Biology, Rearing, and Preliminary Evaluation of Host Range of Two Potential Biological Control Agents for Mile-a-Minute Weed, *Polygonum perfoliatum* L.

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ABSTRACT Basic biology and rearing methods were determined for *Timandra griseata* Peterson (Lepidoptera: Geometridae) and *Homorosoma chinensis* Wagner (Coleoptera: Curculionidae), two potential biological control agents of mile-a-minute weed (*Polygonum perfoliatum* L., Polygonaceae). Both species also were tested for their ability to feed and develop on crop plants in the family Polygonaceae. *T. griseata* defoliated potted mile-a-minute weed, developing from egg to adult in ≈26 d. However, *T. griseata* also fed and developed on common buckwheat (*Fagopyrum esculentum* Moench) and tartary buckwheat (*Fagopyrum tartaricum* Gaertn), and accepted these species and mile-a-minute weed equally in choice tests. Thus, the host range of *T. griseata* appears to be too broad for it to be considered for release in the United States. *Homorosoma chinensis* had a relatively high reproductive rate and short generation time on potted mile-a-minute weed. Internal feeding by *H. chinensis* larvae caused mortality of entire stems. Adult weevils fed on foliage of common buckwheat and rhubarb (*Rheum rhabarbarum* L.) when given no choice during an 8-wk test period, but laid no eggs on these hosts. In the same test, an average of over 130 eggs per female was laid on mile-a-minute weed. Newly emerged *H. chinensis* adults strongly preferred mile-a-minute weed to buckwheat and rhubarb in a choice test, and neonate larvae placed on buckwheat and rhubarb all died within 24 h. Thus, *H. chinensis* may be host specific to mile-a-minute weed, but further testing must be conducted on other potential host plants before release in the United States can be recommended.

KEY WORDS *Timandra griseata*, *Homorosoma chinensis*, mile-a-minute weed, *Polygonum perfoliatum*, host specificity, biological control

MILE-A-MINUTE WEED (*Polygonum perfoliatum* L.) is an annual vine indigenous to Korea, China, the Malay Peninsula, India, Japan (Ohwi 1965), Taiwan (Reed 1977), and Bangladesh (Kahn and Hassan 1978). It was first reported in the United States near Portland, Oregon, in the 1890s (Hickman and Hickman 1977), although reports in 1954 suggested that as of that date there were no populations west of the Rocky Mountains (Oliver and Coile 1994).

In 1946, mile-a-minute weed was found in an abandoned nursery in Stewartstown, York County, Pennsylvania, the apparent site of its first establishment in the eastern United States (Moul 1948). Before 1980, the plant's range was limited to five counties in Pennsylvania (Mountain 1995) and parts of Maryland (Reed 1979a, b, Riefner and Windler 1979). The species is now established in Maryland, Delaware, Virginia, West Virginia, New Jersey, New York, Ohio, Pennsylvania, the District of Columbia (Mountain 1995), and Connecticut (R. Reardon, United States Forest Service, Morgantown, WV, personal communication).

Mile-a-minute weed grows rapidly, with stems up to 6 m long, and is covered with retrorse spines on the stems, petioles, and leaf veins. These barbs restrict the movement of wildlife and humans through natural resource areas, and aid the plant in climbing and supporting itself on other plants, while blocking available sunlight (Okay 1997). On recently harvested forest sites, infestations of mile-a-minute weed can form a dense canopy, resulting in mortality of tree seedlings (McCormick and Hartwig 1995). Mile-a-minute plants produce abundant seeds in iridescent blue-purple berries in the fall, which are readily dispersed by birds, small mammals, and water (Okay 1997).

Although hand pulling, cultivation, and herbicides can control the weed on a small scale (Mountain 1989), these methods are not feasible for large infestations or infestations in environmentally sensitive ar-

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eas. Therefore, because of its rampant growth, undesirability, and limited control options, mile-a-minute weed was targeted for biological control. Surveys of insect fauna on mile-a-minute weed in the United States have indicated numerous polyphagous species that have transferred onto the plant, but few oligophagous species, and none that provide any apparent check to the plant's growth and dispersal (Wheeler and Mengel 1984, Fredericks 2001).

