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Flight Habits of the Alfalfa Seed Chalcid, *Bruchophagus roddi* Guss. (Hymenoptera: Eurytomidae)

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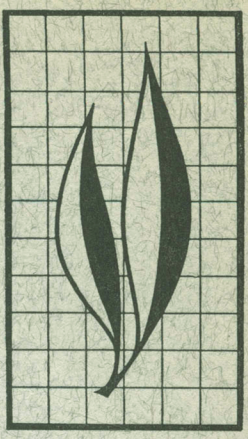

The flight habits of the alfalfa seed chalcid, *Bruchophagus roddi* Guss., were studied using natural field populations and reared insects which were radioactively marked. A minimum temperature of 70°F and a minimum light intensity of 0.2 Langley was found necessary for sustained flight. In a favorable host area, the chalcids dispersed only a few hundred yards within a few days. The movement of chalcids in a breeze less than about 5 mph was both upwind and downwind. In stronger winds, movement was predominantly downwind. The data obtained suggest that when a host area dries or otherwise becomes a nonhost area, the chalcids fly upwards where they encounter the stronger winds and rapidly leave the area. Marked chalcids were recovered 4,100 feet downwind of a release point; others were observed to survive 16 days in the field.

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Flight Habits of the Alfalfa Seed Chalcid, *Bruchophagus roddi* Guss. (Hymenoptera: Eurytomidae)[1]

INTRODUCTION

THE ALFALFA seed chalcid, *Bruchophagus roddi* Guss., a small eurytomid wasp, is one of the most devastating insect pests encountered in the production of seed alfalfa. Damage is especially severe in the western United States. Bur clover, *Medicago hispida,* and volunteer alfalfa growing along roadsides and in wasteland areas are important early-season hosts of the seed chalcid. When these hosts dry in late spring or early summer, it is believed that chalcids move to alfalfa seed fields and there contribute to infestations in the current season's crop. Large numbers of seed chalcids also overwinter as mature diapausing larvae within infested seeds that remain in the field following harvest. The emergence and subsequent movement of adults from these seeds in heavily infested fields may contribute significantly to infestations in newly planted fields.

The need for detailed information concerning the flight habits of the alfalfa seed chalcid has become more critical as the economic importance of this pest has increased. This investigation was initiated to assess the influence that infestations on bur clover, on volunteer alfalfa along roadsides, or in isolated fields of alfalfa may have on the overall loss caused by this pest.

Research published to date on seed chalcids includes studies on the nature of injury, extent and amount of damage, life history, host plant relationships, parasites, sampling methods, and systematic position (Urbahns, 1920; Sorenson, 1930; Hansen, 1955; Butler and Hansen, 1958; Neunzig and Gyrisco, 1958; Bacon, *et al.,* 1959; Strong, 1960, 1962*a*, 1962*b*, 1962*c*).

The flight habits of seed chalcids have not been studied previously. Urbahns (1914) states, "The adults of the chalcis-fly are very active in their flight and without doubt are carried long distances by the strong summer winds. They have been observed being carried in great numbers by the winds on a hot summer day and alighting on almost any object in their course." These observations shed little light on actual flight range or dispersal patterns.

While data on flight habits of seed chalcids are lacking, there have been many investigations of the flight and dispersal of other insects, especially flies, mosquitoes, aphids, grasshoppers and butterflies. The use of radioisotopes as an aid to following the movement of

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these and other insects has been reported by several authors. (For a review on the migration and dispersal of insects, see Schneider, 1962.)

Insect movements are followed most easily when the insect in question can be attracted to baits and trapped. Warner (1959) has reported that radioactively tagged *Drosophila* spp. were trapped in fairly large numbers 4.4 miles from the release point within 48 hours. Many insects, including the alfalfa seed chalcid, cannot be baited. Under this circumstance, the chance of recovery of marked individuals decreases exponentially with the distance from the release point.

Ecologists concerned with the winged movements of insects often refer to "migration" and "dispersal." Defining these terms is difficult, and their meanings differ from one insect group to another. Schneider (1962) cites six definitions of migration to illustrate this point. In this paper the term "migration" shall refer to the movement of seed chalcids from one habitat to another, irrespective of the distance involved, while "dispersal" shall refer to the movement of the insects within a single habitat.

METHODS AND MATERIALS

The experiments were conducted in alfalfa hay and seed fields on the campus of the University of California at Davis or in fields in the vicinity of Davis in 1961 and 1962. Isotopically tagged chalcids as well as naturally occurring field populations were utilized in the investigations.

The tagged chalcids used in the experiments were reared from infested seed-mill screenings. Approximately 2,000 pounds of screenings were collected in November of 1960 and also in 1961, and stored at 43°F. In the spring of 1961 and 1962 when large numbers of chalcids were needed for field release, 150-pound lots of screenings were removed from storage and distributed in large metal trays. These trays were stacked in an emergence room (73°F) equipped with a glass wall lighted from behind. Chalcids collecting on the lighted wall were gently brushed into 1-gallon ice cream cartons for subsequent feeding and tagging. Each carton, containing about 4,000 chalcids, was then covered with a plastic bag. Maximum emergence of adults occurred from 20 to 27 days after the seed was removed from storage at 43°F.

