Microenvironmental Factors Regulating the Flight of *Coptotermes formosanus* Shiraki in Hawaii[1] (Isoptera: Rhinotermitidae)

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ABSTRACT

Wind velocity, light intensity, soil temperature, vapor pressure deficit in the colony, vapor pressure deficit at the surface of the flight slits, and vapor pressure deficit at 1 m above the soil were measured during the swarming season.

The vapor pressure deficits and soil temperature were not critical factors for flight since they were in a favorable range during the observation period. Light intensity had to drop to 10.8 lumen/m² before flight was initiated. Flight was terminated when the light was reduced to 0.14 lumen/m². Light intensity, however, was not limiting since the intensity dropped every evening. The key microenvironmental factor regulating flight was the wind velocity at the flight slits. Flight was initiated if the wind velocity was below 3.7 km/h. If the wind increased to over 3.7 km/h after flight was started, flight was terminated.

Termite flight and the factors affecting the flight of many species of termites has been comprehensively reviewed by Nutting (1969). In Hawaii, *Coptotermes formosanus* Shiraki usually swarms on muggy, still evenings in May and June (Bess 1970, Higa 1981). Flights also occur during other months, but involve only a few individuals (Higa 1981). Bess (1970) reported that the species was crepuscular, with flight durations of less than 30 min.

Little is known, however, about the microenvironmental factors associated with the initiation of flights of *C. formosanus*. It is known that the flights occur during moist, humid evenings with little wind movement. However, there were many evenings when the ambient conditions appeared to be ideal for flight but flight did not occur. It was apparent that there were other keys in the microenvironment which played a major role in the initiation of flight. This study was made to assess the effect of some microenvironmental factors on swarming.

MATERIALS AND METHODS

The colony of *C. formosanus* observed in this study was located on the campus of the University of Hawaii, Manoa. It is one of the three colonies regularly monitored by soil traps (Tamashiro et al. 1973) and was labeled UH-2 (Lai 1977). This UH-2 colony consists of 2.01 ± 0.67 million termites and had been under observation for more than 7 years (Tamashiro et al. 1981). This colony is known to be representative of *C. formosanus* colonies in size and behavior in Hawaii. On evenings when alates swarmed from UH-2 colony, alates usually swarmed from other colonies within a several square mile area.

The contruction of the soil traps used to monitor the colony permitted measurement of the colony's temperatures (wet and dry bulb) with a gun psychrometer. Flight was observed as the alates emerged from a 4.4 × 9.5 × 243.9 cm wooden stud adjacent

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to a walkway located 3.5 m north of the trap site. This stud contained many flight slits for the alates. The location of the stud was such that flight was unobstructed by any building or vegetative growth, and the physical and biotic parameters could easily be monitored. The colony itself extended 30 m north where it infested a building and 40 m southwest where it appeared in traps planted in a courtyard.

Physical parameters. Observations for flight were made from 1900 h since this species is crepuscular and flies at dusk. The following parameters were measured: (1) soil temperature; (2) wind velocity at the flight slits; (3) light intensity; (4) colony's vapor pressure deficit (CVPD); (5) surface vapor pressure deficit (SVPD); and (6) vapor pressure deficit at 1 m above the soil (1 m VPD). Soil temperature (°C) was determined with a temperature probe; wind velocity (km/h) with a Taylor Biram's anemometer; light intensity (Lumen/m^2) with an Optometer light meter; colony VPD using an Atkins Thermister gun psychrometer; surface VPD with a Bendix psychrometer; and VPD at 1 m with a sling psychrometer.

Three measurements of each physical parameter were taken at 6-min intervals, for a 42-min period, or until flight terminated. A similar protocol was followed during evenings when no observable termite flights occurred.

Biotic parameters. Light traps and direct field observations were used to monitor flights of *C. formosanus.* Three light traps were placed along a east-west transect. The first light trap was located 3 m west, the second, 25 m west and the third, 125 m west of the observational site. These traps were placed ca 2 m above ground level and checked daily for alates, from 1 May to 13 June 1980.