Between 1996 and 1998, ≈80 insect species from six orders and 20 families were collected on mile-a-minute weed in northern, central, and southern parts of China (Jianqing et al. 2000). Among them were *Timandra griseata* Peterson (Lepidoptera: Geometridae) and *Homorosoma chinensis* Wagner (Coleoptera: Curculionidae), both thought to be potentially important natural enemies based on their distribution, density, damage to plants, and evidence of a relatively narrow host range within Polygonaceae (Jianqing et al. 2000).

T. griseata, common name bloodvein, is bivoltine in Northern Europe, with adult emergence from late May to early July and again in August and September (Chinery 1986). Adults lay their eggs on leaves or on the ground (Ding Jianqing, Biological Control Institute, Chinese Academy of Agricultural Sciences, Beijing, China, personal communication). Larvae reportedly feed on orache (*Atriplex* spp.), common sorrel and dock (*Rumex* spp.), and knotgrass (*Polygonum* spp.) (South 1980, Skou 1986, Skinner 1998). The larval period lasts for 2–3 wk (Ding Jianqing, personal communication). Pupation takes place in a loosely woven cocoon between leaves, often on a host plant, and the pupal stage lasts 5–10 d (Ding Jianqing, personal communication; Skou 1986). Both larval and pupal stages are capable of diapausing (Skou 1986). Adults emerge and live for 1–2 wk (Ding Jianqing, personal communication).

Little is known about the life history of the weevil, *H. chinensis.* Field observations in China indicate that the adults readily feed on flowers, buds, and young leaves of mile-a-minute weed. No other plant species were found to be attacked (Jianqing et al. 2000).

The apparent narrow host range reported for *T. griseata* and *H. chinensis* in China indicated that they might be suitable biological control agents of mile-a-minute weed in the United States. However, information on basic biology and host range of these two species is lacking. Studies in China suggested that neither species will feed on plants in families other than Polygonaceae (Jianqing et al. 2000). The objective of this study was to rear both species on potted mile-a-minute in quarantine, and investigate their biologies, including duration of life stages and fecundity. In addition, the ability of *T. griseata* and *H. chinensis* to attack and develop on species of North American crops in the Polygonaceae was determined as a preliminary assessment of possible host range in the United States, to help determine whether in-depth host-range testing of these species would be warranted.

Materials and Methods

Plants

Mile-a-minute weed plants were grown initially from seedlings collected in April 1999 from White Clay Creek State Park (Newark, DE). The plants were transplanted into plastic pots with Pro-mix (Premier Horticulture, Red Hill, PA), and maintained in a greenhouse under drip irrigation. Plants used in 2000 were grown from mile-a-minute seeds collected from plants in three locations (White Clay Creek State Park; Quiet Waters Park, Annapolis, MD; and Elk Neck State Park, North East, MD) the previous fall. In January 2000, seeds were mixed with moist peat moss (which had been soaked in water for 2 d) in plastic bags, and placed flat in a refrigerator at 3–4°C. Seeds germinated in ≈60 d, at which point they were planted in pots with Pro-mix. Plants were cut back every other day during the summer because of their rapid growth, and were fertilized biweekly.

Seeds of common buckwheat, *Fagopyrum esculentum* Moench, were obtained from Johnson Seed and Feed (Salisbury, MD), and seeds of tartary buckwheat, *F. tartaricum* Gaertn, were obtained from the United States Department of Agriculture (USDA) Germplasm Resources Information Unit, Cornell University (Geneva, NY). Buckwheat and mile-a-minute weed were planted weekly, to ensure that plants would be of similar age (2 wk) and height (≈30 cm) when used in choice and no-choice tests. Rhubarb, *Rheum rhabarbarum* L., was grown from roots dug from a garden in West Chester, PA, in June 2000, and from roots purchased at Southern States (Newark, DE), in March 2001, in plastic pots with Pro-mix. All plants were maintained in the greenhouse at 23 ± 2°C. Between October 1999 and April 2000, they were provided supplemental light for 16 h per day with a 1,000-W metal-halide lamp.