The chalcids were immobilized prior to tagging by chilling at 40°F for 30 minutes, after which they were shaken to the bottom of the carton. The inner wall of the carton and the plastic cover then were coated lightly with 1:1 solution of honey and glycerol to which was added 1 mc of P^{32} or S^{35} (as sodium phosphate or sodium sulfate in sterile saline solution). A cotton ear swab was used as an applicator. Ten milliliters of the radioactive mixture was sufficient to treat ten cartons. The cartons were held at 73°F for 24 hours, during which time the chalcids actively fed. After feeding, they were placed in a cabinet at 50°F until needed. The chalcids could be held in this manner up to 10 days without appreciable mortality.

The chalcids usually were released at night. This was accomplished by placing the cartons gently on the ground and slowly removing the plastic covers; the chalcids vacated the cartons at will.

Three different methods were used to recapture released chalcids in the field. These were standard insect sweep nets, vacuum machines, and rotary nets. The vacuum machines (figure 1) were patterned after those of Dietrick, *et al.* (1959). The back-pack model was purchased from D-Vac Inc., Ventura, California. The machine consists essentially of a gasoline-engine-driven fan, a flexible air conduit and a collecting head and bag. The collecting head containing the

bag has an opening exactly 1 square foot in area. In operation, the fan creates a vacuum by pulling air through the collecting head. The insects are sucked into the bag when the collecting head is placed over the plants. Samples were taken by dropping the collecting head over the plants 500 times within a rectangular area measuring 10 × 50 feet at each sampling station. The number of stations sampled varied according to the particular experiment. Samples from the vacuum machines were placed in modified Berlese funnels for 12 to 18 hours. All chalcids collected were either scanned individually with a portable Geiger-Muller tube or placed in various counting instruments to ascertain the presence of radioactivity.

The rotary net machines (figure 2) were equipped with two fine-mesh wire-screen funnels mounted each on one end of a 12-foot boom. One net (the upper net) was mounted on the upper side of the boom; the other net (the lower net) was mounted on the lower side. There was a vertical separation of 1.5 feet between the centers of the openings of the two nets. The boom, driven by a gasoline engine through appropriate reduction gears, rotated once per second, resulting in a velocity of 25.8 mph for the nets. The height of the boom was adjustable from a position where the lower net skimmed the ground surface to a height where the upper net was 9 feet above the ground. Organdy bags were attached to the small end of the funnels. The insects in the collections, which were usually made every 30 minutes, were killed in cyanide and the chalcids removed by hand.

Climatological data were obtained on continuously recording instruments for the majority of the investigations. Air temperature, black globe temperature, temperature of the soil surface beneath the plants and wind velocity at low elevations were recorded on battery-operated Foxboro recorders. Wind direction and velocity at higher elevations (9 feet) were recorded on Beckman recorders. A hygrothermograph also was operated to record relative humidity. Light intensity data were recorded on an Eppley pyrheliometer operated by the Department of Agricultural Engineering, Davis.

Fig. 1. Back-pack model vacuum machine. The pick-up head has an area of 1 square foot.

RESULTS

Movement under Natural Conditions

Four experiments were conducted to determine the effects that wind, light intensity, temperature and height above the ground had on the natural movements of the chalcids. One of these experiments was conducted in an area abounding in bur clover; the other three

