Bionomics of *Eucosma monitorana* (Lepidoptera: Tortricidae) Attacking Red Pine Cones in Wisconsin[1]

STANLEY J. BARRAS[2] AND DALE M. NORRIS[3]

ABSTRACT

A localized infestation of *Eucosma monitorana* Heinrich was studied in 1963 and 1964 in southern Wisconsin. Adults are secretive, weak flyers but several were collected in May with sticky trap-boards and light traps. Adult emergence and flight occur at time of red pine pollen release. Eggs were not found in macro- and microscopic examinations of cones, twigs, and needles. Larvae were active from early June through July. External symptoms of cone attack developed slowly, but the interior deteriorated rapidly. A standardized examination of 300 cones revealed that most attacks by migrating larvae were in the mid-ventral surface. Pupation occurred in the soil in late June and the pupae period lasted to the following May. Sexual dimorphism in the pupae was discovered and illustrated. The pupal stage is characterized by a winter diapause which was difficult to artificially interrupt. Attack was unequal between trees, but was random within crowns. As the season progressed, the percentage of newly attacked cones in the top and middle crown area increased at a faster rate than in the lower crown. This increase apparently resulted from the availability of more unattacked cones in the top and middle. An unidentified *Apanteles* sp. was found parasitizing *E. monitorana* larva. Death of the host larvae occurred during the 3rd stage.

Nearly all published information on the life history of *Eucosma monitorana* Heinrich is by Lyons (1957a, b), who was unable to completely elucidate the life cycle because of low population levels. However, he found that larval attack invariably led to death of cones and enclosed seeds. At about the 4th instar, larvae migrated to uninfested cones and this migration resulted in some increase in infestation as the season progressed. Hard (1964a) reviewed Lyon's work and confirmed the report of larval migration and reemphasized that infestation destroys the cone and terminates development of seed not already consumed. Little is known about the within-crown distribution of the insect and the effect of larval migration on the rate and severity of cone damage. The site of pupation was not known; however, Lyons (1957a) suggested the soil beneath infested trees.

DISTRIBUTION AND HOSTS

Distribution and Hosts.—Heinrich (1921) first recorded and described *E. monitorana* from *Pinus* spp. in Pennsylvania. He also recorded a single specimen found in the U.S. National Museum labeled: "*Retinia* on *P. inops,* Va. issued May 28, 1895." Forbes (1923) recorded larvae feeding on cones of an unspecified pine. Lyons (1957a) found low populations of the insect in southern Ontario feeding on cones of red pine, *Pinus resinosa* Aiton. Hard (1964a) also reported larvae in red pine cones but found the insect scarce in northern Wisconsin. In a recent paper Powell (1968) reviewed geographical distribution and host records of the conifer-feeding *Eucosma.*

Geographical Distribution in Wisconsin.—The distribution and relative abundance of *E. monitorana* infestations were surveyed July 22–26, 1963, and in May 1964 (Table 1). The insect seems to prefer locations near rivers with well-drained soil.

In 1962 a relatively high population of *E. monitorana* in a red pine plantation near Lone Rock, Wis., presented an opportunity to study the insect in detail. The infestation was followed closely from 1963 to 1964 to determine life history, attack pattern, and density. Ten additional locations were surveyed to learn the geographical range and population levels within Wisconsin.

METHODS AND MATERIALS

The infestation was situated in a 20-year-old stand with spacing of 6×6 to 10×10 ft on a well-drained site about 1 mile E of Lone Rock. Trees ranged 6–8 in. DBH and 20–30 ft high and were previously pruned to ca. 10 ft above ground. Attempts were made to collect adults in May of 1963 and 1964 with a BL trap and 25 sticky-trap-boards placed 1.5 ft above ground in the pine plantation and within crowns of trees. A stereomicroscope was used in the field and laboratory to search for eggs. Cones, adjacent twigs, and needles were cut into small pieces and soaked in 12.5% (wt/v) sucrose solution to wash and float eggs and small larvae from tissues. The solution and tissues were then filtered with 10-, 35-, 60-, and 80-mesh sieves and the residue on each sieve was filtered onto a fine dark cloth in a Büchner funnel. Larvae collected from cones throughout the season were fixed in

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[2] Present address: Southern Forest Expt. Sta., 2500 Shreveport Hwy., Pineville, La. 71360.