Insects

Insects were collected by Ding Jianqing in Beijing, China, and sent to the USDA- Agricultural Research Service (ARS) Beneficial Insects Introduction Research (BIIR) facility (Newark, DE). Larvae and pupae of *T. griseata* were collected from the field in Henan and Hubei provinces in China and sent in August 1999. *H. chinensis* adults were collected in Changsha, Henan province in China and sent in July of 1999 and 2000. All insects were collected from mile-a-minute weed plants and shipped immediately after collecting in insulated containers containing frozen gel packs.

T. griseata was identified by Xue Dayong, Institute of Zoology, Chinese Academy of Sciences (Beijing, China), and *H. chinensis* as *Homorosoma* sp. by Alexander S. Konstantinov, USDA Systematic Entomology Laboratory (Beltsville, MD), and as *H. chinensis* by Zhang Runzhi, Institute of Zoology, Chinese Academy of Sciences. Voucher specimens were deposited in the Insect Reference Collection of the University of Delaware Department of Entomology and Applied Ecology (Newark, DE). All tests and developmental trials were conducted in quarantine rooms at the USDA-ARS BIIR facility at 22–23°C with a 16-h photophase.

T. griseata

Rearing and Biology. *T. griseata* was reared from August to November 1999, in screened cages (35 × 40 × 46 cm) containing potted mile-a-minute plants, replaced as needed. To determine development time of the different life stages, eggs were collected from the rearing cages and placed in 9-cm petri dishes. Upon eclosion, neonate larvae were transferred individually (using a small paintbrush) into 20 plastic condiment cups (2.5 cm diameter) and supplied with detached young mile-a-minute leaves. Leaves were changed and water was sprayed into each cup every other day. Cups were monitored daily for larval molts (presence of head capsules), pupation, and adult emergence. Three trials were conducted over a 3-mo period (September through November 1999). During all three trials, temperature and relative humidity in the quarantine room were recorded every hour using a Datapod 220 2-channel hygrothermograph (Data-Loggers, Logan, UT). In the second and third trials, upon emergence, adults were sexed (males with plumose antennae and females with filiform antennae) and transferred as pairs where possible into cardboard containers (10 cm diameter, 7 cm tall) with screen tops. Adults were provided with mile-a-minute leaves and a moist cotton wick, and checked every other day for mortality and egg production.

No-Choice Test. Eggs of *T. griseata* were collected and placed in 9-cm petri dishes. Newly hatched larvae were transferred, using a small paintbrush, into cages (28 × 28 × 28 cm) containing plants of common buckwheat, tartary buckwheat, or mile-a-minute weed. There were three cages (replicates) of each host plant with 10 larvae per cage. The larvae were placed directly on the plants, and plants were subsequently replaced as needed. Mortality and development time from hatching to adult eclosion were recorded.

Choice Test. Eggs of *T. griseata* were collected as for the no-choice test, and newly hatched larvae were transferred to cages containing three 125-ml Erlenmeyer flasks, each with a young shoot of common buckwheat, tartary buckwheat, or mile-a-minute weed, with their foliage intermeshed. The flasks were filled with water and stopped with cotton. Larvae were placed on the floor in the middle of the cage, so that they first had to climb one of the flasks before having access to plants. Once on the plants, they could easily move among the foliage of the three plant species. There were five cages (replicates) with 10 larvae per cage. The number of larvae on each plant was recorded after 2 d and again after 4 d.

H. chinensis

Rearing and Biology. *H. chinensis* was reared from July 1999 to October 2000 in screened cages (28 × 28 × 28 cm) containing potted mile-a-minute plants, replaced as needed. To determine the incubation period of eggs, 35 eggs were transferred from plants, using the tip of a syringe, into 9-cm petri dishes containing moist filter paper. Eggs were checked daily for larval eclosion.

The number of eggs laid per female was determined using isolated pairs of adult weevils. Weevils were sexed by placing them on their backs and observing the metasternum, which is more convex in the female than in the male (Charles O'Brien, Florida A&M University, Tallahassee, FL, personal communication). Pairs were placed in plastic containers (11 cm diameter and 8 cm tall) with screened areas for ventilation and a hole in the side. A 10-cm-long mile-a-minute weed stem (still attached to the plant) was inserted through the hole, which was plugged with cotton. Eggs were counted every other day, when a new stem was inserted. Four pairs were followed in the parental generation, four in the F_1 generation, five in the F_2 generation, and three in the F_3 generation.

