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Authors: Ferreira, Maria Teresa, and Scheffrahn, Rudolf H.

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LIGHT ATTRACTION AND SUBSEQUENT COLONIZATION BEHAVIORS OF ALATES AND DEALATES OF THE WEST INDIAN DRYWOOD TERMITE (ISOPTERA: KALOTERMITIDAE)

MARIA TERESA FERREIRA[1,2] AND RUDOLF H. SCHEFFRAHN[1,2]
[1]Fort Lauderdale Research and Education Center, University of Florida,3205 College Avenue, Davie, FL 33314

[2]Azorean Biodiversity Group (CITA-A), Departamento de Ciências Agrárias, Universidade dos Açores, Pico da Urze, Angra do Heroísmo, Portugal

ABSTRACT

Laboratory studies were conducted during the 2007 and 2008 dispersal seasons of the West Indian drywood termite *Cryptotermes brevis* (Walker), a serious urban pest of wooden structures. Attraction to light and subsequent colonization of this species were studied by observing the response of alates to lit and dark chambers. Several intensities of light were tested to determine if light intensity had a role in the alates' attraction to light and subsequent colonization. A bioassay was conducted with semi-shaded wood blocks to quantify negative phototaxis for the dealates. We found that the alates of *C. brevis* preferred flying into lit areas for colonization, and that the number of colonizations was highest in the high light intensity treatments. Negative phototaxis of the dealates was observed because these preferred to colonize in the dark habitat treatments. This information is important when deciding what control methods may be used to prevent *C. brevis* from colonizing wood structures. Traps with a high intensity light to attract *C. brevis* alates and to prevent infestation may be a way to monitor and control this urban pest.

Key Words: *Cryptotermes brevis,* phototaxis, colonization, alates, dealates

RESUMO

Estudos num laboratório foram realizados durante a época de voo de dispersão de 2007 e 2008 para a térmita da madeira seca *Cryptotermes brevis* (Walker), uma praga urbana de estruturas de madeira séria. A atracção à luz e subsequente colonização desta espécie foi estudada, observando a resposta dos alados a câmaras de preferência de luz. Várias intensidades de luz foram testadas para determinar se a intensidade da luz tinha um papel na atracção dos alados pela luz e subsequente colonização. Um ensaio usando blocos de madeira semi-cobertos para quantificar o comportamento fototáctico negativo dos dealados foi conduzido. Nós observámos que os alados de *C. brevis* preferem áreas com maior iluminação para colonizarem, e que o número de colonizações era maior no tratamento com maior intensidade de luz. O comportamento fototáctico negativo dos dealados foi observado porque os dealados preferem colonizar nos tratamentos de habitats escuros. Esta informação é importante quando se tem de decidir que métodos de controlo podem ser usados para prevenir a térmita *C. brevis* de colonizar estruturas de madeira. Usar armadilhas com uma intensidade luminosa elevada para atrair alados de *C. brevis* e prevenir uma infestação poderá ser uma forma de monitorizar e controlar esta praga.

Translation provided by the authors.

The West Indian drywood termite *Cryptotermes brevis* (Walker) (WIDT) is a serious urban pest that causes significant levels of damage to wooden structures. This termite was first described in Jamaica in 1853 and has a tropicopolitan urban distribution except in Asia (Scheffrahn et al. 2008). Like most Kalotermitidae the WIDT nests in its food source, wood, where it spends most of its life cycle. A colony of drywood termites can vary in size from hundreds to a few thousand termites (Nutting 1970), and several colonies can be found inside a single piece of wood. Myles et al. (2007), for example, found as many as 30 colonies of WIDT in a single floor board.

Drywood termites are major pests, accounting for about 20% of the budget spent on termite control in the United States (Su & Scheffrahn 1990). One of the main methods for controlling these pests has been the use of fumigation to eliminate existing colonies. Fumigation, however, does not prevent new infestations, and therefore it is beneficial to combine fumigation with additional preventative control methods. Preventing this species from founding a new colony during the dispersal flight season is an important technique for the control of this pest. This study aims to develop a better understanding of the behavior of the WIDT during the dispersal flight season, the time

when WIDT is most accessible to physical, chemical, or behavioral management efforts.

The life cycle of WIDT includes a dispersal flight where the mature winged forms (alates) leave their previous colony to form new colonies. The dispersal flights are the only occasion when this species is found outside of wood (Kofoid 1934) because it never leaves the nest to forage for new food sources (Korb & Katrantzis 2004). After flying, the alates shed their wings and associate as pairs of female and male dealates. These pairs will crawl on the substrata in search for a suitable place to start a new colony (Snyder 1926; Wilkinson 1962; Nutting 1969; Minnick 1973).

