Effect of Temperature and Host Plant on Survival and Development of *Altica litigata* Fall[1]

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Abstract *Altica litigata* Fall (Coleoptera: Chrysomelidae) is oligophagus, feeding on numerous plants in the Lythraceae and Onagraceae families which include weeds and cultivated plants, such as primroses (*Oenothera* spp.) often found in commercial nurseries. Adult *A. litigata* are important pests of crapemyrtles (*Lagerstroemia* spp.; Lythraceae) grown in container nurseries in the southern United States. The severity of the pest problem attributed to feeding by these beetles has increased substantially during the past decade. Whereas commonly recommended pesticides easily control these beetles, knowing when to time applications to avoid large defoliation events could focus scouting efforts and prevent economic loss.

The objective of our research was to define more closely the relationship between temperature, host plant and development of *A. litigata* to permit prediction of damaging stages of the beetle on landscape and nursery plants. *A. litigata* completed development between 15 and 30°C on six weedy or cultivated hosts: *Gaura lindheimeri* Engelman & A. Gray 'Siskyou pink', *G. lindheimeri* 'Corries gold', *G. lindheimeri* 'Whirling butterflies', *Oenothera speciosa* Nutt., *Oenothera laciniata* J. Hill and *Oenothera missourensis*_Simms. Development was optimal on *Oenothera* spp. Duration of development from eclosion to adult emergence ranged from 13.3 d at 30°C on *O. speciosa* to 64.0 d at 15°C on *G. lindeimeri* 'Whirling butterflies.' Duration of egg development ranged from 4.5 d at 30°C to 15.8 d at 15°C. The relationship between temperature and rate of development was expressed as a linear thermal unit model for each stage and for combined larval/pupal development. Development parameters varied with host plant. Averaged among the six hosts, larval and pupal development required 237.3 degree-days (DD) above a threshold of 9.2°C. Eggs required 87.5 DD above a 9.8°C threshold. Observation of beetles or feeding injury on indicator plants such as weedy or cultivated *Oenothera* spp. in late winter or early spring can alert nursery or landscape managers to anticipate a new generation within 300-400 DD above the approximate 10°C developmental threshold used for many DD calculator models for landscape and nursery pests.

Key Words *Oenothera* spp., *Gaura* spp., *Lagerstroemia* spp., flea beetle, temperature, development, ornamentals

Altica litigata Fall (Coleoptera: Chrysomelidae) is oligophagus, feeding on numerous plants in the Lythraceae and Onagraceae families which include weeds and cultivated plants, such as primroses (*Oenothera* spp.). These plants often can be found in commercial nurseries. Adult beetles are 3-5 mm long and are a metallic blue to blue-green with enlarged hind femora, which allow them to jump and scatter from

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plants when disturbed. Adult *A. litigata* are important pests of crape myrtles (*Lagerstroemia* spp.; Lythraceae) grown in container nurseries in the southern United States (Cabrera et al. 2003, Pettis et al. 2004). Adults emerge from overwintering pupal cells in the ground as sexually mature adults and fly to suitable ovipositional host plants such as the weed, *O. laciniata* J. Hill (cutleaf evening primrose), or the herbaceous perennials, *O. speciosa* Nutt. (Showy primrose), and *O. missourensis* Simms (Missouri primrose). *Gaura lindheimeri* Engelman & A. Gray cultivars are also attacked (Schultz et al. 2001). Adults may migrate to crape myrtle plants as secondary hosts and damage plants by chewing small holes in the leaves. Beetles may defoliate entire crape myrtle plants, leaving only stems and the mid-veins of leaves (Pounders et al. 2004). Oviposition typically does not occur on crapemyrtles. Mated females lay eggs in clusters of 1-15 on the upper and lower surfaces of leaves of herbaceous plants on which the larvae feed after hatching. Once the larvae have reached the third stadium, they migrate to the base of the plant where the larvae burrow 1-2 cm into the soil and create a pupal chamber where molting occurs. Approximately 2-3 generations per year occur in areas in which crape myrtles are extensively grown (LeSage 1995).