For rearing new adults, intact mile-a-minute weed stems with *H. chinensis* eggs were inserted into a plastic container (14 cm diameter and 18 cm tall) containing 5 cm of moist vermiculite in the bottom and with a removable screen top. When larvae hatched, they bored into the stems where they completed development and then dropped down to the vermiculite to pupate. Upon emergence, adult weevils were placed in rearing cages.

To determine development time from egg to adult emergence, 10 stems with a total of 15 eggs attached were inserted into 10 separate rearing containers. The dates that eggs had been laid and adults emerged were recorded.

Adult No-Choice Test. Newly emerged adult *H. chinensis* were sexed, and single pairs were placed on individual potted plants of common buckwheat, rhubarb, or mile-a-minute weed. Each plant was enclosed in a clear Mylar cylinder (13 cm diameter and 30 cm tall), with nylon netting covering the top. There were 12 pots (replicates) of both mile-a-minute weed and buckwheat, and 5 pots of rhubarb. The pots of mile-a-minute weed and buckwheat were replaced every week, for a total of 8 wk. Because of a lack of plants, rhubarb was not replaced weekly, but was replaced when plants began to turn yellow. Mortality and oviposition were recorded weekly. To determine how long individuals could live without any plant material, four pairs of weevils were transferred into separate plastic containers (10 cm diameter and 5 cm tall) containing only a moist cotton wick, and monitored daily for mortality.

Leaf area consumed over the 8-wk test period was measured by transferring leaves of mile-a-minute weed and buckwheat to a plant press and then photocopying them onto transparencies. The transparencies were processed twice through a portable leaf area

Table 1. Duration of life stages (mean ± SEM days) of *T. griseata* on mile-a-minute weed in three trials, September–November 1999

	Larval instar				Pupal stage	Total
	1 + 2	3	4	5		
Trial 1 (Sept.)	7.7 ± 0.2a	4.1 ± 0.2a	4.0 ± 0.2a	6.0 ± 0.3a	5.1 ± 0.2b	26.6 ± 0.4a
Trial 2 (Oct.)	8.1 ± 0.5ab	3.6 ± 0.3ab	4.0 ± 0.2a	5.1 ± 0.3b	6.2 ± 0.3a	27.8 ± 0.9a
Trial 3 (Nov.)	6.8 ± 0.2b	3.0 ± 0.2b	3.6 ± 0.2a	4.9 ± 0.2b	5.8 ± 0.2a	23.4 ± 0.5b
Overall mean	7.5 ± 0.2	3.6 ± 0.1	3.9 ± 0.1	5.3 ± 0.2	5.7 ± 0.1	25.9 ± 0.4

Each trial started with 20 insects; 17, 16, and 17 survived to pupation in trials 1, 2, and 3, respectively. Means within a column followed by the same letter are not statistically different ($P < 0.05$; ANOVA, Ryan's Q test [REGWQ], SAS Institute 1989).

meter (LI-3000A; LI-COR, Lincoln, NE), before and after filling in the area eaten using a permanent black marker. Because the rhubarb leaves were too large for the leaf area meter, feeding on this species was measured by tracing the area fed upon onto clear graph paper and counting mm^2.

Larval No-Choice Test. Initial tests showed that eggs of *H. chinensis* desiccated and larvae failed to hatch if the eggs were removed from the stems where they were laid and placed directly on another plant stem. Therefore, larvae in the process of hatching or immediately after eclosion were transferred to different host plants, using a technique described by Buckingham and Bennett (1998) for a different weevil species. Using the tip of a syringe, eggs were transferred from mile-a-minute weed stems into a petri dish containing moist filter paper. After 4 d, eggs were monitored every 20 min for maturity (embryonic head capsule visible) and hatch. Hatching or newly hatched larvae were then transferred to common buckwheat, rhubarb, and mile-a-minute weed potted plants, using a small piece of moist filter paper. Each larva was placed on a separate stem, and no more than two stems were used per plant. The bottom of each stem was coated with vaseline to prevent the larva from leaving the stem. Twenty replicates were conducted for each host plant species. Larvae were observed for ≈10 min after transfer, and then checked daily for 5 d. Plant stems were dissected on day 20 to determine whether larvae had left the stems for pupation.