According to Light (1934a) most termites castes are negatively phototactic, but the alates, attracted to light, seek to emerge into openings and fly toward light. However, there are no data correlating colonization sites with lighting conditions. Positive phototaxis of *C. brevis* and congenus alates is followed by negative phototaxis of the dealates (Wilkinson 1962; Minnick1973), although no data have been produced to confirm this observation.

The present study quantified the phototactic colony site selection of *C. brevis* alates and dealates. The first hypothesis tested was that favorable colonization sites in lighted areas are more likely to be selected by alates of *C.brevis*, and that colonization will be higher at higher light intensities. The second hypothesis tested was that dealates search for darker areas on the substrate to colonize.

Materials and Methods

Termites

Experiments were conducted at the University of Florida, Fort Lauderdale Research and Education Center (FLREC), Davie, Florida, in a room partially filled with wood infested by *C. brevis* that originated from several sites around South Florida. The wood was stored in a dark room at ambient temperature (average 25.6ºC) and ambient relative humidity (average 73.5%). The termite alates used in the experiments dispersed naturally from the infested wood. The room remained dark except for the time the experiments were conducted, and the alates were free to fly anywhere in the room. The first experiments took place between Apr and Jul 2007, and the second experiments between Apr and Jun 2008.

Light Intensity Experiments

Twenty four transparent plastic boxes (36 × 23 × 28 cm) served as light preference chambers. The boxes were wrapped in aluminum foil to isolate the light box from adjacent boxes. The boxes were placed with the open side facing the infested wood and a hole was cut in the side of each box in order to fit (Fig. 1) an electrical cord for a set of white Light Emitting Diodes (LED) (HolidayLEDS™ model No TS-70) strung in a series of 5 single light bulbs attached with tape and hung through the hole. The LEDs were all connected to each other in a continuous string of lights mounted in a series and connected to a single power source. Electrical tape was used to position the light bulbs in place as well as prevent light from dispersing through the cut hole, so that the only light source was inside each box. The LED sets were randomly distributed among 12 lit boxes and 12 dark boxes. The lit boxes had a light intensity of approximately 40 lux as measured by a light meter (Extech Instruments model No 403125) and the dark boxes had approximately 0.11 lux (due to some contaminating light from nearby experiments occurring at the same time). A cube of wood (5 × 5 × 5 cm) with 6 drilled holes was placed in the center of each box (Fig. 1). Each 2.3 mm diam hole was 1.5 cm deep, and there was a single hole per face of the block. Four thumb push pins were placed on the underside of the block to allow for enough space (3 mm) for the termite to access the hole on the underside.

The difference in colonization between different light intensities was analyzed with the same 24 boxes previously described. The LED lights were also used but this time there were 4 different set ups for the different light intensities with 6 replicates per light intensity (measured by the light meter): 6 of the boxes were dark with (≈0.11 lux); 6 boxes had 1 LED light bulb with an intensity of approximately 11 lux; 6 boxes had 5 LEDs together (≈40 lux); 6 boxes had 10 LEDs attached with an intensity of approximately 480 lux. The boxes with the different light intensities were randomly distributed. A block of wood (15x2x9 cm) with 24 holes (12 on top and 12 on the bottom, and each 1.5 cm deep and 2.3 mm diam) was placed in the center of each box. After 3 months, the blocks were collected and the number of colonized holes per block was counted. A hole was considered to be colonized when a complete fecal seal (covering of the hole with hardened fecal material from the termites) was present.

Negative Phototaxis Experiment

The negative phototaxis of the dealates was studied with a white PVC pipe (51 cm × 7 cm inside diam) wrapped with electrical tape and closed on one end. A 102 × 2 × 5 cm board with 40 holes, each 2.3-mm diam and drilled 2.5 cm apart, was placed inside the pipe. The outermost holes were 1 cm from the edge of the board. Of the 40 holes, 20 were always exposed to light (regular fluorescent indoor lighting) and 20 were exposed to decreasing levels of light toward the closed end of the PVC pipe (Fig. 2). The board was visually

