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Host Specificity Tests of *Galerucella calmariensis* (L.) and *G. pusilla* (Duft.) (Coleoptera: Chrysomelidae), Potential Biological Control Agents of Purple Loosestrife, *Lythrum salicaria* L. (Lythraceae)

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Host specificity tests of *Galerucella calmariensis* (L.) and *Galerucella pusilla* (Duft.) (Coleoptera: Chrysomelidae) were conducted under quarantine to determine the suitability of these beetles as biological control agents of purple loosestrife, *Lythrum salicaria* L., an aggressive emergent aquatic weed of Eurasian origin. Both species of imported Eurasian beetles, natural enemies of purple loosestrife, were tested on 15 species of plants from nine families within six orders. The plants were selected on the basis of preliminary tests by the Commonwealth Agricultural Bureaux International Institute of Biological Control. Adult *G. calmariensis* readily fed and oviposited on *Lagerstroemia indica* L., *Decodon verticillatus* (L.) Ell., and *Lythrum alatum* Pursh. However, only *L. alatum* and *Lythrum virgatum* L., besides the target host purple loosestrife, supported larval development beyond the first instar to the adult stage. Test plants outside the Lythraceae showed minimal feeding or oviposition and were not suitable as hosts. Feeding by adult *G. pusilla* was confined to members of the Lythraceae. Of the five test plants that were accepted for oviposition, only two (*L. virgatum* and *L. alatum*) were suitable for larval development past the first instar. As *L. virgatum* is considered taxonomically similar to *L. salicaria,* it appears that the only test plant that is a suitable host for both *Galerucella* spp., besides the target plant, is *L. alatum.* These results suggest that both species of beetles are highly host specific and should not be a threat to nontarget plants with the exception of *L. alatum.*

KEY WORDS: ***Galerucella calmariensis; Galerucella pusilla;*** **Chrysomelidae; quarantine tests; host specificity tests;** ***Lythrum salicaria;*** **purple loosestrife; Lythraceae; biological control.**

INTRODUCTION

Purple loosestrife, *Lythrum salicaria* L., an exotic perennial plant from Eurasia, is an aggressive invader of meadows and wetlands over much of the temperate United States and Canada (Pfannmueller and Djupstrom, 1983; Thompson *et al.,* 1987). In Europe, purple loosestrife is a minor wetland species and is not considered a major pest. Since its introduction into the northeastern North America in the nineteenth century (Stuckey, 1980), it has spread rapidly westward. As it has been introduced without its natural enemies, classical biological control offers a viable method for control of this weed in North America (Hight and Drea, 1991). A conservative projection of the benefit–cost ratio of a biological control program for this weed for the eastern half of the United States indicates a 27-fold return of the unit cost (Thompson *et al.,* 1987).

Three species of insects were identified as potential biological control agents of purple loosestrife (Batra *et al.,* 1986; Blossey and Schroeder, 1986). One species, *Hylobius transversovittatus* Goeze (Curculionidae), was approved for field cage releases (Kok *et al.,* 1992). Quarantine host specificity tests on the other two species, *Galerucella calmariensis* (L.) and *Galerucella pusilla* (Duft.) (Chrysomelidae) are reported here.

The adult *Galerucella* beetles are light brown, about twice as long as wide, with parallel-sided bodies (widening slightly backwards), and covered with a fine, dense pubescence. *G. calmariensis* (3–5 mm) is more convex with tip of aedeagus blunted and last sternite of female with a deep triangular indentation; *G. pusilla* (3–4 mm) is smaller, somewhat more flattened, with very pointed aedeagus and last sternite of female with a rounded indentation (Palmen, 1945). In Europe, oviposition of overwintered females is from late May until July (Blossey and Schroeder, 1988). Eggs are laid in batches on the basal part of the stem, shoot axils, or lower side of leaves. They hatch in about a week and feed at the top of the plant moving downward. On completion of feeding, they pupate in the soil. Egg to adult stage is about 6 weeks; the adult lives for about 8 to 10 weeks and there is usually one generation a year.

