Influence of Temperature on the Ovipositional Biology of the Redbanded Leafroller and Tufted Apple Bud Moth (Lepidoptera: Tortricidae)[1]

G. C. Rock and R. E. Stinner

Department of Entomology, North Carolina State University
Raleigh, NC 27695

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ABSTRACT Effects of constant temperatures of 10, 15, 20, 25, 30 and 35°C on the preoviposition period and the effects of a constant 25°C on oviposition, fecundity, and longevity of the redbanded leafroller, *Argyrotaenia velutinana* (Walker), and the tufted apple bud moth, *Platynota idaeusalis* (Walker), were investigated. Oviposition did not occur at 35°C for either species and only the redbanded leafroller oviposited at 10°C. The threshold for oviposition for RBLR was calculated to be 8.7°C with 29.4 DD necessary for oviposition, while the oviposition threshold for TABM was calculated to be 10.5°C with 33.5 DD needed for oviposition. The mean oviposition periods for the two species did not differ; however, tufted apple bud moth longevity was significantly greater at 25°C. Fecundity was greater for the tufted apple bud moth (301 eggs/female) than for the redbanded leafroller (221 eggs/female).

KEY WORDS Insecta, *Argyrotaenia velutinana*, *Platynota idaeusalis*, reproduction, oviposition

The redbanded leafroller, *Argyrotaenia velutinana* (Walker), and the tufted apple bud moth, *Platynota idaeusalis* (Walker), are major pests of apple in North Carolina (Shaffer & Rock 1983). Thermal requirements for egg, larval and pupal development have been calculated for the redbanded leafroller (Hawthorne et al. 1988) and the tufted apple bud moth (Boyne et al. 1985). Thermoperiodic effects on larval development and the regulation of larval diapause have been shown for the tufted apple bud moth (Rock 1983, 1985), while similar studies have not been reported for the redbanded leafroller. Several studies on the reproductive biology of the female redbanded leafroller, under insectary conditions, have been reported (Frost 1925, Hough 1927, Long 1953); however, studies on the reproductive biology have not been conducted for the tufted apple bud moth.

The purpose of this research was to study the reproductive biology of the two tortricid species, including oviposition thermal requirements and temperature thresholds, fecundity and longevity. These data are of significance in providing basic reproductive information needed to develop field phenology and simulation models for the species.

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Materials and Methods

Insect Colonies. A laboratory colony of the redbanded leafroller was reared on fava bean plants (*Vicia faba* L.) using the methods described by Glass and Hervey (1962); a laboratory colony of the tufted apple bud moth was reared on a lima bean-based semisynthetic diet as described by Rock and Monroe (1983). The initial stocks of both insect species were collected from apple orchards near Hendersonville, NC (35° 20′ N lat. 82° 28′ W long., elev. 700 m) and were maintained under laboratory conditions ca. six months prior to beginning the study.

Temperature Effects on Oviposition. Redbanded leafroller and tufted apple bud moth pupae (one- or two-days old) were held in separate Petri dishes at room temperature (ca. 24°C) under continuous illumination. Continuous illumination was provided so that newly emerged adults would be exposed to the same photoperiod prior to being placed in an enviornmental control chamber. For each species, newly emerged moths (< 16 h from emergence, one female and two males) were held together in a clear polyethylene bag (20 × 2.7 × 37.5 cm). Polyethylene bags have been used to study the reproduction of adult torticids (Howell 1981). The influence of constant temperatures on oviposition was determined at 10, 15, 20, 25, 30 and 35°C under a photoperiod of 16:8 (L:D) in environmental control chambers (Persival Manufacturing Col., Boone, IA). The moths were provided with cotton soaked in a 20% sucrose-water solution for food, as well as to maintain relative humidity > 50% within the polyethylene bags. Beginning in the morning, the moths were observed several times daily for first egg deposition and the first egg mass oviposited on the bags was cut from the bags, eggs per mass counted with a binocular microscope, placed in a shell vial stoppered with cotton, and the eggs than held under high relative humidity (>85%) at constant 27°C (16L:8D photoperiod) until complete hatch. If two or more egg masses were oviposited on the first day of oviposition, then the eggs per mass were averaged for that day. Infertile egg masses or masses with less than six eggs were not included in data analysis, since these egg masses were observed at all temperature regimes and when combined accounted for < 5% of the total egg masses. Seventeen to 25 females were used at each temperature for each species. Females were observed until either oviposition or death occurred; new males from the laboratory colony were added when male death occurred. Length of the preoviposition period and the number of eggs per mass for the first oviposited egg mass were recorded for each female. The data were subjected to analysis of variance and Duncan's multiple range test (Proc. GLM, SAS Institute 1982).