Adult Choice Test. Four newly emerged adult weevils per cage were transferred to the center of cages (28 × 28 × 28 cm), each containing three flasks with young shoots of common buckwheat, rhubarb, and mile-a-minute weed. The weevils were placed on the floor of the cage in the middle of the flasks, and plant foliage was intermeshed to facilitate movement among plants. Ten replicate cages were used. After 3 d, leaves were collected, and the amount of feeding on each host was quantified using the same methods as in the adult no-choice test.

Data Analysis

For both *T. griseata* and *H. chinensis*, data from no-choice and choice tests were analyzed using analysis of variance (ANOVA), followed by Ryan's Q test for mean separation (REGWQ; SAS Institute 1989). A χ^2 test was used to compare *H. chinensis* mortality on the three plant species.

Results

T. griseata

Biology and Rearing. Eggs were laid on the sides of the rearing cages and (rarely) on plants. Fertilized eggs were bright red, and unfertilized eggs were white. Larvae hatched after 48 h and fed on young mile-a-minute leaves, eventually moving onto older leaves. Pupation took place on the plants or in the corners of the cage.

Duration of life stages of *T. griseata* reared individually in plastic containers on mile-a-minute leaves in three trials is shown in Table 1. Total time from larval eclosion to adult emergence averaged 25.9 ± 0.4 (mean ± SEM) d. There were, however, significant differences in larval and pupal developmental rates among the three trials (Table 1). Temperature did not differ significantly among trials, averaging 22.4, 21.5, and 22.1°C for trials 1, 2, and 3, respectively. Adults from trials 2 and 3 survived an average of 11.3 ± 0.9 d ($n = 25$) when kept in pairs in small containers, but laid very few eggs.

No-Choice Test. When placed on a single species of host plant, larvae of *T. griseata* completely defoliated mile-a-minute weed, common buckwheat, and tartary buckwheat. They completed their development to the adult stage on all three host species, with no difference in survival or development time on the different hosts (Table 2).

Choice Test. Neonate larvae given a choice of three host plant sprigs in Erlenmeyer flasks quickly climbed up one of the flasks (apparently chosen at random) and began to feed on the first foliage they encountered. Larvae were never observed to move to a different plant, and were distributed evenly among the three host species after 2 and 4 d (Table 2; numbers of larvae on each plant in each replicate cage were identical on days 2 and 4).

H. chinensis

Biology and Rearing. Adults of *H. chinensis* fed on young leaves of mile-a-minute weed in the rearing cages and laid eggs on the undersides of leaves and on stems. After hatching, larvae crawled down the stem to the first unoccupied node and bored into the stem, leaving frass visible at the point of entry. By the time the larvae left the stem to drop to the soil for pupation, their feeding had killed the stem from the exit hole to the stem terminal. Adult weevils were black upon

Table 2. ***T. griseata*** **survival and development time (larval hatch to adult emergence) on three host plants, and larval host choice after 4 days**

Host plant	Survival (mean ± SEM)[a]	Development time (mean days ± SEM)[a]	No. of larvae (mean ± SEM)[b]
Common buckwheat	8.7 ± 0.3	23.1 ± 0.1	2.8 ± 1.0
Tartary buckwheat	9.3 ± 0.7	23.0 ± 0.2	3.6 ± 0.8
Mile-a-minute weed	9.3 ± 0.3	22.8 ± 0.6	3.6 ± 0.8

[a] $n = 3$ replicate cages with 10 larvae per cage for each host plant; $F = 0.47$, $P = 0.6553$, and $F = 0.09$, $P = 0.9118$, based on ANOVA of the effect of host plants on mean survival and development time, respectively.