[3] Professor, Department of Entomology, University of Wisconsin, Madison.

Table 1.—Red pine cone attack by *E. monitorana* at 15 locations in Wisconsin.

County	Location	No. sampled	% attacked
	1963		
Wood	Nakoosa	27	26
Wood	Griffith State Nursery	112	12
Portage	Stevens Point	25	0
Pepin	Duran	25	4
Jackson	Hixton	25	0
Lincoln	Merril	25	20
Polk	Amery	10	0
Barron	Poskin	25	0
Vilas	Eagle River	26	8
Sauk	Lone Rock	25	58
	1964		
Columbia	Poynette	25	10
Dane	Univ. Wis. Arboretum	25	0
Jefferson	Ft. Atkinson	25	0
Waukesha	Eagle	25	0
Rock	Milton Junction	25	5

KAAD and stored in 70% alcohol. A detailed larval description was prepared from more than 300 specimens (Barras and Norris 1967).

Preliminary examination of soil (Barras and Norris 1963) had revealed that pupation occurs in the soil, confirming Lyons' (1957a) suggestion. A quantitative determination of pupal density was made by sifting 78 soil samples (1 $ft^2 \times 2$ in. deep) through metal-wire screen to remove pupae from soil and debris. Most of the soil samples were collected in late July.

In 1963, 300 randomly selected cones among 30 trees (10/tree) were examined *in situ* weekly, May 15 through July 19, and on July 30 and Aug. 14 to determine distribution among and within tree crowns. Samples of severely damaged or dead cones were dissected each week to collect larvae and/or parasites.

LIFE HISTORY

Adults.—Two *E. monitorana*[4] males were collected from separate trap-boards near the ground on May 11, 1963, but none was collected with the 15 tree traps. On May 25, 1964, 1 ♀ was captured after we caused it to fly by kicking tall grass and debris in the plantation. Twelve adults were collected in a BL trap on the night of May 19–20, 1964, at Poynette, Wis. Damage to adult coloration was extensive in the trap, so only genitalia could be used for identification. The male genitalia were compared by W. E. Miller with those of type-specimens in the U. S. National Museum, and they could not be distinguished from genitalia of *E. monitorana* and *E. tucullionana* Heinrich. Powell (1968) stated that these 2 species are sometimes taken together. In the laboratory 3 additional adults, 1 ♀ and 2 ♂, were found trapped within dried-up cones on May 25, 1963. This collection was the only incidence of pupation in cones.

These collection data show that *E. monitorana* adults were present at least from May 11 through May 25, but because of their secretive nature these collection dates probably do not include the total emergence period. Powell (1968), in reviewing all records of *E. monitorana,* listed collection dates from May 9 to June 8.

Table 2 presents the phenological observations and mean daily temperatures for the collection period in Wisconsin. Growth of 2nd-year ovulate cones had commenced by May 1, but red pine pollen release and pollination occurred after the initial adult collection. Adult emergence is apparently closely correlated with pollen release.

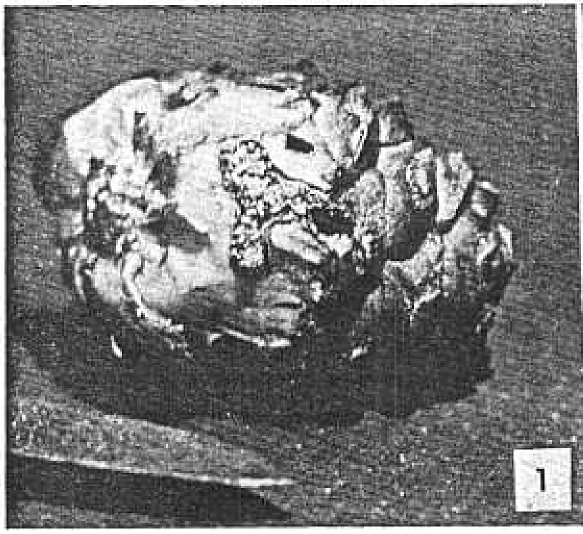
Eggs.—*E. monitorana* eggs were not found in field or laboratory examinations of twigs, needles, and cones of red pine. Eggs were not collected in any of the sieves after soaking these tissues in sucrose solution; however, 1st-stage larvae were collected June 4 and 5. Our inability to float eggs free of tissue was probably caused by a strong adhesive holding them in place. Bakke (1957) was unable to locate eggs of *E. ratzeburgiana* (Ratzeburg) in Norway, and Butcher and Hodson (1949) had the same difficulty with *E. sonomana* (Kearfott) in Michigan.