The severity of the pest problem attributed to feeding by these beetles has increased substantially during the past decade. The increasing availability of suitable food sources and oviposition hosts in nurseries and landscapes may have supported *A. litigata*'s population increase, as has been reported for other chrysomelid beetles (Braman and Corley 1996, Braman et al. 2002). *Phaedon desotonus* Balsbaugh, a chrysomelid previously considered rare (Wheeler and Hoebeke 2001), is currently abundant and damaging in nursery and landscape plantings of *Coreopsis* spp. (Braman and Corley 1996, Braman et al. 2002).

Improved management of *A. litigata* on crapemyrtle and other high value ornamentals requires knowledge of developmental biology as affected by the variety of plants that may serve as developmental hosts. Outbreaks of adult beetles on Lythraceae and Onagraceae in commercial nurseries are sudden and can be quite severe. Hundreds of plants may be defoliated in a 24-h period (Byers 1997). Knowledge of the development of *Altica* spp. flea beetles may optimize management of this pest by improving the nursery producer's ability to predict outbreaks. Whereas commonly recommended pesticides easily control these beetles, knowing when to time applications to avoid large defoliation events could focus scouting efforts and prevent economic loss.

The objective of our research was to define more closely the relationship between temperature, host plant and development of *A. litigata* to permit prediction of damaging stages of the beetle on landscape and nursery plants. The degree-day (DD) approach in predicting phenology of ornamental plant pests has been implemented with success for other ornamental plant pests (e.g., Potter and Timmons 1983, Braman et al. 1992, Herms 2004). Here, we provide thermal unit models for development of *A. litigata* reared on six potential host plants commonly found in or near commercial nurseries.

Materials and Methods

Temperature effects on development of *Altica litigata* on a single host (Trial 1). Duration of development of eggs, larvae and pupae of *A. litigata* was measured at four constant temperatures: 15, 20, 25 and 30°C [all ± 0.5°C and 14:10 (L:D) photoperiod]. F_1 progeny of field-collected adults were used. Adults were collected from naturalized stands of *O. speciosa* and *O. laciniata* in Pike and Spalding counties, GA. Adults were confined to *O. speciosa* cuttings to meet moisture and food requirements and for oviposition in plastic rearing cages described by Klingeman et al. (2001). Eggs deposited during a 24-h period at 24°C were moved to *G. lindheimeri* 'Whirling butterflies' cuttings using a fine sable hair paintbrush (number 0). Our observations of heavy populations of beetles on this plant in landscape and in nursery settings prompted its use in the study. Each 4-5 cm long cutting of *G. lindheimeri*_'Whirling butterflies' which had been grown in pots in a screen house in Griffin, GA, was placed in a clear plastic Petri dish (9 × 1.5 cm) with a friction- fitting lid. Moistened, autoclaved playground sand was placed in the container at a depth of approx. 3 mm, and the stems of the horizontally placed cuttings were pressed into the damp sand to maintain plant turgor. Ten Petri dishes with 10 eggs each (initial $n = 100$) were held at each temperature. Dishes were checked every 24 h for eclosion, pupation and adult emergence of the insects.

Host effects on development of *Altica litigata* at three temperatures (Trial 2). Developmental times for larvae and pupae of *A. litigata* were compared among six host plants at three temperatures. Temperatures were 15, 25 and 30°C [all ± 0.5°C and 14:10 (L:D) photoperiod]. Host plants were *Gaura lindheimeri* 'Siskiyou pink', *G. lindheimeri* 'Corries gold', *G. lindheimeri* 'Whirling butterflies', *Oenothera speciosa*, *O. laciniata* and *O. missourensis*. F_1 progeny of adults collected from *O. speciosa* in Spalding Co., GA, were used. Moist autoclaved playground sand was placed at a depth of approx. 1 cm in the bottom of 32-ml translucent plastic cups. Stems of a 2-3 cm cutting of each of the 6 host plants were pressed into the moist sand to maintain leaf turgor. One newly-eclosed first-instar larva was placed on the cutting in each container. Clear plastic snap type lids were used to prevent escape of the beetle larvae. Cups were checked every 24 h for beetle pupation and adult emergence. Each temperature by host plant combination was replicated between 8 and 25 times.