Preliminary host specificity tests conducted in Europe between 1987 and 1989 under the auspices of the

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Commonwealth Agricultural Bureaux International Institute of Biological Control (IIBC) in Delémont, Switzerland (Blossey and Schroeder, 1991) provided the basis for importation of both *Galerucella* spp. into quarantine at Virginia Polytechnic Institute & State University (VPI & SU), Blacksburg in 1989 for final tests. The objective of these host specificity tests was to determine whether these chrysomelid beetles are suitable for release in the United States for control of purple loosestrife.

MATERIALS AND METHODS

Fifteen species of plants selected for the tests are either taxonomically related to purple loosestrife and in similar habitat, of horticultural importance, or ecologically associated plants of wildlife importance. They belong to nine families in six orders as follows:

Order Myrtales
- Family Lythraceae
  - *Lythrum salicaria* L.—purple loosestrife, introduced target plant
  - *Lythrum virgatum* L.—introduced, taxonomically similar to *L. salicaria*
  - *Lythrum alatum* Pursh.—winged lythrum, native
  - *Decodon verticillatus*(L.)Ell.—water-willow, swamp loosestrife, native
  - *Rotala ramosior* (L.) Koehne—toothcup, native
  - *Lagerstroemia indica* L.-crape myrtle, introduced ornamental
- Family Onagraceae
  - *Circaea quadrisulcata* var. *canadensis* (L.) Hara—enchanter's nightshade, native
  - *Gaura biennis* L.—morning-honeysuckle, biennial gaura, native
- Family Thymelaeaceae
  - *Dirca palustris* L.—leatherwood, native
- Family Melastomataceae
  - *Rhexia mariana* L.—meadow beauty, native

Order Graminales
- Family Poaceae
  - *Zizania aquatica* L.—annual wildrice, native

Order Salicales
- Family Salicaceae
  - *Salix interior* Rowlee—sandbar willow, native

Order Polygonales
- Family Polygonaceae
  - *Rumex verticillatus* L.—swamp dock, native
  - *Polygonum coccineum* Muhl.—swamp smartweed, native

Order Caryophyllales (Centrospermae)
- Family Chenopodiaceae
  - *Chenopodium hybridum* L.—goosefoot, native

Order Ranales
- Family Ranunculaceae
  - *Ranunculus sceleratus* L.—crowfoot buttercup, native

All members of the Myrtales tested are plants taxonomically related to and in similar habitat with purple loosestrife except for *L. indica,* an introduced ornamental; test plants in the other five orders are ecologically associated plants of wildlife importance. Selection of these test plants was based on the list approved (Kok *et al.,* 1992) by the Technical Advisory Group for the Introduction of Biological Control Agents of Weeds (Klingman and Coulson, 1983) and on the need for additional information as a result of the initial tests by IIBC (Blossey and Schroeder, 1991). The plant material was received from locations within the United States; two shipments of insects for the tests were received from Drs. B. Blossey and D. Schroeder, IIBC, Delémont, Switzerland in 1989 and 1990. The former collected the insects from different sites in Germany. Adult feeding, oviposition, and larval development tests were conducted on each test plant in the quarantine facility of VPI & SU.

Vigorous live insects were placed in screened, liter-sized plastic cages with purple loosestrife shoots. Stems were pushed through a hole in the bottom of the cage lid into a cup of water. The imported insects were allowed to acclimatize to the new surroundings for 1 to 2 weeks before being used in the initial adult feeding and oviposition tests. Adult beetles were maintained on purple loosestrife shoots for at least a week between tests. Progenies of the imported insects were used in the subsequent tests.