Larvae.—Larval activity extended from June 1 through July 30, the last date on which specimens could be found. First-stage larvae enter the 2nd-year cone at the junction of scales and mine between scales toward the axis as described by Lyons (1957a). For the first 2 weeks in June as many as 16 young larvae were found per cone and on June 15 an average of 7.2 larvae were found in each of 10 cones. At this time infested cones were a mass of frass and dead tissue. All seed embryos had been destroyed either by direct feeding or drying of tissue. The largest larvae (4th or 5th instar) usually occupied the bored-out axis of the cone.

[4] Identification was confirmed by Dr. William E. Miller, Lake States Forest Expt. Sta., St. Paul, Minn.

Table 2.—Phenological observations and mean daily temperature recorded during the observed flight period of *E. monitorana* at Lone Rock, Wis., May 1–25, 1963.

Observation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	2				
E. monitorana adults																									
Red pine pollen release																									
Pollination of 1st-year cones																									
Growth of 2nd-year cones																									
Mean daily temperature, °C	6	15	16	15	11	13	17	22	18	9	9	9	16	11	12	10	11	12	10	12	9	2	7	13	14



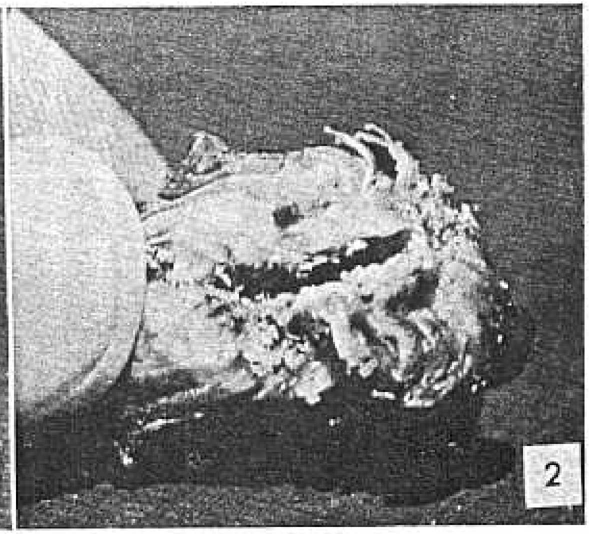


FIG. 1.—Red pine cone with frass-filled tunnel constructed by single 5th-stage *E. monitorana* larva.
FIG. 2.—Cone axial chamber constructed by 5th-stage *E. monitorana* larva.

Undamaged cones continued to be attacked by migrating 4th- and 5th-instar larvae until July 5. Cones attacked by migrating larvae could be easily identified by large holes between scales on the mid-ventral surface. These cones had 1–2 larvae each (Table 3). The larvae constructed frass-filled tunnels (Fig. 1) and fed on only 1 or 2 seeds and little cone tissue as they moved toward the axis where a large chamber was constructed (Fig. 2). At first this chamber was thought to be an additional pupation site, but no pupae were observed. Once the axis was mined, the cone died quickly.

Larval collection data and head capsule measurements (Fig. 3) suggests there are 5 instars in southern Wisconsin. The measurements closely corresponded to those made by Lyons (1957a). Fifth-stage larvae were noted as early as June 15 indicating that pupation could have begun about that time and continued after July 30. No larvae were observed on Aug. 14. Average body length ranged from 1.97 mm for 1st instars to 12.31 mm for 5th instars. Lyons (1957a) reported the mature larvae in Ontario were ca. 12 mm long. The more than 300 larvae collected in our investigation were used to prepare a description of the 5th-stage larva (Barras and Norris 1967).

Table 3.—Average number of *E. monitorana* larvae collected per cone on 5 sampling dates, June 15–July 30, 1963, at Lone Rock, Wis.

