide as wide a variety of habitats as possible; stream banks, swamps and pastures, with and without tree canopies (table 1). A total of 16,674 adults were released in the open, 11,516 from the Taim, 4,979 from the Maruim and 179 from the Curitiba colonies. The numbers per release ranged from 16 to 1,100 (mean 372) with 27 of the 46 releases having 300 or more adults. All releases were made during the months October to March, that is, during spring and summer. At 8 sites, 2 to 8 successive releases were made (table 1) in case seasonal factors affected establishment.

Release sites were inspected at intervals of 1 or 2 months for feeding damage and presence of larvae and adults. Adults were recovered 1 month after release on several occasions at Oakfield Road, Williamtown, but not at other sites. Inspections of the sites continued until May 1983 but no evidence of establishment by *D. argentinensis* was found.

TABLE 2

Altitude, mean temperatures and annual rainfall for meteorological locations nearest sites in South America where D. argentinensis *was collected or known to overwinter and nearest release sites in Australia*

	South America*					Australia**	
	Porto Alegre (Taim)	Salvador (Maruim)	Aracaju (Maruim)	Curitiba	Buenos Aires	Parramatta (Sydney area)	Newcastle
Climate type***	humid subtrop.	humid equatorial	humid equatorial	low tierra fria	marine subtrop.	subtrop. pampean	marine subtrop.
Latitude	30°02′	13°00′	10°54′	25°25′	34°35′	33°49′	32°35′
Altitude (m)	10	47	4	908	25	52	34
Mean temperatures (°C)							
annual	19.5	25.3	26.1	16.5	16.4	17.2	17.9
coldest month	14.2	23.4	—	—	9.4	10.9	12.6
hottest month	25.0	26.7	—	—	23.4	22.7	23.0
Annual rainfall (mm)	1,247	2,076	945	1,397	962	883	1,042

* Anon — 1958.
** Anon — 1956.
*** Papadakis, J. — 1975.

When, after earlier releases, no evidence was found of breeding or survival in the field, it was postulated that adults might have dispersed too widely to develop founder populations. In attempts to prevent this, and also permit assessment of breeding and survival, additional releases were made into field cages.

Two sizes of cages were used. Small cages were dome-shaped and comprised 2 rods of cane bent so that the centres crossed 1 m above ground and the ends were inserted in the ground at the corners of a 1 m square and were covered in fine nylon gauze cloth buried around the edges. A large 2 m cube, metal-framed, walk-in cage, covered with nylon gauze was held in place with metal pegs and wire braces. The gauze was buried around the periphery. All cages were placed over alligator weed growing in a pasture at Williamtown.

Twenty pairs of Taim adults were placed into each of 2 small cages and 20 pairs of Maruim adults were placed into another 2 small cages in January 1981. The cages were carefully checked but no adults were observed after 2 months and no evidence of breeding was found during the following 11 months.

In October 1981, 500 Taim adults were released into the large, walk-in cage. On 5 occasions during the following 10 months adults and larvae were counted during a 20 minute period of search and an assessment of leaf damage was made. Leaf damage was always present when adults were found until June but the number of leaves chewed and the level of damage was always low. Immature stages were never found and the numbers of adults increased from December to March and then declined (fig. 1) and no evidence of survival was found over the following 12 months. Maximum and minimum temperatures for the periods between observation dates were recorded inside and outside the cage 0.5 m above the alligator weed. Average temperatures inside and outside the cage were within 1 °C and ranged from 15.8 °C to 23.5 °C. The highest maximums were 42 °C outside and 40 °C inside the cage; the lowest minimum was − 2 °C inside and outside. Frosts killed alligator weed stems in the paddock but not in the cage. Flooding to a depth of 15 cm occurred in September but alligator weed stems and a mound of soil, litter and alligator weed inside the cage remained above water level.

DISCUSSION

Populations of *D. argentinensis* were low in the field in Argentina and were able to overwinter at Buenos Aires (**Cordo** *et al.*, 1984). Populations were also low in Brazil and were thought to overwinter at the sites of collection (**I. W. Forno,** pers. comm. 1989). Comparing climates for Buenos Aires and the Brazilian sites with Parramatta and Newcastle (table 1), macroclimate should not have limited survival of the beetle in Australia.

Most areas infested with alligator weed in Australia were subjected to inundation by flood waters, sometimes several times each year. Similar flooding also occurred at the Taim and Maruim collection sites in Brazil and such occurrences could be expected to reduce populations of this beetle since oviposition and pupation occur in litter or soil. However, while flooding occurred within months after releases at some of the sites, none occurred within 10 months of releases at others. In addition, multiple releases were made at sites that flooded and at drier sites, yet no indications of survival or breeding were found.