Galerucella calmariensis

Adult Feeding Tests

Single-host tests. In 1989, the newly imported adults were placed in liter-sized plastic cages fitted with fine-mesh screen as described above. Each cage contained one species of test plant. There were five cages (replicates) per test plant with 10 pairs of adults per cage. Each test was conducted simultaneously with a control, *L. salicaria.* As the number of adults available decreased because of mortality, later tests had three replicates per host with six adults per cage. The cages were placed in a growth chamber maintained at 20°C day, 10°C night, and a 14-h light/10-h dark period. After 7 days, the amount of leaf material eaten was determined by placing each leaf over a 10 × 10 grid of 2.5-cm graph paper and the number of squares eaten from the leaf was recorded. Tests in 1990 were conducted on healthy potted plants instead of shoots with beetle progenies from the original and the 1990 shipment. Records of feeding were made as in the previous year, and after each test, the adults were placed on *L. salicaria* for a week.

Multiple-host preference test. Ten pairs of adults were placed in a large plexiglass cage, 40 × 50 × 40 cm with fine-mesh screening on the opposite sides. Each cage contained several cut shoots of all test plants excluding *L. salicaria,* and there were five replicate cages. Another cage contained shoots of *L. salicaria* as control. After 12 days, defoliation was recorded. All adults were then placed on *L. salicaria.*

Oviposition Tests

In the single-host tests described above, eggs deposited on each test plant were counted at the end of each test, but were not removed from the stem and leaves. Test plants with known numbers of eggs were placed in screened cages and closely observed for larval development. Eggs on cut shoots of the multiple-host test were also observed for larval development.

Larval Development Tests

Newly eclosed larvae from eggs in the oviposition tests were allowed to continue development on the same plant. Where no oviposition occurred on a given test plant, newly eclosed vigorous first instars from rearing cages were transferred with a fine camel-hair brush (number 00) onto healthy potted test plants. All test plants were placed in observation cages and larval development was monitored every 3 days. The number of larvae reaching the adult stage on each test plant was recorded. For larvae completing development to the adult stage on *L. virgatum,* a host that was not used in the adult feeding and oviposition tests because of a shortage of plants, the new adults were allowed to remain on the potted plants for observation of feeding and oviposition.

Galerucella pusilla

Adult Feeding Tests

Single-host tests. In 1989, each cage containing one test plant species had eight adults on cut shoots, and this was replicated four times. Each test lasted 7 days, and defoliation was recorded as described above. In 1990, two to four replicates of 10 to 30 adults per test species were tested using caged potted plants. A control was used simultaneously for comparison during each test in both years.

Multiple-host preference test. Ten pairs of adults were placed in each of the large plexiglass cages described above. Five cages contained four potted test plant species and one cage contained four *L. salicaria* as control. This test lasted 12 days. Defoliation and oviposition on each test species were recorded as described above. After the test, all the adults were placed on *L. salicaria.*

Oviposition Tests

In the above single-host and multiple-host tests, eggs deposited on each test plant were counted and left to develop on the respective plant at the end of each test. The test plants were placed in screened cages and monitored daily to observe egg hatch.

Larval Development Tests

Eggs oviposited on test plants during the oviposition tests were allowed to hatch on the respective hosts and were monitored for development. For plants in which no oviposition occurred, newly hatched larvae were transferred by fine camel-hair brush onto potted test plants held in fine-screened cages. Larvae were checked every 7 days for feeding and the development of larvae on each test species was recorded.

Analysis of variance, t tests, and Tukey's mean separation tests (SAS Institute, Inc., 1985) were used to determined differences ($P < 0.05$) in feeding and oviposition.

RESULTS AND DISCUSSION

Galerucella calmariensis

Adult Feeding Tests

Single-host tests. *L. indica* was fed on extensively by *G. calmariensis,* with three times as much feeding as on purple loosestrife (Table 1). Feeding was greater on *D. verticillatus* shoots, but less on potted plants than on purple loosestrife. The amount of feeding was not significantly different between purple loosestrife and *L. alatum* on shoots, but feeding on the latter was significantly less when potted plants were used. A small amount of feeding occurred on *R. ramosior, R. verticillatus, S. interior,* and *G. biennis,* but no feeding occurred on the remaining test plants (Table 1).

Multiple-host preference test. *D. verticillatus* and *L. alatum* were the only two test plants that showed feeding besides purple loosestrife, but with significantly less feeding on them (48% and 12%, respectively) than on purple loosestrife. None of the other test species had any feeding (Table 2).