Date	No. infested cones	No. larvae	Avg no. larvae/cone
June 15	10	72	7.2 (3–16)[a]
21	23	60	2.6 (1–9)
26	30	57	1.9 (1–4)
July 5	39	63	1.6 (1–5)
12	6[b]	9	1.5 (1–3)
30	1[b]	-	1.0

[a] Range.
[b] Small sample was due to difficulty in finding cones with larvae present.

Pupae.—Twenty-six soil samples collected in 1962

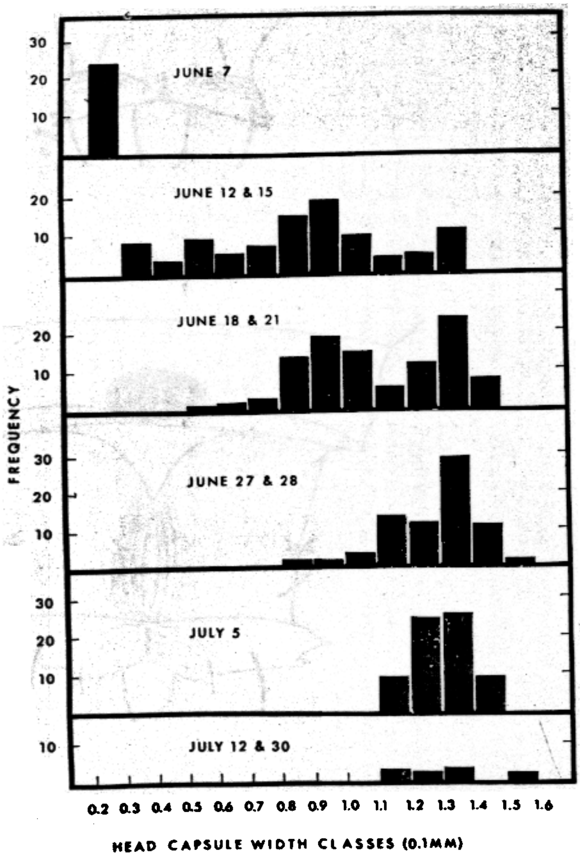


FIG. 3.—Frequency distribution of head capsule width classes (0.10 mm) for *E. monitorana* larva collected from red pine cones, 1962–63, Lone Rock, Wis.

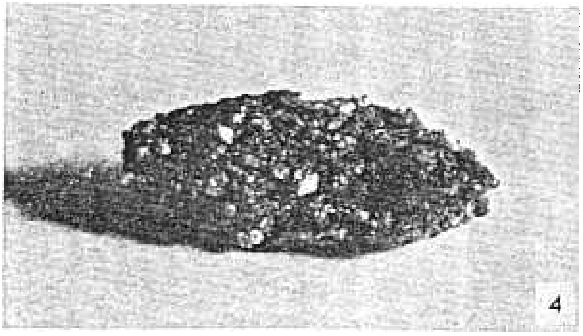


FIG. 4.—Soil-covered cocoon of *E. monitorana* pupa.

