Laboratory Studies on the Developmental Period and Feeding Behavior of *Aphidecta obliterata* (L.) (Coleoptera: Coccinellidae), an Introduced Predator of the Balsam Woolly Aphid[1]

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ABSTRACT

Aphidecta obliterata completed its developmental period (egg through pupal stage) in 53 days at 15°C and 75% RH. Feeding studies showed that a straight-line relationship existed between length of larvae and the number of balsam woolly aphid, *Adelges piceae* (Ratzeburg), eggs consumed per capita per day. The average number of aphid eggs consumed per capita during larval development was 1853, with a range from 1579 to 2456. In the 4th stage, larvae consumed more eggs per capita than they did in the 1st 3 stages combined. The consumption of prey was reduced when predator density increased.

The balsam woolly aphid, *Adelges piceae* (Ratzeburg) (Homoptera: Phylloxeridae), was accidentally introduced into North America about 1900—probably on nursery stock imported from Europe (Balch 1952). The aphid has caused considerable damage and mortality to true firs, *Abies* spp., in North America (Balch 1952, Johnson and Wright 1957, Carroll and Bryant 1960, Amman and Speers 1965). Following the discovery of *A. piceae* in North Carolina in 1957 (Speers 1958), a research program was initiated in 1959 to establish its predators (Amman 1961). One of the predators introduced from Germany was *Aphidecta obliterata.*

Several attempts have been made to establish *A. obliterata* in North America (Brown and Clark 1959, Harris et al. 1964, Amman 1966, Mitchell and Wright 1967). The only apparent establishment has been in North Carolina following its free release in 1960 and 1963 near Mt. Mitchell; after 4 years of survival, it appears to be a permanent addition to the predator complex (Amman 1966). To help in evaluating the success of this introduction of *A. obliterata* into North Carolina, laboratory studies were conducted there on its developmental period and feeding behavior. Information on its life history in Europe has been presented by Wilson (1938), Van Dinther (1951), Delucchi (1953), and Wylie (1958).

MATERIALS AND METHODS

Adults of *A. obliterata* were received from Europe through the facilities of the Commonwealth Institute of Biological Control and the Agricultural Research Service, USDA. Some of the predators were placed on small, potted, Fraser fir, *Abies fraseri* (Pursh) Poir., seedlings enclosed within bottomless 1-gal glass jars. The tops of the jars were covered with nylon mesh to allow ventilation and to prevent escape of the beetles. Aphid-infested bark was cut from Fraser fir bolts and placed in the jars. *A. obliterata* adults ate the aphids and laid eggs on needles of the fir seedlings. Needles on which eggs had been laid were removed from the seedlings daily.

Development Period.—Freshly laid *A. obliterata* eggs were separated from the egg cluster and placed individually in 5×25-mm glass vials. A plastic film was placed on the top of the vial to prevent escape of the larvae after hatch. Small pinholes were punched in the film for ventilation. After hatching, larvae were transferred to individual 2.8-cm² plastic boxes. They were supplied with fresh balsam woolly aphid eggs or adults and several drops of water daily, because larvae required free water and food to survive. Studies of the developmental period (egg through pupal stage) were conducted at 15°C and 75% RH, parameters close to the average for the Mt. Mitchell area during the developmental period of *A. obliterata* in the field. The number of replications ranged from 12 to 31 for the various stages studied.

Effect of Temperature on Incubation and Hatching.—The effect of different temperatures on the incubation period and hatching of eggs of *A. obliterata* was determined. Temperatures between 5 and 25°C were chosen, because this range was encountered on Mt. Mitchell in April and May during oviposition by *A. obliterata.* A 75% RH was used throughout the study. The number of replications ranged from 25 to 45 for the various temperatures.

Feeding Study.—The methods and conditions of rearing *A. obliterata* were the same as those used in the developmental period studies, except that the number of aphids supplied to the predator and the number eaten were tallied daily. When the aphid eggs were counted, the predator was removed with a no. 00 artist's brush and placed in another box containing aphid eggs. This procedure was repeated daily throughout larval development of the beetle. Two methods were used in obtaining *A. piceae* eggs for the study. In the 1st method, eggs were removed from the bark with a dissecting needle. In the 2nd method, infested bark was brushed lightly over 6–8 thicknesses of nylon mesh stretched tightly over the top of a glass funnel (Gentry and Wilson 1966). The eggs which passed through the nylon mesh were collected in a plastic box; but adult aphids, wax masses, and bark flakes were retained by the mesh. The number of replications ranged from 8 to 12 for the various stadia studied.