Oviposition Tests

Single-host tests. Only one test plant had more eggs on it than on purple loosestrife; oviposition was more than nine times greater on *L. indica* than on purple loosestrife (Table 1). *D. verticillatus* and purple loosestrife had nearly the same numbers of eggs. Cut shoots of *L. alatum* and purple loosestrife also received similar egg numbers, but fewer eggs were laid on *L. alatum* when potted plants were used. *G. biennis* and *S. interior* had

TABLE 1

Feeding and Ovipositing by Adults of *Galerucella calmariensis* on Single Test Plants Compared with Those on *L. salicaria* Taken as 100%

Family Test species[a]	% Adult feeding		% Oviposition	
	Cut shoots	Whole plant	Cut shoots	Whole plant
Lythraceae				
Lythrum salicaria	100[b]	100[c]	100[d]	100[e]
Lythrum alatum	67	25*	100	13*
Decodon verticillatus	150*	50*	x	91
Rotala ramosior	17*	0*	x	0*
Lagerstroemia indica	x	300*	x	938*
Onagraceae				
Circaea quadrisulcata var. *canadensis*	0*	x	0*	x
Gaura biennis	x	1*	x	6*
Thymelaeaceae				
Dirca palustris	x	0*	x	0*
Melastomataceae				
Rhexia mariana	0*	0*	x	0*
Poaceae				
Zizania aquatica	0*	0*	x	0*
Salicaceae				
Salix interior	17*	2*	0*	4*
Polygonaceae				
Rumex verticillatus	17*	x	0*	x
Polygonum coccineum	0*	x	0*	x
Chenopodiaceae				
Chenopodium hybridum	0*	0*	0*	0*
Ranunculaceae				
Ranunculus sceleratus	x	0*	x	0*

[a] Three to five replicates of 5–10 pairs of beetles/replicate.
[b–e] Mean ± sd: [b]0.3 ± 0.1 cm^2/adult/week; [c]0.7 ± 0.4 cm^2/adult/week; [d]1.3 ± 1.2 eggs/female/week; [e]11.4 ± 9.8 eggs/female/week.
* Significantly different from *L. salicaria* ($P < 0.05$, *t* test); x, not tested.

significantly fewer eggs laid on them than on purple loosestrife; the remainder of the test plants had no eggs.

Multiple-host preference test. Eggs were found only on purple loosestrife. This confirms the preference for oviposition on purple loosestrife over the other test plants (Table 2).

Larval Development Tests

The only test plants other than purple loosestrife to support larval development to the adult stage were *L. virgatum* and *L. alatum* (Table 3). The new adults continued to feed on both plant species and oogenesis was confirmed when the new adult beetles maintained on each respective test plant oviposited. *L. indica* and *D. verticillatus*, despite supporting very high oviposition (Table 1), were not suitable hosts as none of the larvae completed development beyond first instar (Table 3), even though they had respectively 5 and 2 times as many test larvae on them than on *L. virgatum*, and 7.5 and 3 times more larvae than on *L. alatum*. This indicates that only *L. virgatum* and *L. alatum* are suitable as hosts besides the target plant.

A summary of the feeding, oviposition, and larval development tests (Table 4) shows that *L. indica, D. verticillatus,* and *L. alatum* were highly acceptable for feeding and oviposition by *G. calmariensis,* but only *L. alatum* and *L. virgatum* supported larval development to the adult stage. Test plants outside the Lythraceae showed minimal feeding or oviposition, and were not suitable as hosts. Since *L. virgatum* is very similar to purple loosestrife (Kok *et al.*, 1992), and they are often considered to be the same species, these results indicate that *G. calmariensis* is highly host specific, and that only *L. alatum* is a suitable host besides the target plant purple loosestrife. Feeding intensity on purple loosestrife is greater than on *L. alatum,* and the capability of *G. calmariensis* for rapid multiplication makes this a desirable insect with potential for suppressing purple loosestrife.