Direct field observations. The aerial parts of the colony containing the flight slits were periodically examined from 1200 h to observe termite behavior prior to flight. The flight slits, 3 to 20 cm in length by 1 to 2 cm in width, were previously cut through to the surface of the wood by the workers and resealed. When flight started, the numbers of alates and soldiers involved in the flight were quantified by photographing the flight slits and the surrounding area. A camera was mounted on a tripod ca 60 cm away from the slits so that a 35.6 cm section of wood could be photographed. A photograph was taken just prior to flight. Upon initiation of flight, photographs were taken at 2-min intervals until the flight terminated and most of the soldiers had returned to the tunnels. The electronic flash used to photograph the flight apparently did not affect the behavior of the termites.

Data analyses. Data were analyzed in two steps. The first was to determine the frequency of flight days based on observed and light trap data. The second was to determine if flight days could be differentiated from non-flight days, solely on the abiotic parameters. Nine flight days were compared with 12 non-flight days. The 21 measurements (3 reps/6 min; 42 min total) were compared for each day of observation to determine whether there were any differences in the two groups.

RESULTS AND DISCUSSION

Flight vs. non-flight days. The observed and non-observed flights for May and early June are given in Table 1. Observed flights were those where alates were actually seen leaving the galleries. The non-observed flights were those originating from sites other than the one under observation. Light trap captures were used as evidence of non-observed flights. The first observed flight occurred on 12 May and subsequently on 9 of the next 18 days (Table 1). The inital non-observed flight occurred on 9 May and alates were collected on 18 of the next 29 days.

The differences in the frequency of observed and non-observed flights were due to the nature of the samples. The observed flights came from only one small section of

TABLE 1. Flights of *Coptotermes formosanus* Shiraki from colonies on the campus of the University of Hawaii, Manoa. Observed flights are actual observations of alates emerging from the colony. Non-observed flights are based on evidence from light trap captures.

	Flights			Flights	
	Observed	Non-Observed		Observed	Non-Observed
May 1980			May 1980		
9		+	25		+
10			26		
11			27		+
12	+	+	28		
13			29	+	+
14	+	+	30		+
15	+	+	31	+	+
16	+	+	June 1980		
17		+	1		+
18			2		
19	+	+	3		
20		+	4		
21	+	+	5		
22		+	6		
23	+	+	7		
24	+	+	8		+

one colony. The non-observed flights included alates from a large area which included alates from other parts of the same colony and from other colonies. The differences suggested that microclimate at the colony level probably had a significant effect on the initiation of flight since there were termites emerging from some flight slits but not others in another section of the same colony.

Table 2 presents the comparison of 5 microenvironmental variables on 9 observed flight days and 12 days when there were no flights from the flight slits under direct observation. These days were selected from the period from May 15 to June 8, 1980.

There were no significant differences in vapor pressure deficits, temperature, and light intensity between flight and non-flight days. The low VPD's showed that the humidity was high throughout the period. The temperature was uniform and the light intensity dropped every evening. These factors, therefore, were not limiting since they were in a favorable range for swarming. Light intensity, however, determined when swarming started and when it ended.

The key microenironmental factor which regulated flight was the velocity of the winds at the flight slits. This was the only microenvironmental factor which was significantly different between flight and non-flight days ($t > .01$). The termites were very sensitive to wind and to changes in the velocity of the wind. There was no flight if the wind reached or exceeded 3.7 ± 0.94 km/h.

On several occasions, preparation for flight, or a flight actually in progress, stopped abruptly when the wind went over 3.7 km/h. On other occasions, swarming continued even during a light rainfall, as long as the wind did not surpass 3.7 km/h. This may explain why swarming occurs in scattered locations on some nights and over

TABLE 2. Means and standard deviations (SD) of five environmental variables measured during nine flight days and twelve non-flight days, May-June, 1980. Sample size is N = 21 for each day of observations.

	Flight Days		Non-Flight Days	
	$\bar{X}$	SD	$\bar{X}$	SD
Colony Vapor Pressure Deficit	0.05	0.03	0.07	0.02
Surface Vapor Pressure Deficit	0.21	0.05	0.23	0.02
Vapor Pressure Deficit at 100 cm	0.22	0.04	0.20	0.06
Wind km/h	1.64*	0.82	3.72*	0.93
Soil Temperature °C	24.03	1.04	23.99	0.07

*t > .01.

the entire island on other nights with similar ambient conditions. In addition to wind, however, there obviously were other internal triggers for swarming in the colony. The alates did not swarm on every night when the wind was low but when they did swarm, the wind was low.