Oviposition, Fecundity and Longevity at 25°C. Adults were set up as described above and held at constant 25°C (16L:8D photoperiod) in the environmental control chambers. The moths were examined several times daily and egg masses oviposited were cut daily from the polyethylene bag and held individually in shell vials as described above. When necessary, females and males were transferred to new bags until death of the females; new males from the laboratory colony were added if needed. The variables measured were female longevity, preoviposition and oviposition periods, and fecundity. Variable differences between the two species were analyzed using t-tests (SAS Institute 1982).

Threshold Calculations. The rates (1/time) for the preoviposition periods were regressed (Proc. GLM, SAS Institute 1982) against temperatue (10, 15, 20, 25 and 30°C for the redbanded leafroller and 15, 20, 25 and 30°C for the tufted apple bud moth). Degree day (DD) requirements for oviposition (inverse of the slope) and the low temperature threshold for oviposition (x-intercept) were calculated from the regression equations.

Results And Discussion

Temperature significantly affected the length of preoviposition for both redbanded leafroller and tufted apple bud moth, with cool temperatures of 10 or 15°C either preventing oviposition or prolonging preoviposition (Table 1). Oviposition did not occur at 35°C for either species and only redbanded leafroller oviposited at 10°C. At 35°C, redbanded leafroller females died within three to seven days and tufted apple bud moth females died within two to eight days. At 10°C, 16 of 20 tufted apple bud moth females were alive at 70 d without oviposition, at which time the test was terminated. All 23 redbanded leafroller females held at 10°C were dead by 53 d. Temperatures between 15 to 30°C did not significantly effect size of the first egg mass oviposited by redbanded leafroller or tufted apple bud moth.

Table 1. Effect of temperature on the ovipositional characteristics of redbanded leafroller and tufted apple bud moth.

						First day of oviposition*	
	Temp.	No.	No. females	Preoviposition period (days)*		$\bar{X}$ egg masses/	$\bar{X}$ (±SEM)
Insect	(°C)	pairs	ovipositing	$\bar{X}$ (±SEM)	range	female	eggs/mass
Redbanded leafroller	10	23	9	19.2 (4.4)a	5-36	1.0	23.9 (4.9)b
	15	24	19	6.0 (0.9)b	2-17	1.0	30.9 (4.5)ab
	20	20	19	1.7 (0.2)c	0-5	1.2	45.2 (5.9)a
	25	21	14	1.3 (0.2)c	0-4	1.7	33.6 (5.1)ab
	30	18	16	1.7 (0.3)c	0-6	1.7	33.6 (5.3)ab
	35	22	0	- -	-	-	- -
Tufted apple bud moth	10	20	0	- -	-	-	- -
	15	20	15	8.3 (0.9)a	4-16	1.2	53.7 (6.6)a
	20	20	17	2.8 (0.4)b	1-6	1.1	76.7 (10.6)a
	25	17	16	1.6 (0.2)b	1-4	1.1	73.9 (8.5)a
	30	25	18	1.9 (0.2)b	0-5	1.3	66.1 (8.4)a
	35	18	0	- -	-	-	- -

* Means in a column followed by the same letter are not significantly different ($P \leq 0.05$).

Redbanded leafroller oviposited at cooler temperatures than tufted apple bud moth in our study, which is in agreement with their behavior in the field. Oviposition by the overwintering generation of redbanded leafroller occurred in an apple orchard at Clayton, NC at mid March, or prior to the presence of foliage on the apple trees (Hawthorne et al. 1988), while in this orchard oviposition by the overwintering generation of tufted apple bud moth occurred in mid May or after the presence of apple foliage (Boyne et al. 1985). The regressions for both redbanded leafroller ($F_{1,60} = 74.45$, $P < 0.0001$) and tufted apple bud moth ($F_{1,46} = 74.21$, $P < 0.0001$) preoviposition rates against temperature had both slopes and intercepts

significantly different from zero ($P < 0.0001$). The preoviposition requirements for redbanded leafroller yielded fewer DD at a low threshold (29.4 $DD_{8.7}$) than that required by tufted apple bud moth (33.6 $DD_{10.5}$). These calculated thresholds support the experimental data (Table 1), showing that the actual temperature thresholds for oviposition for redbanded leafroller is < 10°C, while > 10°C temperature is required for tufted apple bud moth. The calculated threshold temperature of 8.7°C for oviposition by the redbanded leafroller is higher than of the developmental thresholds for the egg (7.8°C) and larval (7.0°C) stages, but not the pupal stage (9.8°C) (Hawthorne et al. 1988), while the calculated threshold temperature of 10.5°C for tufted apple bud moth oviposition is higher than the threshold for the larval (9.8°C) and pupal 9.7°C) stages (Mawby & Rock 1986), as well as for the egg stage (9.8°C). The low temperature threshold for the egg stage of the tufted apple bud moth was determined by regression (Proc. GLM SAS Institute 1982) of the rate of egg development time against temperature (Boyne 1984). These results agree for the most part with thermal studies for the leafminer *Liriomyza trifolii* (Burgess), showing that the oviposition threshold should be similar to thresholds of other insect activities (movement, flight, mating, etc.), but higher than developmental thresholds (Parrella 1984). The DD requirement for preoviposition is ca. 30 and 34 DD for redbanded leafroller and tufted apple bud moth, respectively, which would account for ca. 4.3% of the total thermal requirement for redbanded leafroller development (652 DD required for egg, larval and pupal stages combined, Hawthorne et al. 1988) and 5.2% of total thermal requirement for egg, larval and pupal stages of the tufted apple bud moth (594 DD requirement, Mawby & Rock 1986).