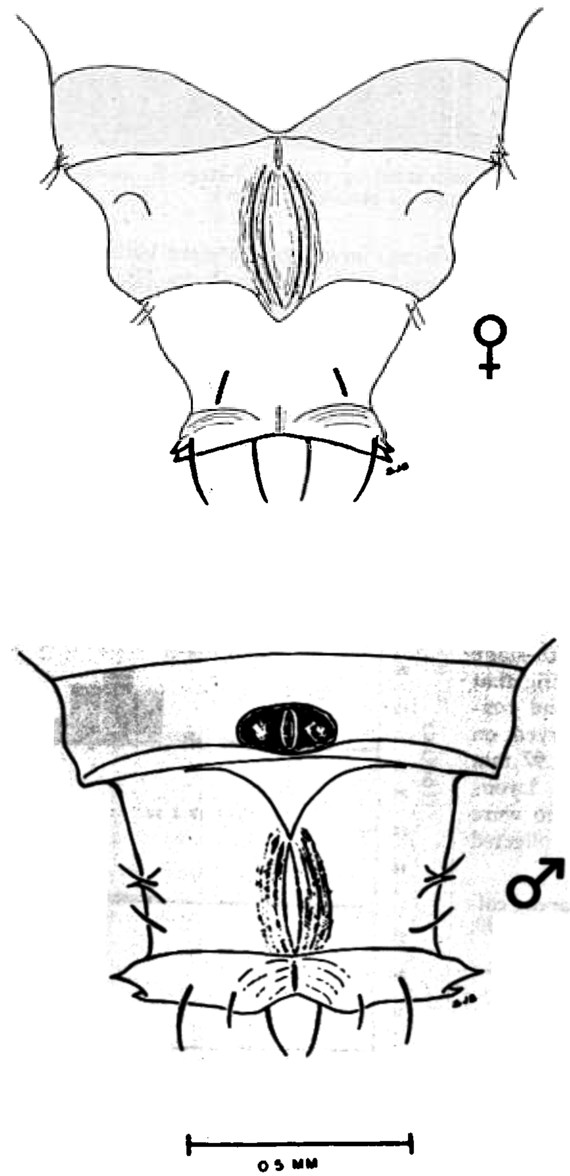


FIG. 5.—Ventral view of posterior segments of male and female *E. monitorana* pupae, illustrating sexual dimorphism.

Table 4.—Percent cones attacked by *E. monitorana* in each of 7 sections of the crowns of red pine on June 15 and 25, and change in percent through July 10. Lone Rock, Wis., 1962.

Date	No. cones examined	Vertical quarters				Horizontal thirds		
		N	E	S	W	Top	Middle	Bottom
				Lot I				
June 15	96	71	81	67	64	71	74	67
July 10	96	86	95	88	88	93	91	85
Change		+15	+15	+21	+24	+22	+17	+18
				Lot II				
June 25	144	93	84	84	90	85	90	85
July 10	144	93	84	84	90	85	90	85
Change		0	0	0	0	0	0	0

and 52 collected in 1963 were examined, and 26 elongated, thin-walled, soil-covered cocoons (Fig. 4) ca. 7–8 mm long, were recovered. Thus, for these samples, pupal density was 0.3/ft^2 of surface area or 2/ft^3 of soil. Thirteen of the cocoons were empty, but no pupal exuviae were found in these; evidently the pupae forced their way out before transferring to adults. These cocoons had the same characteristics as the remaining 13 which contained pupae identified as *E. monitorana*.

The mean length of pupae removed from cocoons was 5.53 mm (range: 4.56–6.39), 2 mm less than the length given by Lyons (1957a) for those he reared from cones in the laboratory. A pupal sexual dimorphism was discovered on the ventral aspect of the posterior segments (Fig. 5) and confirmed by dissection of unemerged adults. When arranged by sex the mean lengths of 7 ♂ and 6 ♀ pupae were 5.23 mm (4.99–5.46) and 5.89 mm (5.54–6.39), respectively.

Pupae collected from soil and reared from infested

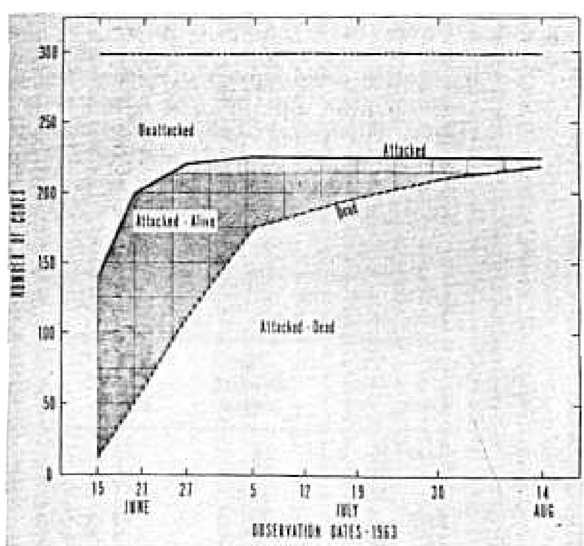


FIG. 6.—Weekly accumulated number of red pine cones attacked and killed by *E. monitorana* June 15–Aug. 14, 1963, at Lone Rock, Wis.