Galerucella pusilla

Adult Feeding Tests

Single-host tests. Galerucella pusilla fed on only three test plants in the family Lythraceae besides *L. salicaria: L. alatum, D. verticillatus,* and *L. indica.* The amount of feeding on these plants was significantly less than on purple loosestrife (Table 5).

Multiple-host preference test. Besides *L. alatum* and *D. verticillatus,* some feeding also occurred on *R. ramosior* (Table 6). Preference, however, was for purple loosestrife over the other test plants.

TABLE 2

Multiple-Host Test on Cut Shoots with *Galerucella calmariensis* Adults

Test species	Cm^2 eaten/adult/week ± SD[a]	No. eggs/female/week ± SD[a]
Lythrum salicaria	0.25 ± 0.12 a	1.3 ± 1.2 a
Decodon verticillatus	0.12 ± 0.05 b	0.0 b
Lythrum alatum	0.03 ± 0.02 bc	0.0 b
Rotala ramosior	0.0 c	0.0 b
Rumex verticillatus	0.0 c	0.0 b
Salix interior	0.0 c	0.0 b
Circaea quadrisulcata	0.0 c	0.0 b
Rhexia mariana	0.0 c	0.0 b
Polygonum coccineum	0.0 c	0.0 b
Zizania aquatica	0.0 c	0.0 b
Chenopodium hybridum	0.0 c	0.0 b

[a] Means followed by a different letter in the same column are significantly different ($P < 0.05$, Tukey's test); five replicates, 10 pairs of beetles/replicate.

TABLE 3

Development of Larvae of *Galerucella calmariensis* on Test Plants[a]

Family Test species	Initial number of larvae	Number survived to adulthood
Lythraceae		
Lythrum salicaria	31	28
Lythrum virgatum	30	20
Lythrum alatum	20	16
Decodon verticillatus	58	0
Rotala ramosior	30	0
Lagerstroemia indica	150	0
Onagraceae		
Circaea quadrisulcata	20	0
Thymelaeaceae		
Dirca palustris	13	0
Gaura biennis	20	0
Melastomataceae		
Rhexia mariana	30	0
Poaceae		
Zizania aquatica	30	0
Salicaceae		
Salix interior	30	0
Polygonaceae		
Rumex verticillatus	7	0
Polygonum coccineum	20	0
Chenopodiaceae		
Chenopodium hybridum	20	0
Ranunculaceae		
Ranunculus sceleratus	30	0

[a] Potted plants were used and development was monitored every 3 days.

Oviposition Tests

Single-host tests. *L. alatum* was the most favored and had twice as many eggs as purple loosestrife on cut shoots (Table 5); *D. verticillatus* and *L. indica* had significantly fewer eggs on them than on purple loosestrife in whole-plant tests. *G. pusilla* laid a few eggs on *C. hybridum,* but did not oviposit in any of the other test plants.

Multiple-host preference test. Besides *L. salicaria,* eggs were found on only one of the test plants (Table 6), *L. alatum* (0.3 eggs/plant). This was significantly lower than the number of eggs oviposited on purple loosestrife (4.4 eggs/plant).

Larval Development Tests

In the first series of tests using cut shoots, *L. virgatum* and *L. alatum* supported larval development to the pupal stage (Table 7). The larvae pupated on the bottom of the lid and were affected by water condensation and failed to emerge as adults. No feeding or development occurred on the other test species. When this was repeated on potted plants which provided a more natural site for pupation, *L. alatum* was the only other test plant that produced adults. *D. verticillatus, R. ramosior,* and *L. indica* which either had some adult feeding or oviposition, did not support larval development beyond the first instar. There was very little larval feeding on these species. Thus, *L. alatum* and probably *L. virgatum* appear to be the only test plants that would be suitable as hosts for *G. pusilla* besides the target plant, purple loosestrife. As in the case for *G. calmariensis,* newly emerged *G. pusilla* adults readily fed and oviposited on *L. alatum,* confirming that oogenesis had occurred.