Behavior of C. formosanus during the swarming period. Workers started opening the flight slits as early as 1200 h. The antennae of soldiers could be seen protruding through these openings. The velocity of the wind at this time was not critical, and winds higher than 3.7 km/h did not change the behavior of the termites. As the day progressed, the workers opened more slits and made many small perforations in slits which were not open.

At dusk, when light intensity decreased to ca 10.8 lumen/m^2, the workers removed the rest of the cover of the flight slits if the wind was below 3.7 km/h. If the wind at this time was too high for flight, the slits were sealed and flight did not occur. If the wind was not too high, the soldiers came out of the slits and surrounded the area. The alates emerged shortly after the soldiers had moved out of the tunnels and took flight from the openings. They flew directly away from the slits. As the flight progressed, larger numbers of alates and soldiers came out of the colony.

The emergence pattern of the alates was skewed with peak emergence occurring ca 12 min after the flight started (Fig. 1). The average duration of swarming which was not terminated by an increase in wind velocity was 30.5 min with a minimum duration of 17 min and a maximum of 40 min.

Observations also revealed that all of the alates in the colony did not emerge in a single night. Swarming was protracted over a 3 week or longer period. Moreover, it was difficult to estimate the number of alates emerging from a colony or even from the slits under observation. Although photographs were taken a 2-min intervals, this only accounted for the adults emerging at the instant the photograph was taken. There were a large number of alates emerging between photographs which were not recorded. The number of alates (Fig. 1), therefore, was underestimated.

The counts of soldiers, on the other hand, were probably accurate, since the same soldiers were photographed each time. During a flight, soldiers radiated out as far as 15 cm from the flight slits to protect the area. On two occasions, acutal combat between soldiers and argentine ants, *Iridomyrmex humilis* (Mayr) was observed.

Swarming was terminated when the light intensity dropped below 0.14 lumen/m^2. The physical parameters which were measured at six-minute intervals during the flight period showed no significant changes, except for the gradual drop in

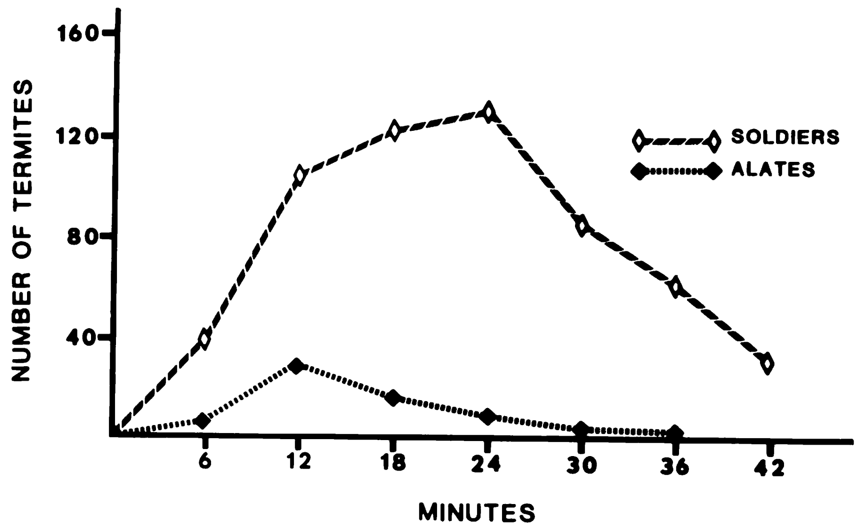

FIGURE 1. The emergence patterns of *Coptotermes formosanus* Shiraki alates and soldiers during an average flight in May - June, 1980, as determined by photographs taken at 2-min intervals.

light intensity. After the flight terminated, the soldiers slowly returned to the colony, while the workers closed the flight slits. By the time the slits were closed, most of the soldiers were back in the galleries.

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