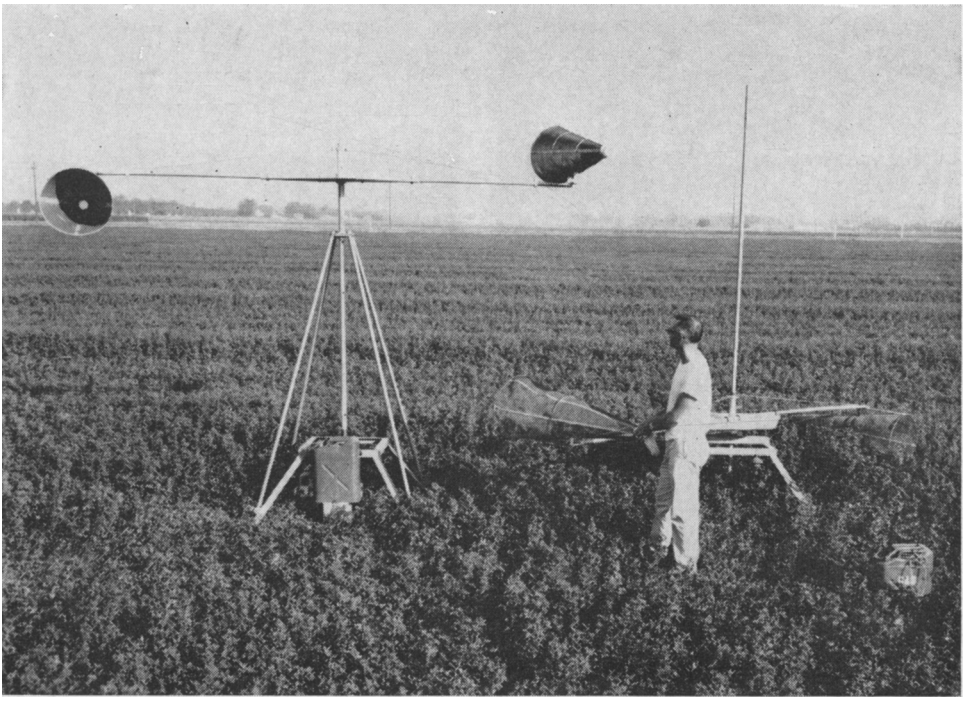

Fig. 2. Rotary net machines used to capture flying alfalfa seed chalcids, shown in a host area with the boom in the high position at the left and in the low position at the right.

were conducted in alfalfa seed fields. The data from these experiments (figures 3, 4) were obtained using the rotary nets.

Light intensity strongly influenced flight activity. Almost no chalcids were captured in the rotary nets when the light intensity fell below approximately 0.2 Langley units (1 ly = 1 calorie/cm^2/min) (figures 3B, 3C, 4A, 4B). This level of intensity occurred about 30 to 40 minutes before sunset or after sunrise when there was no cloud cover. No chalcids were collected when rotary nets were operated at night.

Ambient air temperature also profoundly influenced flight activity. Limited flight activity began when the temperature rose to about 70°F. Mass flight began when the temperature reached about 74°F and generally increased as the temperature increased. Flight was observed at temperatures as high as 110°F (figure 5A).

There was an interaction of light and temperature on flight activity, as shown in figure 3B. At 7:30 A.M. on June 1, the light intensity was 0.75 Langley units (not plotted), exceeding the minimum for flight. However, the temperature was only 67°F; thus, no flight occurred. At 8:00 P.M. the temperature was high enough to permit flight (78°F), but by then light intensity had dropped to 0.11 Langley units and flight for the day ceased.

Observations on the flight activity of the chalcids in relation to air movement were made on four separate days (figures 3, 4). At the bur clover location (figure 3A) chalcids were captured at an elevation of 5 feet in winds ranging from 10 to 15 mph, although catches were considerably smaller than at the 1.5-foot level.

Large numbers of chalcids were captured in an alfalfa seed field at elevations 1.5 and 3 feet above the ground in a steady 6 mph wind (figure 3B). Figure 3C shows the results of an ex-