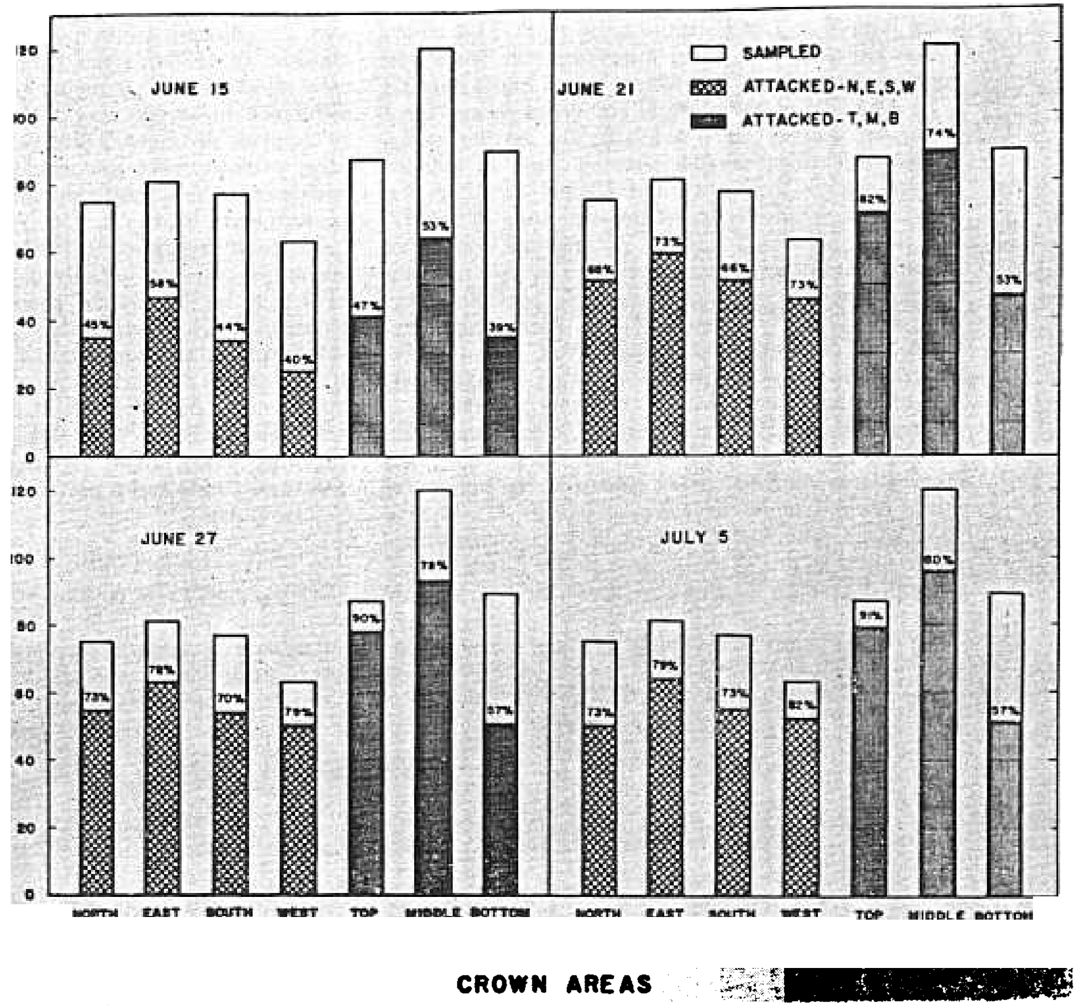


FIG. 7.—Number of red pine cones sampled, accumulated number attacked, and percent attacked by *E. monitorana* n 7 crown areas on 4 dates in 1963 at Lone Rock, Wis.

cones in late July were held at room temperature (25–30°C) for periods up to 7 months in an unsuccessful attempt to obtain adults. This result shows there was evidently no 2nd generation. Pupae held at 0°C for 5 days and then at 2°C for 34 days also did not develop to adults when returned to room temperature, indicating an apparent diapause unaffected by short exposure to severe cold.

Pupae reared from larvae on an artificial diet (Barras and Norris 1965) at 24°C and 16-hr photoperiod apparently entered diapause, since no adults were produced. It is believed the diet was sufficient for adult production, because it had been used to rear numerous other Lepidoptera with success, and dissection of pupae revealed the presence of a physically characteristic adult with developed genitalia. Diapause induction possibly was caused by environmental conditions before collection of larvae from cones or the 16-hr photoperiod used in rearing. This photoperiod falls between those found in nature—17 hr 7 min on May 1 to 14 hr 36 min on July 30. Since the insect is exposed to extended periods of daylight, it is possible that the 16-hr photoperiod actually aided the induction of diapause.