Statistical analyses and thermal unit model. In all trials, unless otherwise specified, data were subjected to ANOVA using the GLM procedure, and mean separations were performed using Fisher's least significant difference test (SAS Institute 2003). To express the relationship between development and temperature, the reciprocal of development time, in days, was regressed on temperature using a linear least squares technique (Steel and Torrie 1960). Temperature thresholds (T_o) for each stage were determined by extrapolation of the regression line to the abscissa. Mean thermal unit requirements (K) for each stage were calculated by taking the mean (across all temperatures) of K_t which was calculated by the following equation:

$$K_t = (T - T_o) * D_t$$

where T = 15, 20, 25, or 30; T_o = temperature threshold for a particular stage; D_t = mean development time (in days) for a particular stage at temperature T.

Results

Temperature effects on development of *Altica litigata* on a single host (Trial 1). Although eggs hatched at 15°C, no beetles completed development at this temperature when *G. lindheimeri* was the host (Table 1). *Altica litigata* completed development on this host at 20, 25 and 30°C. Duration of development of the egg stage varied with temperature ($F = 156.46$; df = 9, 3; $P < 0.0001$) from 4.5-15.8 d. Larval development required from 12.1-36.2 d ($F = 29.67$; df = 9, 2; $P < 0.0001$), whereas

Table 1. Mean (± se) duration (days) of development of *A. litigata* (Coleoptera: Chrysomelidae) on *G. lindheimeri* 'Whirling butterflies' (Trial 1)

Temp (°C)	Egg*	Larva	Pupa	Total
15	15.8 ± 0.4 a	—**	—	—
20	9.3 ± 0.2 b	36.2 ± 1.1 a	14.3 ± 1.2 a	59.0 ± 0.6 a
25	5.2 ± 0.1 c	17.2 ± 1.0 b	7.1 ± 0.3 b	28.8 ± 1.0 b
30	4.5 ± 0.2 d	12.1 ± 0.3 c	5.8 ± 0.7 b	22.5 ± 0.8 c

* Means not followed by the same letter within a column are significantly different ($P < 0.05$) as determined by Fisher's protected least significant difference (LSD) mean separation test.

** No survival.

time spent in the pupal stage ranged from 5.8-14.3 d ($F = 6.31$; df = 9, 2; $P = 0.0449$). Almost 2 months were required to complete the life cycle at 20°C, whereas less than 1 month was necessary at 25 or 30°C ($F = 24.54$; df = 15; $P = 0.0036$).

Host effects on development of *Altica litigata* at three temperatures (Trial 2). Duration of larval development varied with host plant ($F = 18.0$; df = 17, 5; $P = 0.0001$) and temperature ($F = 950.0$; df = 17,2; $P = 0.0001$) with a significant interaction ($F = 6.6$; df = 17,9; $P = 0.0001$). Pupal development was influenced more by temperature ($F = 55.5$; df = 17, 2; $P = 0.0001$) than by host ($F = 1.0$; df = 17, 5; $P = 0.40$), although a significant interaction was observed ($F = 2.6$; df = 17,9; $P = 0.01$). Complete development also varied with host plant ($F = 9.5$; df = 17, 5; $P = 0.0001$) and temperature ($F = 899.1$; df = 17, 2; $P = 0.0001$) with a significant interaction ($F = 2.1$; df = 17,9; $P = 0.03$). Development was, therefore, compared within each temperature and host plant combination (Table 2). Duration of larval development ranged from 9.9 d on *O. missourensis* at 30°C to 53.0 d on *G. lindheimeri* 'Whirling butterflies' at 15°C. Pupal development was most rapid (3.2 d) at 30°C when larvae had fed on *O. speciosa*, and longest (13.0 d) at 15°C on *O. missourensis.* Complete development ranged from 13.3 d at 30°C on *O. speciosa* to 64.0 d at 15°C on *G. lindheimeri* 'Whirling butterflies.' Survival (Table 2) was least on *G. lindheimeri*_'Siskiyou Pink' (25.6% averaged among temperatures) and greatest on *O. speciosa* (69.8% averaged among temperatures). On the more suitable hosts, *O. speciosa* and *O. missourensis* survival was greatest at 30°C (>90%). Survival on all other hosts was greatest at 25°C and always poorest at 15°C.