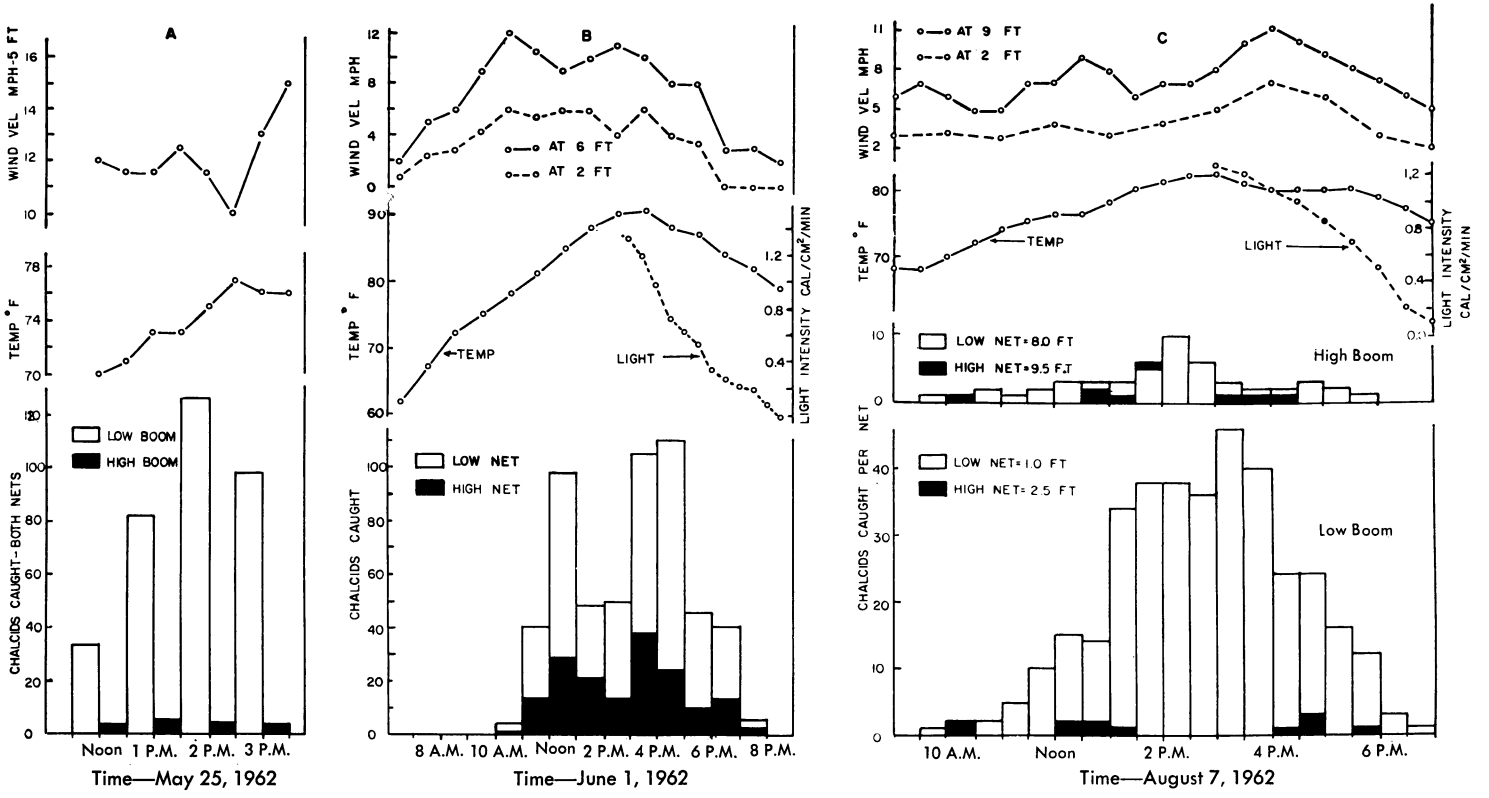

Fig. 3. Frequency histograms showing the effect of height of nets, temperature, wind velocity, and light intensity on the numbers of chalcids captured from natural populations at 30-minute intervals. Davis, California.

A. Catches of adults in a bur-clover area. The boom position was alternated each 30 minutes between 5 feet (high boom) and 1.5 feet (low boom).

B. Catches of adults in one rotary net in an alfalfa-seed field in 20 per cent bloom. Low net—1.5 feet above ground. High net—3 feet above ground.

C. Catches of adults from two adjacent rotary nets operated simultaneously in an alfalfa-seed field. The low net of the low boom was below the tops of the plants, while the high net of the low boom was just above the tops of the plants.

periment in which two adjacent rotary nets were operated simultaneously for 10 hours. On one machine the two nets were located 1.0 and 2.5 feet above the ground. On the other machine nets were placed at 8.0 and 9.5 feet. In this experiment significantly more chalcids were captured at 8.0 and 9.5 feet than at 2.5 feet, but not more than at 1.0 foot. This was despite the fact that the wind was stronger at the upper levels than at 2.5 feet. These data indicate that flight activity is not always directly proportional to wind velocity.

Because of the persistent air movement during the day at the higher elevations, it was not possible to separate the influence of air movement from any other contributing influence that height above the ground may have had on flight activity.

The distribution of the sexes in relation to elevation (figures 4A, 4B) was determined with the use of two adjacent rotary nets. At the low elevations there were approximately twice as many males as females when the experiment was started. The catch of males then began to decrease sharply. This decrease is difficult to explain; one can postulate that the supply of males in the immediate area of the net was not being replenished by males from the surrounding areas. The number of females at the high level increased continuously for 3 hours, while the male population at that elevation remained roughly constant.

The above results do not provide information concerning the movement of chalcids in relation to wind direction. To investigate this, a release of 35,000 tagged adults was made after dark in an alfalfa hay field (plants 12 inches high) on June 28, 1962. At 8:00 A.M. the following morning, two rotary nets