Groups of reared pupae were held at 1°C and −7°C for 6 months in an effort to terminate diapause. Four days after the temperature was raised to 24°C only 1 ♂ emerged from the group stored at −7°C. Dissection of remaining pupae showed that adults appeared normal in all physical characteristics.

DISTRIBUTION AMONG AND WITHIN TREES

Distribution of attack within crowns was studied in 1962 and 1963 at Lone Rock. In 1962, 2 lots (I and II) of cones were examined as follows: 96 on June 15 and again on July 10, and 144 on June 25 and again on July 10. Table 4 shows the degree of cone attack in various sections of the crowns. The data were subjected to tests of significance and no differences were found at the 0.05 probability level. The data also show that there was an increase in infestation by migration which occurred between June 15 and July 10 in Lot I; however, there was no increase after June 25 in Lot II in the same area. This observation indicates that larval migration and hence new cone infestation ceased between June 15 and June 25.

In 1963, 296 of the original 300 cones chosen for a permanent sample were available for further study. Widespread attack was evident on June 12 and increased rapidly between June 15 and 21 (Fig. 6). The rate of attack decreased between June 21 and 27, and the accumulated number of attacked cones had stabilized at 226 (76%) on July 5. The rate of death for the attacked cones held steady at about 50 cones/week from June 15 through July 5. Cones continued to die at a reduced rate through Aug. 14. The destructiveness of *E. monitorana* attack was demonstrated by the death of 97% of the attacked cones.

Attack increased in all 7 crown areas during the sampling period (Fig. 7). Attack in the 4 crown quarters was uniform, while attack in the horizontal thirds showed more variation. Analysis of variance revealed no difference in attack between the quarter-crown areas as in 1962. On June 15 there was no significant difference in attack between the top, middle, and bottom crown areas. However, on July 5 there was a significant difference between the top (91%) and bottom (57%) areas. These results suggest that cone selection for egg laying is random, and the later difference in attack was probably due to difference in number of cones available to migrating larvae. Most ovulate cones are produced in the upper and middle crown and most staminate flowers in the lower crown (Hard 1964b).

An examination of individual tree data revealed that attack was not equally distributed among all 30 trees used for permanent samples. When trees were arranged in ascending order of infestation, based on July 5 data, it was found that the point corresponding to 50% attack in marked cones was between trees 20 and 21 (Fig. 8). One-half of the attack was concentrated among ⅓ of the trees. These data were not subjected to analysis of variance, but they suggest the insect may have had a preference for certain trees in the plantation.