Predator-Prey.—The effects of predator density on predation rate was also studied. Predator densities

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of 1, 2, 3, 4, and 5 larvae per 4.5-cm³ plastic box were used. Prey densities of 50, 100, 150, and 250 *A. piceae* eggs per individual per day were used with the 1st-, 2nd-, 3rd-, and 4th-stage larvae, respectively. The methods and conditions used in obtaining and counting eggs were the same as those described in the feeding study.

RESULTS AND DISCUSSION

Developmental Period.—Table 1 gives the duration of the developmental period of *A. obliterata* at 15°C and 75% RH. The difference in developmental time between larvae fed on aphid eggs and larvae fed on adult aphids was not statistically significant. Therefore, the 2 sets of data were combined.

Van Dinther (1951) and Delucchi (1953) studied the duration of stages of *A. obliterata* at constant temperatures of 20°C and higher, and Wylie (1958) conducted studies at temperatures fluctuating between 15 and 19°C. The length of the developmental period obtained in my study was longer than that obtained by other authors. This difference is attributable to the effect of lower temperature on the length of each stadium. The results obtained in the laboratory correlated extremely well with the length of the seasonal history observed in the field by Amman (1966) and by me.

Effect of Temperature on Incubation and Hatching.—The incubation period varied from 3.6 days (range 3–5) at 25°C to 33.8 days (range 24–42) at 7°C (Fig. 1). Eggs failed to hatch at 5°C and had a reduced hatch at 7°C. Therefore, the lowest temperature at which egg development and hatching could be completed should fall between 5 and 7°C. The highest hatch, 90%, occurred at 25°C, while the lowest, 68%, occurred at 7°C. The percent hatch was about the same at all temperatures between 10 and 25°C. The average percent of eggs which hatched in the laboratory was 84%, almost identical to the corresponding average (85%) for field-collected eggs.

Feeding Study.—Table 2 presents the number of *A. piceae* eggs consumed per capita per day by *A. obliterata* larvae. The large standard deviations indicated considerable variation in daily consumption of aphids. However, much of this variation was attributable to the few aphids that were consumed when the larvae were about to molt. The number of eggs consumed daily by each instar varied only slightly for the following number of days: 1st instar, 4; 2nd instar, 3; 3rd instar, 5; and 4th instar, 6.5.

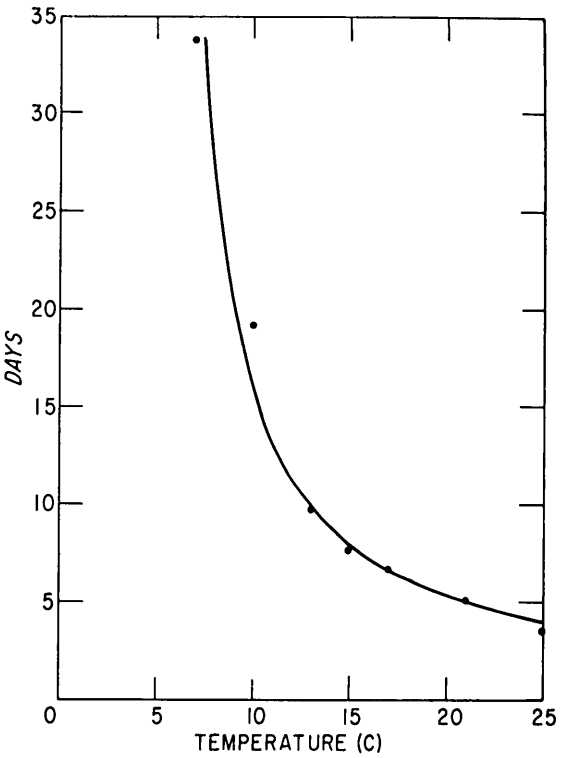

FIG. 1.—Incubation period for eggs of *A. obliterata* at various temperatures and 75% RH.

A straight-line relationship with a correlation coefficient of 0.91 existed between length of larvae and the number of aphid eggs consumed per capita in 24 hr (Fig. 2). In the 4th stage, larvae consumed more eggs per capita than they did in the first 3 stages combined (Fig. 3). The average number of eggs consumed per capita during larval development was 1853, with a range from 1579 to 2456. At an aphid density of 96 eggs and 8 adults/in.²—the mean number in a field plot in early June 1964 (Amman 1966[3])—1 *A. obliterata* larva could eliminate the aphids from 16 in.² of bark surface.

Smith (1958) made a microscopical examination of 1-in. bark sections at intervals of 24 hr and then estimated the number of prey destroyed by *A. obliterata* larvae. The number of aphids consumed by *A. obliterata* in the present study was greater than that reported by Smith. I found it impractical to use infested bark sections as a food source, even though the results obtained would have had more meaning,

Table 1.—Duration of the developmental period of *A. obliterata* reared on the balsam woolly aphid at 15°C and 75% RH.