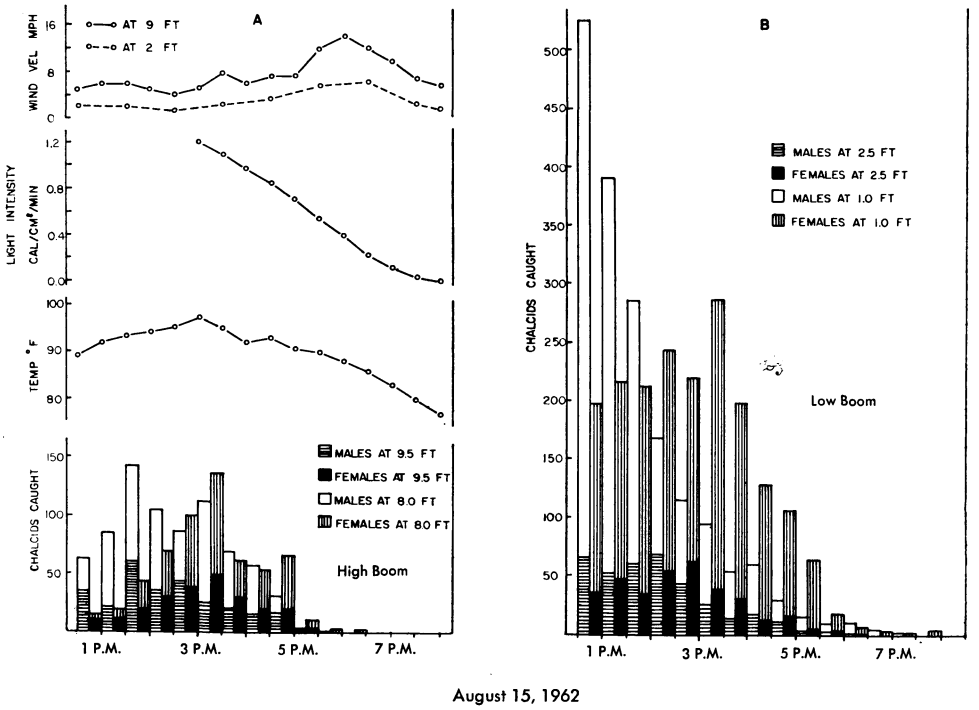

Fig. 4. Effect of height of nets, temperature, light intensity, and wind velocity on catches of male and female chalcids from a natural population using two adjacent rotary nets operated simultaneously in an alfalfa seed field. A. High boom. B. Low boom.

were placed in continuous operation. One was situated 100 yards upwind and the other 100 yards downwind of the release point. By 11:00 A.M., one tagged chalcid had been captured in each of the rotary nets; the wind was steady at 4 to 5 mph. At 11:15 A.M. the wind increased to 10 to 12 mph. During the remainder of the day no additional chalcids were captured in the upwind trap; seven marked ones were captured downwind. It thus appeared that movement was in the direction of the wind. Movement into the wind apparently occurs when the velocity is less than about 5 mph. A preliminary experiment conducted in 1961 on radioactively tagged chalcids yielded similar results (see figure 5).

Dispersal of Radioactively Tagged Chalcids

The following experiment was conducted to observe the mass movement of a group of chalcids. At 9:30 P.M., May 20, 1961, approximately 90,000 tagged adults were released in an alfalfa hay field. The field had no blooms and the plants were 14 to 16 inches high. When sustained flight was noted first at 9:30 A.M. (temperature = 71°F) the next morning, a sampling program was initiated using four 180° sweeps with an insect-sweeping net. Samples were taken at eight points on concentric circles 5, 10, 15, and 20 yards from the release point. The results (table 1) revealed that: 1) in 1 hour adults moved

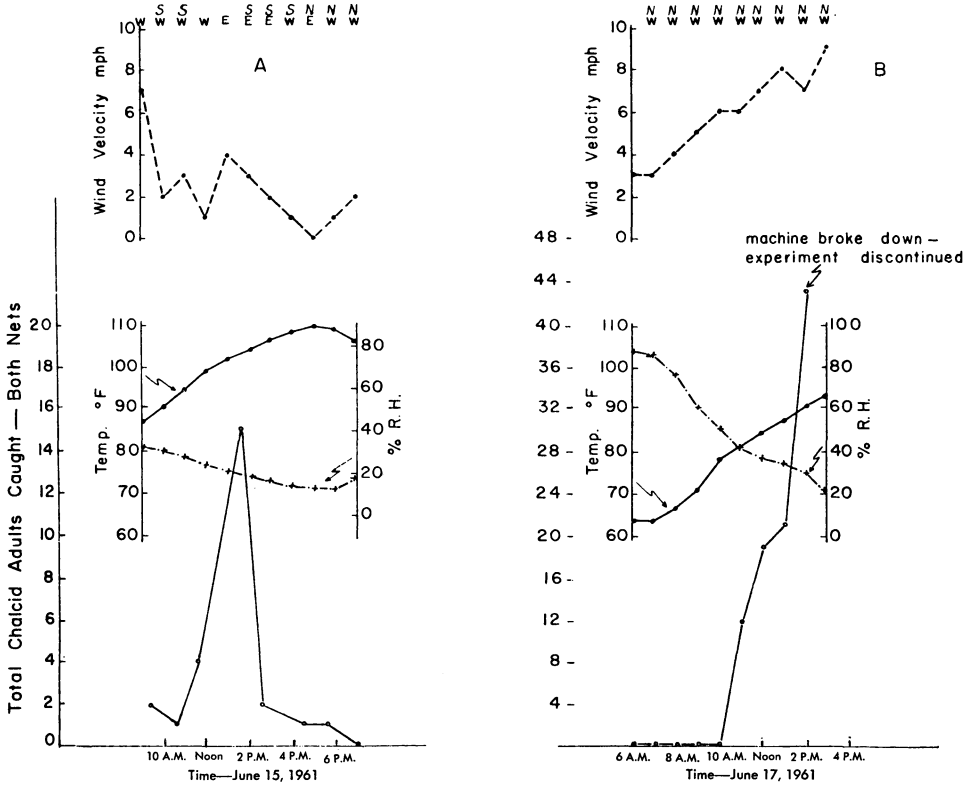

Fig. 5. Effect of temperature, relative humidity, wind direction and velocity on catches of radioactively tagged chalcids released in a mown ryegrass field. Davis, California.