[b] $n = 5$ replicate cages with 10 neonate larvae per cage (each cage containing all three host plants); $F = 0.30$, $P = 0.7489$, based on ANOVA of the effect of host plants on larval host choice.

emergence from the vermiculite, but turned orange-brown soon after feeding on mile-a-minute weed, apparently because of staining from mile-a-minute weed exudate (weevils that fed on other plant species remained black even after several weeks, and exudate from cut mile-a-minute stems and foliage produced orange-brown stains on clothing).

Weekly egg production per female averaged 9.8 ± 1.1 for the parental generation; 11.5 ± 1.3 for the F_1 generation; 6.5 ± 0.5 for the F_2 generation; and 1.7 ± 0.5 for the F_3 generation (Fig. 1). Total eggs laid per female over one season averaged 66.8 ± 23.0, 230.8 ± 52.5, 89.8 ± 28.2, and 20.0 ± 7.6 for the parental, F_1, F_2, and F_3 generations, respectively.

On moist filter paper in petri dishes, larvae hatched in 5.4 ± 0.1 d ($n = 30$). The total development time (egg to adult) of *H. chinensis* reared on mile-a-minute weed averaged 26.4 ± 0.3 d ($n = 15$). Most adults from the first year (October 1999) lived until August 2000, and a few until late September 2000. Survival rate from egg to adult was 54.5% (121 of 222).

Adult No-Choice Test. When given only one species of host plant, adult female *H. chinensis* laid an average of 16.4 ± 1.1 eggs per female per week on mile-a-minute plants, for a total of 131.2 ± 15.1 over the 8-wk test period (Fig. 2). No eggs were laid on common buckwheat or on rhubarb plants. Significantly more mile-a-minute weed foliage was consumed than the other host species (Table 3), and more mile-a-minute than buckwheat foliage was consumed each week (Fig. 3). Although a higher percentage of beetles died over the 8-wk test period on rhubarb (4 of 10, or 40%) and buckwheat (8 of 24, or 33.3%) than on mile-a-minute weed (3 of 24, or 12.5%), this difference was not significant ($\chi^2 = 3.187$, $P > 0.05$). Weevils provided with moist cotton wicks, but no plants, survived an average of only 8.3 ± 1.5 d ($n = 8$).

Larval No-Choice Test. Survival of *H. chinensis* transferred as neonates onto mile-a-minute weed was 75% at day 20, while all larvae transferred onto common buckwheat and rhubarb plants died within 1 d (Table 3). Larvae were observed crawling on these plants, but they did not bore into the stems to feed. Larvae placed on mile-a-minute weed generally crawled down and bored into the stem within ≈10 min of transfer.

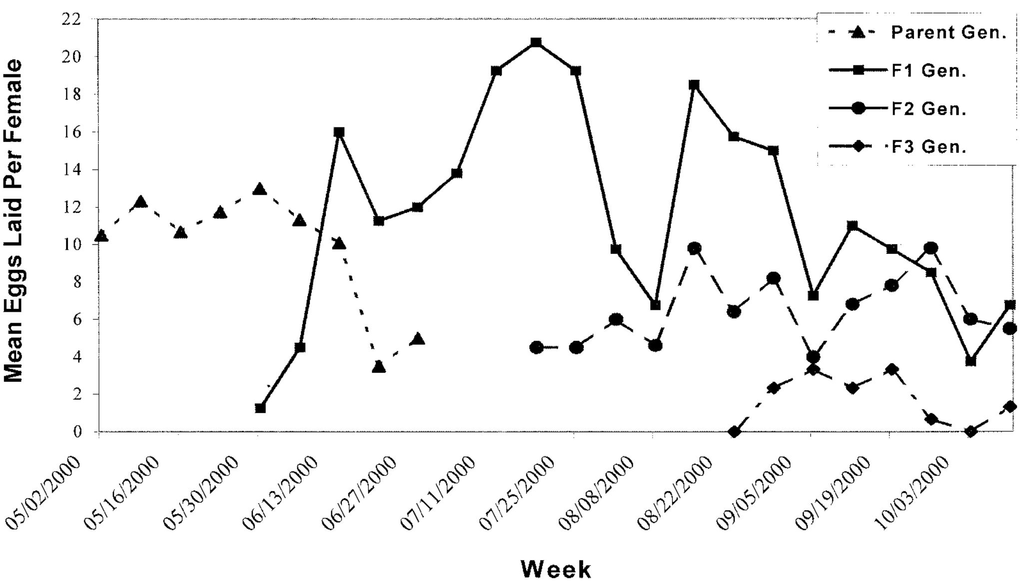

Fig. 1. Mean number of eggs laid over an entire season by *H. chinensis* on mile-a-minute weed. Parent generation $n = 4$, F_1 generation $n = 4$, F_2 generation $n = 5$, and F_3 generation $n = 3$ females. Eggs were counted every other day, but totals for each week are shown.