Stage	Duration in days				No. replications
	Min	Max	Avg	SD	
Egg	6	9	7.61	0.88	31
1st instar	5	8	6.17	1.06	12
2nd "	4	7	5.33	0.99	12
3rd "	5	8	6.83	.98	12
4th "	9	10	9.50	.52	12
Prepupa	3	6	4.08	1.08	12
Pupa	12	14	13.08	.51	12
Developmental period[a]	50	56	53.42	2.00	12

[a] No single insect went through each stage of its developmental period in the maximum or minimum number of days recorded above. This line of figures represents distinct observations and is not a summation of the numbers above it.

[3] G. D. Amman. 1966. A study of native predators of the balsam woolly aphid, *Chermes piceae* Ratz. (Homoptera: Chermidae), in North Carolina. Ph.D. dissertation, University of Michigan, Ann Arbor. 226 p.

Table 2.—Number of balsam woolly aphid eggs consumed per capita per day by *A. obliterata* larvae in the laboratory at 15°C and 75% RH.

Stadium	Duration (days)	Avg no. eggs offered/ capita per day	No. eggs consumed/capita per day			SD	No. replications
			Min	Max	Avg		
1st instar	6.2	43.4	0	54	20.8	14.4	12
2nd "	5.1	57.7	2	74	37.0	23.1	8
3rd "	7.4	94.3	0	130	56.2	32.0	8
4th "	9.8	195.3	2	299	115.3	75.1	8

because (1) the time involved to get an accurate count of eggs and adults of *A. piceae* under wax and bark scales was too great, (2) additional eggs were laid by living *A. piceae* adults on the bark sections between daily counts, and (3) early-stage larvae of *A. obliterata* were injured or killed in the pitch along the edges of bark sections.

The 1st-stage larva of *A. obliterata* took 9 min to pierce the egg chorion with its mandibles and draw out the contents, whereas the 2nd-stage larva took only 3 min. The 3rd-stage larva consumed the entire egg in 30 sec, and the 4th-stage larva ate 5 eggs in 20 sec. Adult aphids were pierced and sucked by 1st- and 2nd-stage larvae, and the empty skin remained in the box. The 3rd- and 4th-stage larvae usually ate the entire adult. Larvae were sometimes observed feeding on their own cast skins within 24 hr after molting.

Cannibalism was observed during the laboratory studies. *A. obliterata* eggs were attacked by freshly hatched larvae, and larvae were eaten by other larvae. Smith (1958) and Wylie (1958) also observed cannibalism. The newly emerged larva fed on its own chorion before leaving the needle to search for food. The length of feeding on the chorion depended on the temperature, with the larva leaving the chorion sooner at higher temperatures. The newly emerged larva seldom left its chorion during the 1st 24 hr, even at high temperatures. Most of the eggs in the egg mass had hatched by then.

Predator-Prey Study.—Chant and Turnbull (1966) reported in their study on the interaction between goldfish and *Daphnia pulex* that 4 factors affected the number of prey captured: (1) the number of prey required to satiate the predator; (2) the effect of ever-decreasing prey density on the efficiency of prey discovery; (3) the number of prey available to each predator; and (4) the effect of one predator on the activities of another when more than one were present. Factors 1 and 4 applied to the interactions between *A. obliterata* and *A. piceae*. Factors 2 and 3

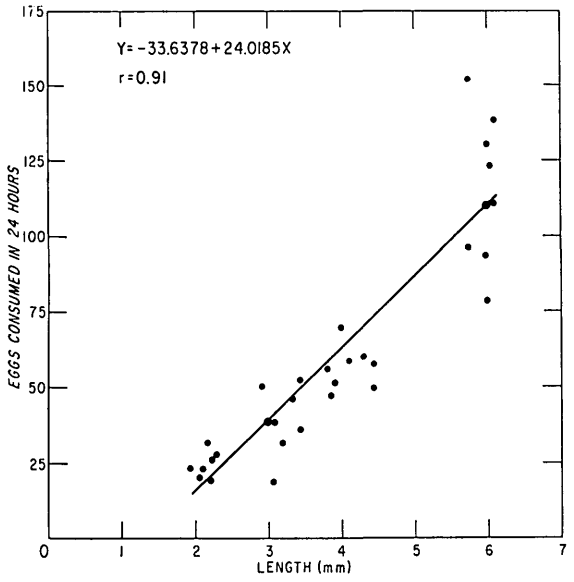

FIG. 2.—Relationship between length of *A. obliterata* larvae and number of eggs of *A. piceae* consumed per capita in 24 hr.