A. 40,000 adults released 40 yards northwest of a single rotary net machine at 9:15 P.M. June 12, 1961.

B. 30,000 adults released 30 yards southwest of the machine at 9:30 P.M. on June 16, 1961.

TABLE 1

HOST HABITATS

EFFECT OF WIND DIRECTION, DISTANCE, AND TIME INTERVAL ON RECOVERY OF 90,000 RADIOACTIVE CHALCIDS FOLLOWING FIELD RELEASE, DAVIS, CALIFORNIA, MAY 20, 1961*

Station	Direction from release area†	Number of chalcids recovered							
		Distance from release area and time (A.M.)							
		5 yd 9:30	5 yd 9:50	10 yd 10:03	10 yd 10:10	5 yd 10:30	10 yd 10:50	15 yd 11:10	20 yd 11:30
1	S	0	1	0	3	12	0	1	1
2	SW	0	1	0	2	5	1	0	1
3‡	W	0	2	0	0	8	11	1	1
4‡	NW	0	0	0	0	11	15	1	4
5‡	N	0	1	0	0	15	17	6	4
6‡	NE	0	0	1	0	18	14	10	3
7	E	1	1	0	0	7	3	5	0
8	SE	1	1	1	0	8	0	0	0

* See text for experimental methods.
† At 10:15 A.M. the wind changed from essentially calm to approximately ESE, 2 to 5 mph.
‡ Catches at these stations were predominately downwind after 10:15 A.M.

in large numbers 5 yards, but not 10 yards; 2) in 1.33 hours adults reached the 10-yard circle and movement was predominately downwind; 3) in 1.66 hours adults reached the 15-yard circle and in 2 hours large numbers of adults reached the 20-yard circle; at both times movement was downwind. Thus, the overall dispersal of a population of chalcids in a host habitat appears to be quite slow.

The chalcids from this release were sampled with a vacuum sampler (500 ft^2 areas) at the points shown in figure 6 during the next 16 days. The recovery of chalcids from these samples is shown in table 2. Large numbers of chalcids were still within 30 feet of the release point 2 days after the release; a few live ones were found in the same area 16 days after release. The fact that no tagged chalcids were recovered beyond 850 feet in this experiment probably was due to the dilution factor and the relatively small area sampled.

Dispersal and migration habits were studied further in 1962, using rotary net machines as recovery devices. Two lots of about 40,000 insects each were released on May 31, 1962. One lot was tagged with S^{35} and the other with P^{32}. Those tagged with S^{35} were released in an alfalfa seed field having about 20 per cent bloom; the P^{32} lot was released 0.45 miles east of this field in a freshly plowed barley field. Between the two release points were plantings of barley and castor bean, and bare land, but no alfalfa. A single rotary net was operated on June 1, 350 feet southeast of the S^{35} release point, for 14 continuous hours, with the low net just brushing the plant tops. The wind was steady from the north-northwest at 8 to 11 mph.

The first tagged chalcid was captured at 11:30 A.M., 3 hours after the temperature reached 72°F. Tagged individuals were captured hourly thereafter until 6:30 P.M. A total of 52 was recovered, all females and all tagged with S^{35}. On June 2 when the wind shifted to south-southwest at 12 to 15 mph, the rotary net was moved 350 feet northwest of the S^{35} release point. After continuous operation in this position for 5.5 hours, 194 chalcids tagged with S^{35} were recovered. Thus, the catches for June 1 and 2 both represent downwind catches. On June 4, when the wind had shifted back

to north-northwest, the net was operated for 5 hours at a point 1,200 feet south of the S^{35} release point. Only 4 tagged chalcids, 2 males and 2 females, were recovered.

As none of the P^{32}-marked individuals had been recovered in the alfalfa seed field between May 31 and June 5, the rotary net was moved to a point 2,400 feet directly downwind of the P^{32} release point and operated in an alfalfa hay field for 4.5 hours. One tagged (P^{32}) male was recovered. The following day, the net was operated in a small alfalfa plot 4,100 feet downwind of the P^{32} release point; this time, one P^{32}-marked female was recovered. With the exception of June 2, the wind was steadily from the north-northwest from June 1 to June 8.

From this experiment it was concluded that in a host habitat, the chalcids do not disperse *en masse* more than a few hundred yards within a few days,