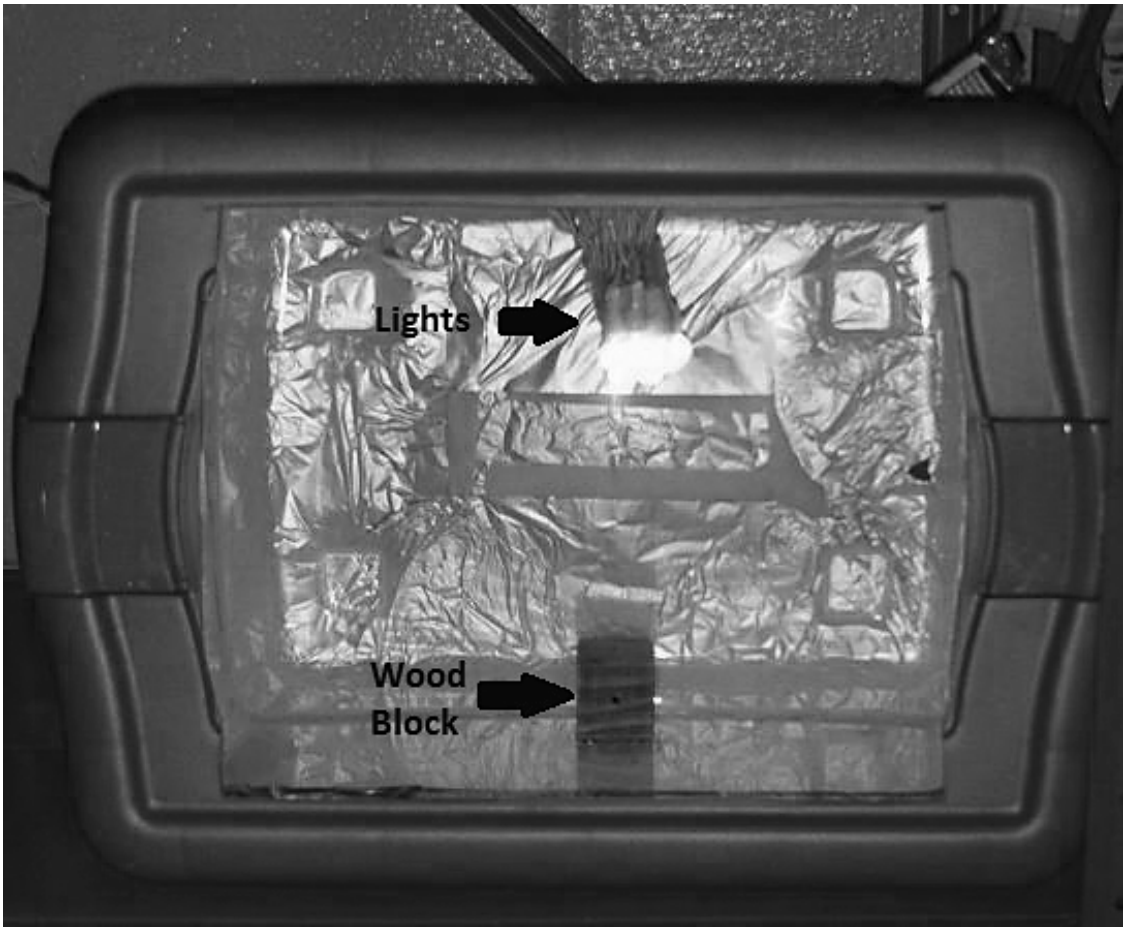

Fig. 1. Arena for light intensity experiments. Aluminum foil isolated the box and the LED lights were placed above the block of wood.

divided into 10-cm sections (excluding 1 cm at each end). Each section had 4 holes available for colonization. A board with the same dimensions and number of holes was used as a control and was completely exposed to the same light intensity. The 10-cm sections were lettered from A to J with sections A, B, C, D, and E inside the PVC pipe and sections F, G, H, I, and J outside (Table 1). This experimental protocol was replicated 4 times. Light measurements were made inside and outside the PVC pipe (Table 1). After dispersal flight season was over the number of colonized holes was counted for each 10-cm section based on the previously described colonization criteria.

Statistical Analysis

The data for the lit versus dark boxes were analyzed by a non-parametric Wilcoxon Matched Pairs test (SAS Institute 2003) to test whether the numbers of colonizations in the dark and lit areas were different. Colonization differences between the light intensities were tested with Student's *t*-test (SAS Institute 2003).

A Chi-squared test for independence (SAS Institute 2003) was used to test whether the distribution of colonizations was dependent on the light intensity. A Student's *t*-test for dependent samples was used to determine whether the differences between the numbers of colonizations in each 10-cm section were significant, (SAS Institute 2003).