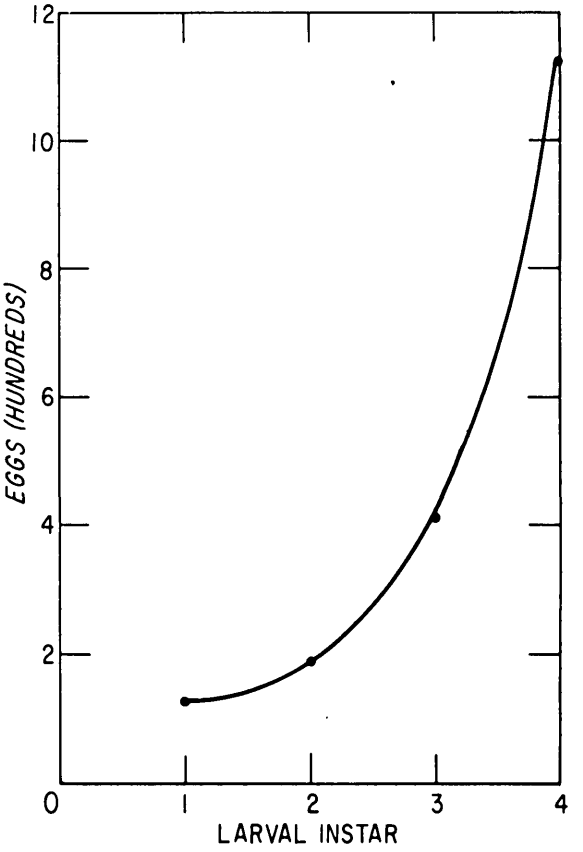

FIG. 3.—Per capita consumption of *A. piceae* eggs by larvae of *A. obliterata* in each stage.

did not apply, because the prey density used for each instar was considerably more than each predator needed to be satiated.

In the 1st stage, the number of prey eaten per capita per day decreased when predator density increased (Fig. 4). In the 2nd stage, the number of prey consumed per capita per day decreased when the predator density increased from 1 to 2 and from 2 to 3; but a slight increase in the number of prey consumed was apparent when the predator density increased from 3 to 4 and from 4 to 5.

This apparent increase was caused entirely by slight variations in molting times of the larvae. Because a breaking point for the number of prey eaten per capita per day had to be chosen for each instar, the group was elevated to the next instar when the 1st larva in the group molted. Larvae tended to consume a smaller number of prey when they were about to molt, and some larvae were about a day behind in molting because of individual variations. Because of this lag, a few larvae never entered the 1-day lull of below-normal feeding before the group was elevated to the next instar.

In the 3rd stage, a slight increase in the number of prey consumed was apparent when the predator density increased from 1 to 2 (Fig. 4). This increase was again caused by the larvae molting at different times. In the 4th stage, there was a decrease in the number of prey consumed per capita per day when the predator density increased from 1 to 2. Because of cannibalism, predator densities greater than 2 did not occur in the 3rd and 4th stages.

Cannibalism occurred at about the same time in each replication, usually within 24 hr after the 1st larva in a group molted. This larva would then kill 1 or more of the other larvae while they were still inactive just before molting.

The cannibalism noted and the reduction in per capita consumption of prey as predator density increased probably resulted from the limited feeding area available. The limited area apparently caused crowding and mutual interference on the part of the larvae.

Although the overlap of feeding and molting activities noted in this study would be found under natural conditions, I realize that the results are not so concise as they might have been if larvae of a given stage had been used as study criteria only during the peak of the feeding period. In an experiment with larvae on predator-prey interaction, it would be better to have a stock of larvae present and use only larvae of the same age.