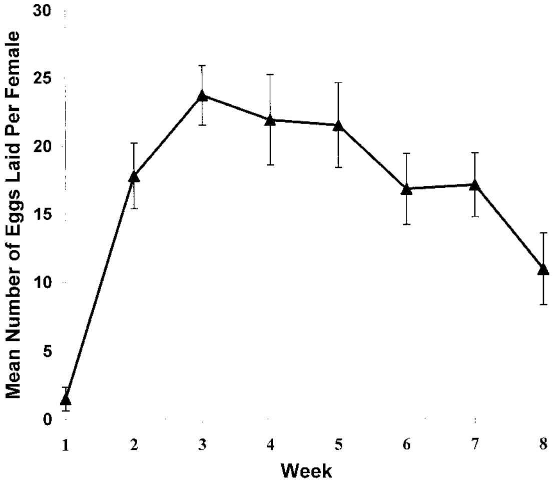

Fig. 2. Eggs laid per female per week on mile-a-minute weed during no-choice feeding and oviposition test with *H. chinensis*. The $n = 10$ pairs were in separate cages; in two additional cages, females died during the test and were therefore not included. Error bars indicate standard error. No eggs were laid on buckwheat or rhubarb.

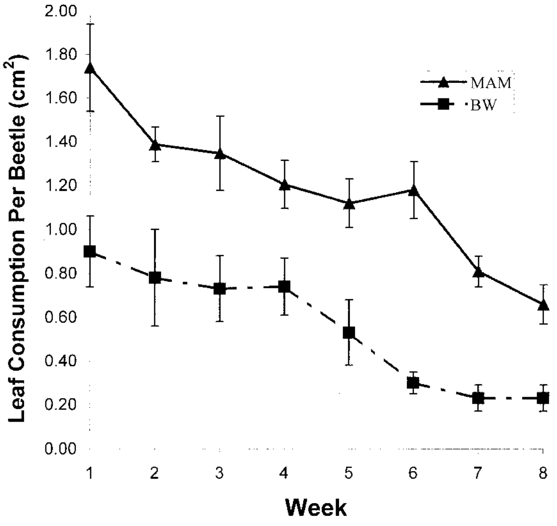

Fig. 3. Weekly consumption of mile-a-minute weed (MAM) and buckwheat (BW) by *H. chinensis* adults in no-choice test. Error bars indicate standard error.

Adult Choice Test. Given a choice of three host plants, four weevils per cage consumed an average of 1.24 ± 0.16 cm^2 of mile-a-minute weed foliage in 3 d. A total of 4 of the 10 cage replicates showed some feeding on buckwheat as well as on mile-a-minute, but average consumption of buckwheat per cage was only 0.03 ± 0.02 cm^2, <3% of that of mile-a-minute. No feeding occurred on rhubarb in the choice test.

Discussion

The life history described in this study for *T. griseata* reared in a quarantine room is similar to its biology as described under natural conditions in Europe and in China, except for the observation that most eggs were laid on the sides of the rearing cages rather than on plants in our studies. It is common for moths in confinement to lay a large proportion of their eggs on the walls, even when the cages are relatively large (Ramaswamy 1988, Eigenbrode and Bernays 1997). In the field, *T. griseata* probably lays its eggs on or near its host plants. Although other geometrid moth species have been reported to lay eggs when collected in the field and then confined in 50-ml plastic vials (Tammaru and Javoiš 2000), in our studies *T. griseata* laid few eggs when kept in pairs in small containers, possibly because of failure to mate because of lack of appropriate substrate or space.