Results

Light Intensity Experiments

Lit vs dark boxes. A total of 43 holes were colonized. There were significantly (t-$t$est = 4.01E-05, $P < 0.0001$) more holes colonized in the lighted boxes (2.8 ± 0.3, mean ± SEM) than in the dark areas (0.8 ± 0.2 (mean ± SEM)).

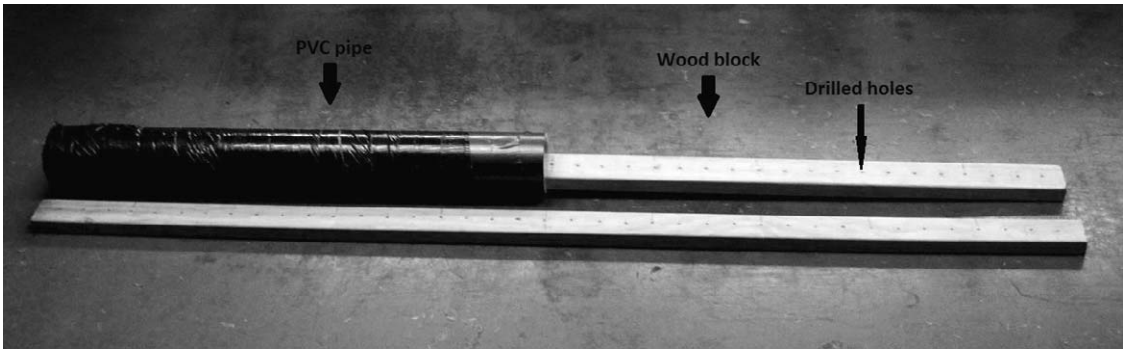

Fig. 2. Arena for negative phototaxis experiment. PVC pipe wrapped in black tape covered half of the wood block. Controls had no PVC pipe cover.

Light intensity. A total of 76 holes were colonized in the light intensity experiment. A higher number of colonizations was recorded in high light intensity boxes. There were significant (*t*-test, $P < 0.05$) differences in colonizations among the various light intensities (Fig. 3).

Negative Phototaxis Experiment

A total of 175 holes were colonized during the negative phototaxis experiment. There were no significant differences in number of colonizations between the 10-cm sections ($P \geq 0.29$) in the control boards. The distribution of number of colonizations was independent of the section where the colonizations occurred (Chi-squared = 5.9541, P = 0.75; n.s.) with no section of the control board preferred over any other section.

In the boards placed in the PVC pipes colonization distribution was not independent of the section where it occurred (Chi-squared = 33.3939, P = 0.001) with a significantly higher number of colonizations occurring in the dark sections (Fig. 3). Sections A, B, C, and D inside the PVC pipe had a significantly higher number of colonizations than sections G, H, I, and J outside the PVC pipe ($P <$ 0.05). Section E (inside the PVC pipe) was not significantly different ($P \geq 0.16$) from sections G-J (outside the PVC pipe); and section F (outside the PVC pipe) was not significantly different ($P \geq 0.08$) from sections A-D (inside the PVC pipe) (Fig. 4).

Discussion

The results of the light versus dark experiment confirmed the hypothesis that colonization of the alates occur more frequently in lit areas. The termite *C. brevis* in South Florida flies mainly between 1:00 and 2:00 AM (unpublished data) when it is very dark. These results showed that colonization sites located in areas that are lit during the night may be more susceptible to infestation by *C. brevis* during dispersal flights. The presence of artificial lights may cause a change of behavior for some species of animals (Longcore & Rich 2004), but artificial lights may be beneficial to structure infesting termites like *C. brevis.* The attraction of these termites to artificial lights puts structures that have a continuous nighttime light source at higher risk of being infested than structures near by that are not lit.

The light intensity experiment showed that increasing light intensities increased the number of termite colonizations (Fig. 3). Minnick (1973) reported differences in the wavelength of light preferred by *C. brevis,* and Guerreiro et al. (2007) reported differences in color preference for the alates. Neither of them reported results based on light intensity. The fact that we found that 11 lux of light intensity was significantly different from 480 lux shows that the increase in light intensity caused an increase in colonization of the wood blocks by the termites. *Cryptotermes brevis* has

TABLE 1. DISTANCES OF 10-CM WOOD SECTIONS FROM THE CLOSED END OF 51-CM PVC PIPE AND THE LIGHT INTENSITY AT THE CENTER OF EACH SECTION.