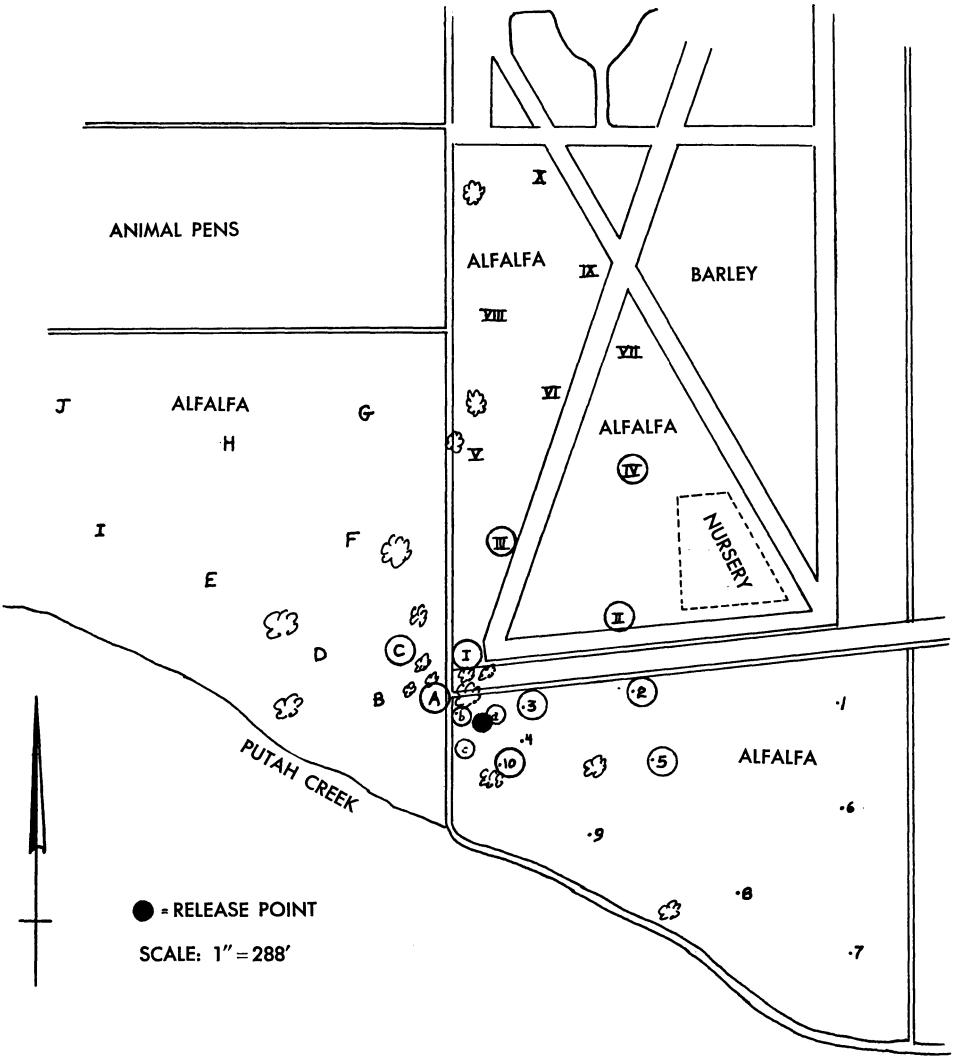

Fig. 6. Arabic and Roman numerals and letters represent points sampled with the vacuum sampler at various time intervals after 90,000 tagged adult chalcids were released on May 20, 1961. Circled points indicate those stations at which tagged chalcids were recaptured. Davis, California.

TABLE 2

HOST HABITATS

SIXTEEN-DAY RECOVERY RECORD ON 90,000 RADIOACTIVE CHALCIDS; FIELD RELEASE, DAVIS, CALIFORNIA, MAY 20, 1961*

Station†	Distance in feet and direction from release area	Number of chalcids recovered‡											
		May 21		May 23		May 24		May 26		May 29		June 5	
		♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
1	1,050 - E	–§	–	–	–	–	–	0	0	–	–	–	–
2	450 - E	0	0	–	–	–	–	0	1	–	–	–	–
3	150 - NE	1	0	–	–	1	1	0	1	–	–	0	0
4	150 - E	0	0	–	–	–	–	–	–	–	–	0	0
5	450 - ESE	1	0	–	–	–	–	0	1	–	–	0	0
6	1,050 - ESE	–	–	–	–	–	–	0	0	–	–	–	–
7	1,250 - SE	–	–	–	–	–	–	0	0	–	–	–	–
8	825 - SE	–	–	–	–	–	–	0	0	–	–	–	–
9	450 - SE	0	0	–	–	–	–	0	0	–	–	–	–
10	150 - SSE	0	0	–	–	0	2	0	0	–	–	0	0
I	250 - N	–	–	1	0	–	–	–	–	0	0	–	–
II	500 - NE	0	0	0	0	–	–	–	–	0	3	–	–
III	600 - N	1	0	0	0	–	–	–	–	–	–	0	0
IV	850 - N	–	–	0	0	–	–	–	–	1	1	–	–
V	850 - NE	–	–	0	0	–	–	–	–	0	0	–	–
VI	1,000 - NNE	–	–	0	0	–	–	–	–	–	–	–	–
VII	1,200 - NE	–	–	0	0	–	–	–	–	0	0	–	–
VIII	1,200 - N	–	–	0	0	–	–	–	–	–	–	–	–
A	200 - NW	–	–	–	–	0	2	–	–	–	–	–	–
B	400 - WNW	–	–	–	–	0	0	–	–	–	–	0	0
C	350 - NW	0	0	–	–	1	0	–	–	–	–	–	–
a	30 - N	–	–	126	22	–	–	–	–	0	5	3	0
b	120 - NW	–	–	11	4	–	–	–	–	0	2	0	0
c	120 - SW	–	–	–	–	0	4	–	–	–	–	0	0