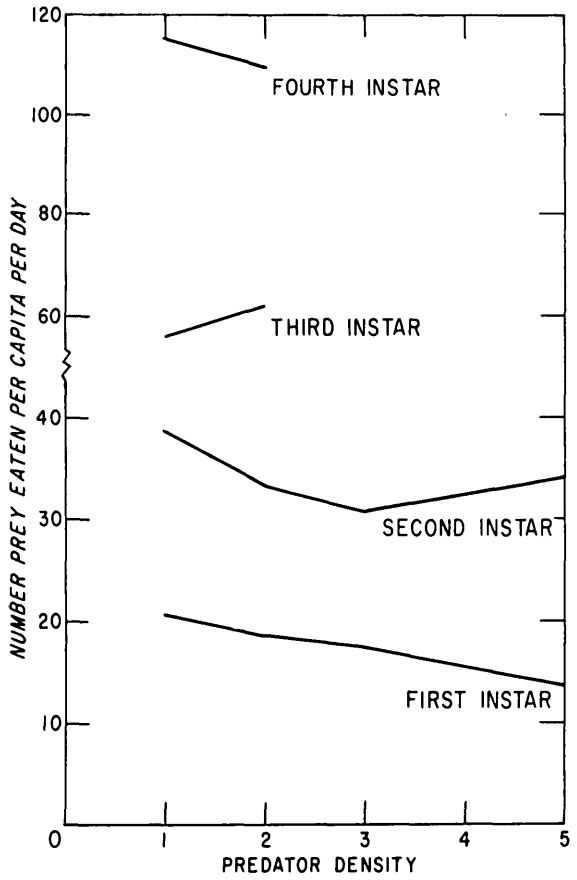

FIG. 4.—Relationship between number of *A. piceae* eggs consumed per capita by *A. obliterata* and predator density for each instar.

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Observations on *Platypus flavicornis* (Coleoptera: Platypodidae) in Southern Pine Beetle Infestations[1]

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ABSTRACT

The flight and attack pattern of the ambrosia beetle *P. flavicornis* (F.) was studied in southern pine beetle, *Dendroctonus frontalis* (Zimmermann) infestations in eastern Texas. The ambrosia beetle flew mostly within 9 feet of the ground and attacked the lower stems of pines which had been mass-attacked previously by the southern pine beetle. Four to six days elapsed from the time of *D. frontalis* mass-attack until *P. flavicornis* began to land on the trees. The rate of landing increased until the 10th day and then declined slowly. The slow accumulation of attacks suggests the orientation primarily to odors originating from the host, as opposed to insect-produced volatiles.

The family Platypodidae is represented in the United States by 7 species of the genus *Platypus* Herbst (Arnett 1963). Of these, only *P. flavicornis* (F.) is known to be a pest of southern pines. This ambrosia beetle is found from Texas east to Florida and north to New Jersey (Chamberlin 1939). In spite of its widespread occurrence as a forest pest, little is known of its ecology and behavior.

Under normal conditions, *P. flavicornis* is found only in widely scattered dead or dying trees. Certain conditions, such as the current southern pine beetle, *Dendroctonus frontalis* Zimmerman, epidemic in eastern Texas, provide an abundance of host material for the ambrosia beetles. The following observations were made in 1966–67 in conjunction with studies on southern pine beetle behavior.

MATERIALS AND METHODS

Trees infested by *P. flavicornis* are easily detected by the piles of fluffy, white boring dust around their bases. Southern pine beetle infestations in Hardin County, Tex., exhibiting ambrosia beetle activity were chosen as the sites for observations. The infestations were typically in loblolly pine sawtimber stands containing an admixture of magnolia, sweetgum, beech, and oaks.

Vertical flight distribution was sampled using 18× 18-in. polyethylene sheets coated with an adhesive. A flight-panel set consisted of 4 such sheets fastened to a cord and suspended from a crossarm nailed to a hardwood tree. The sticky sheets were positioned on the cord so that the tops of the sheets were 3, 6, 9, and 12 ft above the ground. The flight-panel sets were positioned at least 30 ft from trees attacked by the southern pine beetle, to lessen any possible artifact caused by visual and olfactory orientation to the pines. Five such sets were operated for about 3 weeks each at various times during the summers of 1966 and 1967.

Attack density was sampled on 8 trees in 1966. A 6-in. × 8-ft section of tree bark was removed to expose the wood surface, and the number of *Platypus* pinholes was tallied at 1-ft-height intervals above the ground. *P. flavicornis* pinholes are noticeably larger than the tunnels of associated scolytid ambrosia beetles (viz. *Gnathotrichus* and *Xyleborus*).

The vertical distribution of *P. flavicornis* landings on trees killed by southern pine beetles was determined by use of adhesive-coated plastic strips stapled to the standing trees. Since the attack density counts had shown no attacks above 8 ft, sticky traps longer than 8 ft were not used. Two strips were placed on each tree, one extending from ground level to 8 ft on the north side of the tree and a similar strip on the south side of the tree. Beetles were removed and tallied by 1-ft height classes above the ground every 1–3 day period.

Two sleeve olfactometers (Gara 1967) were installed on loblolly pines immediately after they had been mass-attacked by southern pine beetles (Fig. 1). Another olfactometer was placed on a nearby but unattacked pine. The olfactometers were operated for 3–4 hr between 8:00 AM and 12 M and once again for 3–4 hr in the late afternoon from ca. 4:00 to 8:00 PM. Beetles caught in the olfactometers were collected and counted daily.

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