Thermal unit models. Regression equations for the reciprocal of development times on temperature for each life stage, and values for T_o and K differed when development was averaged among multiple hosts rather than based on that which occurred on a single host (Table 3). T_o values for larval, pupal and complete development derived from trial 1 data on a single host plant cultivar, *G. lindheimeri* 'Whirling butterflies', were considerably higher than the same values derived from combined trial 2 data that included development on apparently more suitable hosts (*Oenothera* spp.). During trial 1, development was arrested at 15°C, although some larvae survived to the point of burrowing into the sandy substrate prior to pupation, and the base temperature of 14.45°C reflects this occurrence. During trial 2, some survival at 15°C did occur, even on *Gaura* cultivars, and was as high as 50% on *O. missourensis*, although development was considerably prolonged at this temperature. The lower

Table 2. Host plant and temperature influences on development and survival of *Altica litigata* (Coleoptera: Chrysomelidae) (Trial 2)

Temp (°C)	*G. lindheimeri* 'Whirling butterflies'*	*G. lindheimeri* 'Corries Gold'	*G. lindheimeri* 'Siskiyou Pink'	*O. speciosa*	*O. laciniata*	*O. missourensis*
Mean (± se) Larval Development Time (days)						
15	53.0 ± 0 Aa	46.0 ABa	—***	40.7 ± 1.8 BCa	35.0 ± 0 Ca	39.3 ± 1.8 (7)BCa
25	16.0 ± 0.6 Bb	15.8 ± 1.1 Bb	17.0 ± 0 B	10.7 ± 0.2 Ab	11.3 ± 0.3 Ab	10.4 ± 0.2 (16)Ab
30	11.0 ± 0 ABc	12.0 ± 0 Ab	10.0 ± 0 BC	9.7 ± 0.1 Cb	10.3 ± 0.3 BCc	9.9 ± 0.2 (18)BCb
Mean (± se) Pupal Development Time (days)						
15	11.0 ± 0 Aa	11.0 ± 0 Aa	—	12.3 ± 0.3 Aa	11.0 Aa	13.0 ± 1.3 (7)Aa
25	4.5 ± 0.3 Ac	4.2 ± 0.5 Aa	4.0 ± 0 Aa	5.4 ± 0.7 Ab	6.2 ± 0.6 Aa	6.1 ± 0.3 (16)Ab
30	8.0 ± 1 Ab	4.0 ± 0 Ba	6.0 ± 3 ABa	3.2 ± 0.2 Bc	3.7 ± 0.3 Ba	4.2 ± 0.5 (18)Bc
Mean (± se) Complete (larval/pupal) Development Time (days)						
15	64.0 ± 0 Aa	57.0 ± 0 Ba	—***	47.4 ± 4.6 BCa	49.5 ± 3.5 Ca	52.3 ± 1.4 BCa
	(33.3)**	(11.1)		(48.0)	(22.2)	(50.0)
25	20.5 ± 0.3 Bb	20.0 ± 0.6 Bb	20.0 ± 0 Bb	16.1 ± 0.5 Ab	17.9 ± 0.5 Ab	16.5 ± 0.3 Ab
	(50.0)	(75.0)	(50.0)	(70.0)	(58.3)	(68.0)
30	19.0 ± 1.0 Ab	15.3 ± 0.3 BCb	17.0 ± 2 ABb	13.3 ± 0.4 Cb	14.0 ± 0 BCb	14.1 ± 0.4 Cc
	(25.0)	(37.5)	(15.8)	(91.3)	(23.0)	(90.0)

* Means not followed by the same capital letter in a row or the same small letter within a column are significantly different ($P < 0.05$) as determined by Fisher's protected least significant difference (LSD) mean separation test.