A summary of the test results on feeding, oviposition, and larval development of *G. pusilla* (Table 8) indicates that this chrysomelid beetle is highly host specific. The adults fed on only members of the Lythraceae; a few of the test plants were accepted for oviposition, and only *L. virgatum* and *L. alatum* were suitable for larval development. The results strongly indicate that this beetle is safe for release in the United States for control of purple loosestrife.

Our findings are quite similar to those of Blossey and Schroeder (1991) except for some differences with regards to feeding and oviposition on *D. verticillatus, L. indica,* and *L. alatum.* Blossey and Schroeder also reported moderate oviposition and successful larval development to the adult stage on *L. alatum* in tests using potted plants in screened cages in the greenhouse. However, they concluded that *L. alatum* was an unsuitable field host because potted plants exposed to the insects under field conditions were not fed on. They attributed any feeding, oviposition, and larval development on *L. alatum* and other Lythraceae to be laboratory artifacts of insects under confinement. Our quarantine tests consistently showed that both *Galerucella* species readily fed, oviposited, and developed on *L. alatum,* and we conclude that both *G. calmariensis* and *G. pusilla* accept this plant for reproduction and development. However, *L. alatum* is not a preferred host when given a choice between *L. alatum* and purple loosestrife. We also found that both insects readily fed and oviposited on *D. verticillatus* and *L. indica* while Blossey and Schroeder found no oviposition by either insect on *D. verticillatus,* and no adult feeding or oviposition on *L. indica.* The large amount of feeding and oviposition on *L. indica* by *G. calmariensis* observed in our tests suggests that this is unlikely to be an artifact. A possible explanation for this difference in results could be the quality of plant material used in the tests. We used several potted *L. indica* with luxuriant leaves in the test as opposed to shoots obtained from plants in the botanical gardens of Kiel as used by Blossey and Schroeder (1988). Thus, difference in plant quality may explain the lack of feeding activity in their tests. When shoots were used in some of our tests, they tended to dry rapidly and had to be changed frequently.

In conclusion, the feeding results for the two test insect species *G. calmariensis* and *G. pusilla* were similar, with very little or no feeding on species not in the family

TABLE 4

Summary of Results of the Acceptance and Suitability Tests of Plants Screened as Hosts of *Galerucella calmariensis*

Family Test species	Acceptance[a]		Suitability:[a] larval development	Final host status[b]
	Adult feeding	Oviposition		
Taxonomically related plants in similar habitat				
Lythraceae				
Lythrum virgatum	+	+	+	Yes
Lythrum alatum	+	+	+	Yes
Decodon verticillatus	+	+	−	No
Rotala ramosior	+	−	−	No
Onagraceae				
Gaura biennis	+	+	−	No
Circaea quadrisulcata	−	−	−	No
Thymelaeaceae				
Dirca palustris	−	−	−	No
Melastomataceae				
Rhexia mariana	−	−	−	No
Taxonomically related plant of horticultural importance				
Lythraceae				
Lagerstroemia indica	+	+	−	No
Ecologically associated plants of wildlife importance				
Poaceae				
Zizania aquatica	−	−	−	No
Salicaceae				
Salix interior	+	+	−	No
Polygonaceae				
Rumex verticillatus	+	−	−	No
Polygonum coccineum	−	−	−	No
Chenopodiaceae				
Chenopodium hybridum	−	−	−	No
Ranunculaceae				
Ranunculus sceleratus	−	−	−	No

[a] +, positive response on test plant; −, negative response on test plant.
[b] Whether the species could serve as a host to *G. calmariensis*.

Lythraceae. Oviposition and larval development of both beetles were restricted mainly to the genus *Lythrum*. Although *L. indica* and *D. verticillatus* were fed on and were acceptable for oviposition by both *G. pusilla* and *G. calmariensis*, they were not suitable for larval development beyond the first instar, and thus are not suitable hosts. None of the other test species that were accepted for feeding or oviposition supported larval development. Based on the large number of hosts tested by IIBC and the 15 species (from 9 families) tested in our studies, the results indicate that both species of *Galerucella* are host specific and should be recommended for release for the biological control of purple loosestrife, *L. salicaria*, in the United States.