NATURE CONTROL FACTOR

Twenty-one white cottony pupal cocoons were col-

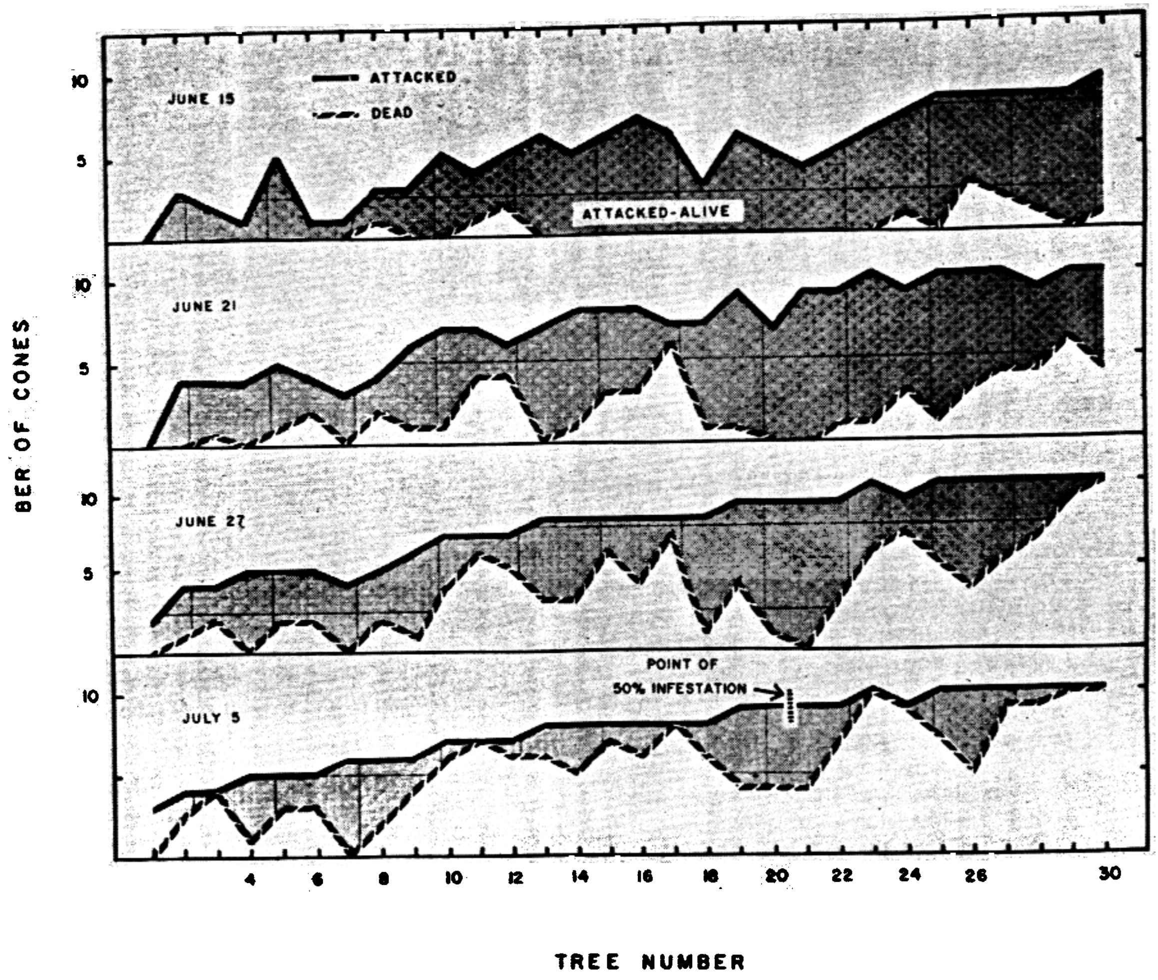


FIG. 8. Accumulated number attacked and dead cones on each of 30 trees on 4 dates at Lone Rock, Wis.

lected from 226 *E. monitorana* infested cones. Seven adults reared in shell vials were identified as Braconidae, and according to C. F. W. Muesebeck of the U. S. National Museum (personal communication, Mar. 5, 1964), they represented an undescribed species of *Apanteles*. The specimens were deposited in the insect collection of the University of Wisconsin.

E. monitorana larval head capsules and body remains were collected at the base of 13 *Apanteles* sp. cocoons. The head capsule widths of most were between 1.04 and 1.20 mm, suggesting the parasites kill 3rd-stage host larvae. Larvae of *Apanteles* sp. were found in host abdominal cavities. The larvae were 3 mm long and 0.75 mm wide.

DISCUSSION

The damage by *E. monitorana* found in the Lone Rock area was much greater than that reported recently for this insect by Mattson (1968) in north-central seed-production areas. Over a 6-year period he reported damage ranged between 2 and 10%. In contrast, at Lone Rock attack ranged from 91% in 1962 to 76% in 1963. As has been reported in this paper and elsewhere the larvae destroyed the whole cone, thus preventing seed production in each attacked cone.

Present knowledge indicates that *E. monitorana* individually is not a serious pest in its more northern range and occurs only as localized infestations. However, there may be circumstances in which this insect could become an important pest in northern seed-production areas. For instance, Lyons (1957b) found 1 area near Sault Ste. Marie, Ontario, where damage from *E. monitorana* was responsible for most seed mortality. No damage was caused by the red-pine cone beetle, *Conophthorus resinosae* Hopkins, the usually more prevalent red pine cone insect. In northern Wisconsin (Table 1) scattered populations were effectively competing with *C. resinosae*, and these populations may be important in the future.

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