** Numbers in parentheses are percent survival.

*** No survival.

Table 3. Linear thermal unit models, threshold temperatures (T_o) and mean thermal unit requirements (K) for development of each stage of *Altica litigata* Fall

Stage	Equation and R^2	T_0 °C	K,DD
Trial 1 (reared on *G. lindheimeri* 'Whirling butterflies')			
Egg	$Y^* + 0.011t - 0.11$		
	$R^2 = .93$	9.71	87.52
Larval	$Y = 0.01t - 0.08$		
	$R^2 = .91$	14.45	190.18
Pupal	$Y = 0.01t - 0.14$		
	$R^2 = .62$	12.76	96.97
Egg eclosion	$Y = 0.003t - 0.05$		
through pupation	$R^2 = .87$	13.36	301.63
Complete	$Y = 0.003t - 0.03$		
	$R^2 = .89$	12.69	391.76
Trial 2 (average development over six hosts)			
Egg**	**	**	**
Larval	$Y = 0.005t - 0.05$		
	$R^2 = 0.83$	9.19	213.17
Pupal	$Y = 0.01t - 0.14$		
	$R^2 = .37$	9.83	75.22
Eclosion to pupation	$Y = 0.003t - 0.03$		
	$R^2 = 0.85$	9.20	237.35

* Y = reciprocal of mean developmental times; t = temperature; R^2 = coefficient of correlation.

** Data for days for eggs to develop were not collected in this trial.

thresholds of 9.2 (larval), 9.8 (pupal) and 9.2 (eclosion to pupation) are more similar to the 9.7 (egg) developmental threshold calculated from trial 1 data where egg hatch did occur at 15°C.

Discussion

The F_1 progeny of *A. litigata* collected from *Oenothera* spp. developed successfully at constant temperatures ranging from 15-30°C on *Oenothera* spp., but were less able to develop at 15°C on *G. lindheimeri* cultivars. It is possible that the prior parental host relationship affected the success of larvae on *Gaura*. All the potential hosts included in this study are well represented in nurseries, landscapes and wildflower plant mixes, where these highly mobile beetles have access to multiple food and oviposition hosts. A wide range in plant damage and larval survival were demonstrated by *A. litigata* feeding on 12 genotypes of field- grown *Oenothera* and *Calylophus* spp. (sundrops) (McKenney et al. 2003). In a study in Virginia (Schultz et al. 2001), flea beetle adults first appeared on May 24, 2000 with highest beetle numbers on May 31. That study evaluated three cultivars of *Oenothera* and found 'Sundrops' had the highest number of beetles. Foliar damage was highest on *Oenothera* 'Siskiyou.' During 2001, beetles first appeared on 'Sundrops,' but highest numbers occurred in *Guara* on June 3.

Anecdotal information from (Georgia) growers indicates that beetles are often first observed on Missouri primrose, *O. missourensis*. This species was among the most suitable for the beetle in this study with a high survival rate and short developmental times similar to Showy primrose, *O. speciosa*. We have observed larvae feeding in abundance on Showy primrose in March in the landscape and in roadside wildflower plots. Beetles that attack new growth on crapemyrtles in May and June are probably second- generation adults. Whirling butterflies and other *Gaura* cultivars are also commonly infested in late spring through mid summer. Beetle activity declines during the late- summer months. However, perennial plant growers recently have been treating high populations on susceptible plants as late as October in north Georgia.

Sufficient thermal units accumulate in central and north Georgia (average of 4,845 DD above a threshold of 10°C during the last 4 y from 1 January to 31 October in Griffin, GA) for several generations of the beetle to occur. The apparent summer aestivation may in some situations precede feeding by a final fall generation before overwintering. Observation of beetles or feeding injury on indicator plants such as weedy or cultivated *Oenothera* spp. in late winter or early spring can alert nursery or landscape managers to anticipate a new generation within 300-400 DD above an approximate 10°C developmental threshold.

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