Although there may be some concern about *L. alatum* (which may be placed on the endangered list by some U.S. states) being a host for both insects, and the likely adult feeding damage on *L. indica*, an important ornamental plant, the potential benefits of these insects contributing to the suppression of purple loosestrife outweighs the possibility that these nontarget plants might be adversely affected. *L. alatum* primarily occupies two types of plant communities: wet meadows and mesic prairies (Eggers and Reed, 1987). Although *L. alatum* is more mesophytic than purple loosestrife, it is a relatively obscure component of the community where both species occur sympatrically north of the 35th parallel. *L. alatum* is widely distributed outside the range of purple loosestrife, occurring throughout the southeastern states from North Carolina into Texas and the southern Midwest (Gleason and Cronquist, 1963). The results also clearly indicate that purple loosestrife is the preferred host and that the likelihood of the insects adapting to *L. alatum* is remote. Thus, it is unlikely that *L. alatum* will be in danger following the release of the *Galerucella* beetles.

TABLE 5

Feeding and Ovipositing by Adults of *Galerucella pusilla* on Single Test Plants Compared with those on *L. salicaria* taken as 100%

Family Test species[a]	% Adult feeding: Cut shoots	% Adult feeding: Whole plant	% Oviposition: Cut shoots	% Oviposition: Whole plant
Lythraceae				
Lythrum salicaria	100[b]	100[c]	100[d]	100[e]
Lythrum alatum	36*	x	230*	x
Decodon verticillatus	50*	18*	x	19*
Rotala ramosior	0*	0*	20*	0*
Lagerstroemia indica	x	26*	x	16*
Onagraceae				
Circaea quadrisulcata var. *canadensis*[f]	0*	x	0*	x
Gaura biennis	x	0*	x	0*
Thymelaeaceae				
Dirca palustris	x	0*	x	0*
Melastomataceae				
Rhexia mariana	0*	0*	x	0*
Poaceae				
Zizania aquatica	x	0*	x	0*
Salicaceae				
Salix interior	x	0*	x	0*
Polygonaceae				
Rumex verticillatus	0*	x	0*	x
Polygonum coccineum	0*	x	0*	x
Chenopodiaceae				
Chenopodium hybridum	x	0*	x	3*
Ranunculaceae				
Ranunculus sceleratus	x	0*	x	0*

[a] Three to five replicates of 5–10 pairs of beetles/replicate.

[b–e] Mean ± sd: [b]0.5 ± 0.6 cm^2/adult/week; [c]0.6 ± 0.5 cm^2/adult/week; [d]1.4 ± 0.5 eggs/female/week; [e]7.2 ± 4.5 eggs/female/week.

[f] Data from multiple-host test.

* Significantly different from *L. salicaria* ($P < 0.05$, t test); x, not tested.

TABLE 6

Multiple-Host Test on Potted Plants with *Galerucella pusilla* Adults

Test species	Cm^2 eaten/adult/week ± SD[a]	No. eggs/female/week ± SD[a]
Lythrum salicaria	0.66 ± 0.49 a	4.4 ± 4.9 a
Lythrum alatum	0.13 ± 0.02 b	0.3 ± 0.4 b
Decodon verticillatus	0.04 ± 0.02 b	0.0 b
Rotala ramosior	0.04 ± 0.04 b	0.0 b
Circaea quadrisulcata	0.00 b	0.0 b
Rumex verticillatus	0.00 b	0.0 b
Salix interior	0.0 b	0.0 b
Rhexia mariana	0.0 b	0.0 b
Polygonum coccineum	0.0 b	0.0 b
Zizania aquatica	0.0 b	0.0 b
Chenopodium hybridum	0.0 b	0.0 b

[a] Means followed by a different letter in the same column are significantly different ($P < 0.05$, Tukey's test); four replicates of 10 pairs of adults/replicate.