Observations in the large field cage suggest that some of the females released in October laid eggs that developed to adults after about 52 days (December 9) and that new adults continued to develop until early March (fig. 1). The duration of a generation at 23 to 26 °C was about 49 days in the laboratory (**Cordo** *et al.*, 1979). These researchers also found that adults lived on average 147 days, the maximum being 306 days. The latter duration was

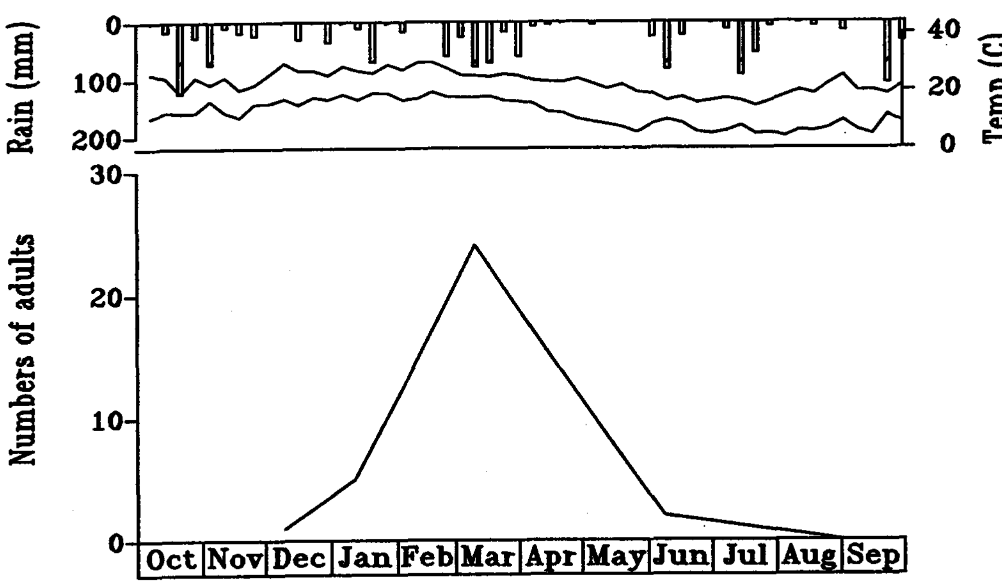

Fig. 1. Numbers of adults of *D. argentinensis* found in a large field cage after 500 adults were released in October 1981 and the weekly mean maximum and minimum temperatures and daily rainfall for the nearest meteorological station (Williamtown Aero).

greater than the length of time that adults were observed in the cage, but the increasing numbers from December to March (fig. 1) suggests the emergence of a new generation which, thereafter, failed to survive.

In October 1981, 250 adults from the Taim colony were exported to DSIR, New Zealand and progeny of these were first released in February 1982. Despite releases into field cages and over 15,000 beetles released at 15 other field sites establishment did not occur (**Roberts** *et al.*, 1983).

It is difficult to understand why this insect failed to establish in either country. We can only tentatively conclude that microclimate was unsatisfactory or that predation prevented establishment. *Agasicles hygrophila*, the closest extrageneric relative of *D. argentinensis* (**Vogt** *et al.*, 1979), can be found in terrestrial areas of Australia in very low numbers because small, ineffective populations persist in adjacent drains and swamps. These 2 species of Chrysomelidae are very similar except that *A. hygrophila* lays eggs on leaves and pupates inside the hollow stem of alligator weed growing in aquatic habitats, while *D. argentinensis* lays eggs and pupates in litter or soil. Consequently, for *D. argentinensis*, eggs and pupae may be susceptible to desiccation and predation. We found that control of humidity was important in successful rearing in the laboratory. Predators of eggs and pupae of these beetles are not known although spiders and reduvid bugs prey on larvae and adults of *A. hygrophila* (**Julien & Chan**, unpubl. data). Two predator-ectoparasites (Carabidae : Lebiinae) were noted attacking *D. argentinensis* in South America by **Vogt** *et al.* (1979), *Lebia securigera* Chaudoir and *L. concinna* Brulle, but neither of these species occurs in Australia.

Relatively minor environmental differences may affect establishment success, so our results should not preclude any attempt to establish *D. argentinensis* in North America, China or elsewhere. However, a biological solution to the control of terrestrial alligator weed is still urgently required for Australia.

RÉSUMÉ

Essais infructueux de lutte biologique contre *Alternanthera philoxeroides* à l'aide de la chrysomèle *Disonycha argentinensis* en milieu terrestre

En Australie, la lutte biologique contre *Alternanthera philoxeroides*, mauvaise herbe se développant en milieu aquatique, a été couronnée de succès mais les auxiliaires utilisés, un Coléoptère *Agasicles hygrophila* et un Lépidoptère *Vogtia malloi* sont inefficaces en milieu terrestre.

Un autre Coléoptère, *Disonycha argentinensis*, fut donc introduit en Australie pour lutter contre le développement de cette mauvaise herbe en milieu terrestre. Les descendants des adultes récoltés au Brésil dans des zones similaires par le climat et le biotope à celles où croît la mauvaise herbe en Australie ont été relâchés mais ne se sont pas installés. Des œufs furent pondus par des femelles lâchées dans une grande cage sur le terrain et des adultes ont ainsi été obtenus, mais ceux-ci ne se reproduisirent pas.

Cet échec peut s'expliquer par le microclimat ou la prédation qui auraient empêché l'installation de *Disonycha argentinensis*. Cependant ces résultats ne devraient pas empêcher des essais d'installation de cet insecte en Amérique du Nord, en Chine ou ailleurs.

MOTS CLÉS : *Disonycha argentinensis*, milieu terrestre, lutte biologique, *Alternanthera philoxeroides*.

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