* See text for experimental details.
† See figure 6 for identification of station codes shown on a map of the area.
‡ Each sample represents 500 square feet of alfalfa.
§ Dash indicates no data recorded.

whereas, if they originate in a nonhost area, at least some individuals will travel downwind long distances. They apparently do not move any great distance directly crosswind, for no P^{32}-marked individuals were recovered in the seed field 0.45 miles west of their origin. If one considers the possibly tremendous dilution of indivduals while traveling 4,100 feet, and the fact that one chalcid was recovered at this distance, it seems logical to assume that in a nonhost area, the chalcids are capable of traveling downwind several miles within a day or two.

Further studies were conducted to observe the migration of chalcids from nonhost habitats. On July 2, 1962, approximately 40,000 chalcids were released at 9:55 A.M. in a dry, cut barley field 100 yards upwind of the nets. At the same time, both rotary nets were put into operation, one with the boom at 1.5 feet and the other with the boom at 9.0 feet above the ground. Beginning at 10:00 A.M. and each 5 minutes thereafter, the low net of the low boom was changed; the other nets were changed at 30-minute intervals. The results of these catches are shown in table 3. From these results, it seems that something like a mass exodus occurs very rapidly. The first tagged adult was captured within 5 minutes after release. Assuming it was caught at the end of the 5-minute period, its average speed was about 0.75 mph. At the end of 30 minutes, 31 individuals were recovered at the 9-foot level while only 11 had been taken at the 1.5-foot level. This in-

dicates that the chalcids were going to the higher elevations and migrating with the wind. It is of interest to note that 28 of the 31 adults captured in the first 30-minute interval in the nets of the high boom were females. During the next two 30-minute periods, only 2 and 4 adults were recovered, respectively, in the high boom, indicating that the initial movement involved the majority of indivduals released. The catch in the nets on the low boom varied from 0 to 4 per 30-minute interval for 5 hours after release. Thus, some of the individuals manifested movement of a dispersal type rather than of a migratory nature.

TABLE 3

NONHOST HABITATS

EFFECT OF TIME INTERVAL, HEIGHT OF NETS, AND WIND VELOCITY ON RECOVERY OF 40,000 TAGGED CHALCIDS, DAVIS, CALIFORNIA, JULY 2, 1962*

Recovery time†	Number of chalcids recovered 100 yards downwind of release point								Wind velocity mph	
	Low boom = 1.5 feet				High boom = 9.0 feet					
	Low net		Upper net		Low net		Upper net		Average at 9.0 feet	Peak gust
	♀	♂	♀	♂	♀	♂	♀	♂		
10:00 A.M.	1	0	-‡	-	-	-	-	-	-	-
10:05 A.M.	2	0	-	-	-	-	-	-	7	18
10:10 A.M.	1	0	-	-	-	-	-	-	12	18
10:15 A.M.	0	1	-	-	-	-	-	-	9	20
10:20 A.M.	0	0	-	-	-	-	-	-	11	18
10:25 A.M.	0	0	-	-	-	-	-	-	10	15
10:30 A.M.	0	2	4	0	14	1	14	2	10	13
11:00 A.M.	1	2	2	0	1	0	1	0	8	18
11:30 A.M.	1	1	1	2	1	1	2	0	10	18
12:00 M.	0	0	0	1	0	0	0	0	8	20
12:30 P.M.	0	2	0	0	0	3	0	1	8	15
1:00 P.M.	0	1	0	0	0	0	1	0	6	16
1:30 P.M.	1	0	0	1	0	0	0	0	4	8
2:00 P.M.	0	1	1	0	0	0	0	0	4	7
2:30 P.M.	0	0	0	0	0	0	0	0	7	18
3:00 P.M.	0	0	1	0	0	0	0	0	9	12

* See text for experimental details.
† Release time, 9:55 A.M.
‡ Dash indicates no data recorded.

SUMMARY AND CONCLUSIONS

1. Light intensity must be at least 0.2 Langley units before flight of the alfalfa seed chalcid occurs.

2. A temperature of at least 70°F is needed for sustained flight.

3. Chalcids move upwind as well as downwind in a gentle breeze (less than 5 mph). In a strong wind, movement is predominantly downwind.

4. When flight originates from a non-host area, the female chalcids tend to fly upward where they encounter the stronger winds and, moving with them, rapidly leave the area.

5. In a favorable host area, the chalcids appear to remain close to the plants and disperse only a few hundred yards within a few days.

6. The alfalfa seed chalcid is capable of moving in the air to distances of 4,100 feet and will probably travel considerably farther.

7. Chalcids were observed to remain alive in the field for 16 days.

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[2] Microfilm copies may be purchased from the University of California Library Photographic Service, Berkeley, California 94720.

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