Table 3. Total (8-wk) consumption of foliage by adult *H. chinensis* in no-choice test on three plant species, and survival of *H. chinensis* larvae placed on three plant species as neonates

Host plant	Cm^2 consumed per beetle (mean ± SEM)[a]	Survival (%)[b]		
		Day 1	Day 5	Day 20
Mile-a-minute weed	9.4 ± 0.5a	100	80	75
Rhubarb	6.5 ± 2.3b	0	—	—
Common buckwheat	4.4 ± 0.4b	0	—	—

[a] Twelve replicates (two adult weevils per replicate) were initiated for buckwheat and mile-a-minute weed and five replicates for rhubarb; however, due to early mortality, fewer replicates were used to analyze consumption data for buckwheat ($n = 10$) and rhubarb ($n = 3$). Amount consumed was determined by cm^2 eaten/number of beetles in each cage per week. Means followed by a different letter are statistically different ($F = 17.92$, $P < 0.0001$; ANOVA, Ryan's Q Test [REGWQ], SAS Institute 1989).

[b] $n = 20$ neonates per plant species.

T. griseata is not a significant pest of buckwheat or other crops in China (Jianqing et al. 2000) or in Europe (South 1980, Skou 1986, Skinner 1998), but it is known to feed on a number of *Polygonum* and *Rumex* species in Europe. It is often found in gardens, but rarely in large numbers (Skou 1986). In our studies, *T. griseata* was easily reared on potted mile-a-minute, completing development in ≈26 d and rapidly defoliating the plants. However, it also defoliated and completed its life cycle on common buckwheat and tartary buckwheat, and is therefore not a good candidate for release as a biological control agent in the United States.

H. chinensis was more difficult to rear and study, because eggs were affixed to stems and leaves (and could not be moved to another plant without desiccating), and larvae bored into the stems shortly after hatching. Adult *H. chinensis* did not oviposit on either common buckwheat or rhubarb under no-choice conditions over 8 wk, but consumed some foliage of both crop species. During cage tests, if an insect is confined with a nonhost plant species only, it may eventually accept the plant after habituation to feeding deterrents (Jermy et al. 1982, Marohasy 1998). More than half of the adult weevils kept on buckwheat and rhubarb survived for 8 wk, suggesting that these plants did provide some nutritional value. Weevils given a source of water, but no plant material, all died within 1–2 wk.

When given a choice among mile-a-minute weed, buckwheat, and rhubarb, the weevils strongly preferred mile-a-minute weed. Because the larvae of *H. chinensis* develop internally in mile-a-minute weed stems, they have no effective mechanism of host selection, and therefore the host range of this weevil will most strongly reflect the choices made by the ovipositing adults. However, even when larvae were transferred onto buckwheat or rhubarb as neonates, they were unable to survive. We conclude that buckwheat and rhubarb are not within the physiological host range of *H. chinensis.*

H. chinensis was shown to have a reasonably high reproductive rate (ranging from 20 to over 130 eggs per female) and short generation time (≈26 d). In the tests to determine reproduction over four generations, egg laying decreased substantially in the F_3 generation, in September and October, possibly because of decline in host quality. *T. griseata* development time also varied somewhat in trials conducted at different times. Seasonal phenologically related changes in the nutritional quality and secondary substances of host plants have been reported to affect basic biology (e.g., reproductive capacity and longevity) of herbivorous insects (Raupp and Denno 1983). Although not evaluated in this study, such factors may account for the observed differences among the trials.

Adult *H. chinensis* were quite long-lived, with some surviving nearly a year. Internal feeding by each larva caused mortality of an entire stem, indicating possibly severe impact on plant growth and plant reproduction because of death of stem terminals. The potential effect on plant reproduction is an important consideration, given the annual life history of mile-a-minute weed, and must be critically examined.

While results suggest that *H. chinensis* may be highly specific to mile-a-minute weed, further testing needs to be conducted to determine whether release and establishment of this species might adversely affect ornamental or native Polygonaceae, especially threatened and endangered species. A complete set of test plants is being developed, based on suggestions by the USDA-APHIS Technical Advisory Group for Biological Control Agents of Weeds.

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