As for *L. indica,* since it does not support larval development and is not a suitable host, the amount of foliar damage is not likely to be a major problem that would adversely affect the vigor of the plant. The major occurrence of *L. indica* is farther south than that of purple loosestrife. *L. indica* is an ornamental plant introduced from Asia and is cultivated in warm-temperate to subtropical regions of the southern United States (Cronquist, 1981). The plant occurs as far north as Maryland and Tennessee which, for the most part, are south of the major distribution of purple loosestrife. *L. indica* plants that do occur in the purple loosestrife region are not likely to be attacked by the *Galerucella* beetles because they are planted in dry, highly managed situations, such as around businesses and homes. Such areas are often far away from wetlands infested with purple loosestrife. In the absence of such infested wetlands, both *Galerucella* species would die because *L. indica* does not support larval development. Introduction of these *Galerucella* beetles represents a minimal risk to native plants, as well as the ornamental *L. indica.* The slight probability of occasional feeding on a few plants must be care-

TABLE 7

Development of Larvae of *Galerucella pusilla* on Test Plants

Test species	Initial number	Number surviving
1989—Cut shoots[a]		
Lythrum salicaria	20	4 pupa
Lythrum virgatum	20	2 pupa
Lythrum alatum	22	1 pupa
Rotala ramosior	20	0
Rumex verticillatus	20	0
Circaea quadrisulcata	20	0
Decodon verticillatus	20	0
Rhexia mariana	20	0
Chenopodium hybridum	20	0
Salix interior	20	0
Polygonum coccineum	20	0
1990—Potted plants		
Lythrum salicaria	32	30 adults
Lythrum alatum	30	7 adults
Decodon verticillatus	30	0
Lagerstroemia indica	20	0
Gaura biennis	22	0
Dirca palustris	30	0
Rhexia mariana	30	0
Ranunculus sceleratus	55	0
Zizania aquatica	30	0
Salix interior	30	0
Rotala ramosior	30	0
Chenopodium hybridum	30	0

[a] Cut shoots were replaced by potted plants in 1990 because soil provided a more natural medium for pupation.

TABLE 8

Summary of Results of the Acceptance and Suitability Tests of Plants Screened as Hosts of *Galerucella pusilla*

Family Test species	Acceptance[a] Adult feeding	 Oviposition	Suitability:[a] Larval development	Final host status[b]
	Taxonomically related plants in similar habitat			
Lythraceae				
Lythrum virgatum	x	x	+	Probable
Lythrum alatum	+	+	+	Yes
Decodon verticillatus	+	+	−	No
Rotala ramosior	+	+	−	No
Onagraceae				
Gaura biennis	−	−	−	No
Circaea quadrisulcata	−	−	−	No
Thymelaeaceae				
Dirca palustris	−	−	−	No
Melastomataceae				
Rhexia mariana	−	−	−	No
	Taxonomically related plant of horticultural importance			
Lythraceae				
Lagerstroemia indica	+	+	−	No
	Ecologically associated plants of wildlife importance			
Poaceae				
Zizania aquatica	−	−	−	No
Salicaceae				
Salix interior	−	−	−	No
Polygonaceae				
Rumex verticillatus	−	−	−	No
Polygonum coccineum	−	−	−	No
Chenopodiaceae				
Chenopodium hybridum	−	+	−	No
Ranunculaceae				
Ranunculus sceleratus	−	−	−	No

[a] +, positive response on test plant; −, negative response on test plant; x, test not conducted.
[b] Whether the species could serve as a host to *G. pusilla*.

fully weighed against the possibility of replacement of the native North American wetland flora by monospecific stands of purple loosestrife. Additionally, current technology involving chemical control of purple loosestrife cannot be conducted without severe negative side effects to the wetland flora. Therefore, the slight possibility of a few nontarget plants being attacked by the introduced insects should not be placed above the potential benefits that come with the control of the exotic purple loosestrife. In June 1992, the Animal and Plant Health Inspection Service, U.S. Department of Agriculture approved the field release of both *Galerucella* species as well as *H. transversovittatus* (Kok *et al.*, 1992) in the United States.

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