	Inside of PVC pipe					Outside of PVC pipe				
Section	A	B	C	D	E	A	B	C	D	E
Distance from closed end of PVC pipe (cm)	10	20	30	40	50	60	70	80	90	100
Light Intensity (lux)	0.01	0.04	0.08	0.20	0.70	600	600	600	600	600

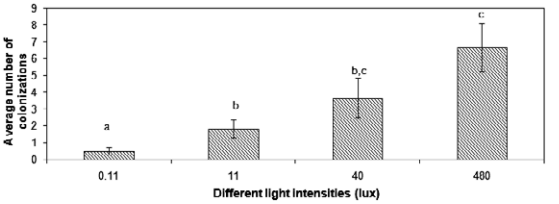

Fig. 3. Average number of holes colonized by *C. brevis* per light intensity (n = 43). Different letters represent significant differences at $P < 0.05$.

been observed to have as many as 2 founded colonies in a total of 22 nuptial chambers (Scheffrahn et al. 2001) which means that there is a 9% success rate of colonization. This shows that investing in preventing *C. brevis* alates from founding colonies is important because their success rate is high enough to make prevention methods necessary. The attraction to light by alates can be used to create light traps as a form of preventing infestations and re-infestations by *C. brevis* alates and as a means of partial control of this species. Such light traps inside structures that are already infested may minimize the spread of the infestation, and the results of this study showed that more intense the light used the more alates will be attracted; thereby making the use of light a possible alternative to use of chemicals for prevention. Further studies with different light wavelengths can help improve light traps as an alternative method to prevent the founding of colonies by *C. brevis*.

Previous experiments with *C. havilandi* (Sjöstedt) (Wilkinson 1962) and *C. brevis* (Minnick 1973) showed negative phototaxis in dealates of these species. After landing, the dealates search and colonize dark areas. Due to the nature of wood structures, it could be argued that this behavior is not really negative phototaxis but that because the cracks and holes are usually hidden and in dark areas the dealates end up colonizing there. If so, the behavior would be dependent not on light intensity but on the locations of a good places to colonize. However, the present study showed that negative phototaxis of dealates did occur. Independent distributions of colonizations occurred in the controls, but independent colonizations did not occur in the semi-shaded blocks; this confirmed the negative phototaxis hypothesis. The lighter segment of the wood block inserted in the PVC pipe had significantly less colonizations than the darker segment. However, the numbers of colonizations in section F (immediately outside the PVC pipe) were not significantly different from the numbers in the darker areas inside the PVC pipe.

Colonization of section F might have occurred because the termites colonizing that area had searched for colonizing sites in the dark area inside the PVC pipe where earlier colonizers had already taken all suitable sites, i.e., a site saturation. Also they may have landed near the PVC pipe cueing in on the darker area nearby and colonizing the sites near that dark area. However, further studies on this are needed to understand why the section closest to the PVC pipe on the light side was significantly more colonized than the section immediately inside the dark PVC pipe; where it would be expected considering the negative phototaxis behavior. One way to approach this might be to use a higher density of colonizing holes or fewer termites, so that the number of holes is not a limiting factor.

In termites, both the alates and dealates have well developed compound eyes (Light 1934b) and their behavior during flight season has shown that they do respond to light while in flight (positive phototaxis) and to have negative phototaxis after landing. Further studies on the behavior of *C. brevis* during the flight season can help improve different methods to prevent colonization and subsequent infestation by this species.

This study has shown that alates fly to and colonize more in higher light intensity areas, while the dealates have an opposite behavior colonizing more in darker areas. This knowledge is useful to improve light traps as a control method against colony foundation from *C. brevis*.

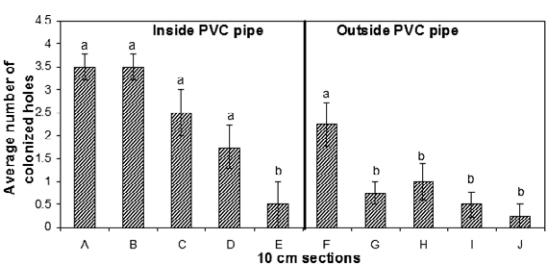

Fig. 4. Average number of *C. brevis* colonized holes per section (n = 175). Sections A, B, C, D, and E were inside the PVC pipe and sections F, G, H, I, and J were outside the PVC pipe. Bars with the same letter were not significantly different at $P < 0.05$.

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