The lower development threshold and DD requirement for oviposition has been reported for only a few fruit feeding tortricids. The obliquebanded leafroller, *Choristoneura rosaceana* (Harris), which is distributed throughout North America, required a period before oviposition of 35.2 $DD_{11.9°}C$ (Gangavalli & Aliniazee 1985), while the light brown apple moth, *Epiphyas postvittana* (Walker), which is a pome fruit pest in Australia and New Zealand, required 29.9 DD $_{7.5°}C$ (Danthanarayana 1975). These results supported the premise that the oviposition temperature threshold for a tortricid may be regulated by the coolest mean temperature generally experienced during oviposition. Oviposition of the overwintering generation of *C. rosaceana* occurs in late June in New York (Chapman & Lienk 1971), which may account for the oviposition threshold > 10°C, while *E. postuittana* oviposition occurs during most of the year, including cool winter months (Danthanarayana 1975), which may account for an oviposition threshold < 10°C.

Mean duration of preoviposition, oviposition, postoviposition, longevity and mean fecundity for redbanded leafroller and tufted apple bud moth females at 25° C are shown in Table 2. The 25°C temperature was chosen because 25°C appears to be near the optimum temperature for reproduction for the two species (Table 1), as well as for larval and pupal development of redbanded leafroller (Hawthorne et al. 1988) and tufted apple bud moth (Boyne et al. 1985). The preoviposition and oviposition periods of the two species did not differ significantly; however, the postoviposition peirod of tufted apple bud moth was significantly longer (3.0 d vs 7.6 d). Egg masses per female were greater for the redbanded leafroller (9.6 masses versus 6.4 masses) than for tufted apple bud moth, while eggs per mass were greater for tufted apple bud moth (47.1 versus 23.1) than for redbanded leafroller.

Table 2. Reproductive characteristics and longevity of redbanded leafroller and tufted apple bud moth females at 25°C ($\bar{X} \pm$ SEM).

Insect	No. females	Duration (days)				Egg masses/ female	Eggs/mass
		Pre-ovipo-sition	Ovipo-sition	Post-ovipo-sition	Longevity		
Redbanded leafroller	17	1.6 (0.3)a	7.7 (0.8)a	3.0 (0.6)a	12.3 (0.8)a	9.6 (0.8)a	23.1 (3.2)a
Tufted apple bud moth	15	1.7 (0.2)a	7.3 (0.7)a	7.6 (1.7)b	16.6 (1.6)b	6.4 (0.5)b	47.1 (8.2)b

* Means in a column followed by the same letter are not significantly different ($P \leq 0.01$); t test).

Mean number of eggs per female was greater for tufted apple bud moth (301) than for redbanded leafroller (221). The data showed no evidence that egg mass deposition was clustered at any particular time during the oviposition period for both species.

The mean duration of preoviposition reported for the redbanded leafroller in our study at constant 25°C (1.6 d) agrees with insectary studies in Virginia showing 1.7 d (Hough 1927) and 2.0 d (Long 1953). We found no reported study on the oviposition period for either redbanded leafroller or tufted apple bud moth. Mean redbanded leafroller female longevity (12.3 d) reported in our study was similar to mean longevity values reported by Hough (1927) for the F_1 and F_2 generations (10.1 and 12.0 d, respectively). The mean of 221 eggs per redbanded leafroller female we obtained at 25°C was greater than the values from insectary studies reported by Hough (1927) during 1925 and 1926 (mean range 46 to 122), Long (1953) during 1949 and 1950 (mean range, 58 to 189) and in Pennsylvania by Frost (1925), with a mean of 134. The mean of 30.0 redbanded leafroller eggs per mass reported by Frost (1925) is slightly greater than the mean of 23.1 found in our study.

Results of these experiments indicate that redbanded leafroller and tufted apple bud moth should oviposit when temperatures approach 9 and 11°C, respectively. However, under field conditions, oviposition may be regulated by factors other than temperature (e.g., rain or wind). Even though weather conditions other than temperature may cause the thermal requirements for redbanded leafroller and tufted apple bud moth to vary, this variability is not as important as larval food in influencing total DD requirement for development (Mawby & Rock 1986).

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