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INFLUENCE OF FREEZING TEMPERATURES ON THE DISTRIBUTION OF *UMBONIA CRASSICORNIS* (HEMIPTERA: MEMBRACIDAE) IN FLORIDA

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The tolerance of cold, often sub-freezing weather is an important factor in determining the range of insects (Le Patourel 1993; Regniere & Bentz 2007; Chong et al. 2008; Scheffrahn 2013). This is especially true of tropical insects that have or may invade sub-tropical or temperate regions like Florida, USA (Cherry 1979a,b; Le Patourel 1993; Simmons & Elsey 1995; Chong et al. 2008; Scheffrahn 2013).

The thornbug, *Umbonia crassicornis* (Amyot & Serville) (Hemiptera: Membracidae), is a tropical treehopper found in southern Florida and from southern Texas to South America. In Florida the treehopper is found from the Florida Keys north to Winter Haven in central Florida, it is a minor pest of its leguminous host plants (Fabales: Fabaceae) including, *Albizia*, and *Calliandra* spp. which are found throughout southern Florida and farther north (Mead & Fasulo 2004; USDA 2013) than the treehopper. We investigated the ability of *U. crassicornis* adults to survive freezing temperatures and use these data to determine whether the treehopper's cold tolerance can explain its distribution in Florida.

Adults were used in this study because preliminary data indicated that they were the more cold tolerant stage. *Umbonia crassicornis* is a presocial insect whose females guard their egg mass and offspring until they become adults. Loss of the parental female during the egg stage and first 3 nymphal instars results in the death of all offspring (Wood 1976, 1977).

We tested the effects of single and multiple exposures to freezing and sub-freezing temperatures on the survival of winter acclimatized adults collected in Davie, Broward County, Florida in Jan and Feb 1980. Although the winter temperatures in Davie, Florida are mild compared with most temperate areas, the average Dec and Jan low in 1979-1980 was 17.6 °C, these are the winter temperatures to which *U. crassicornis* was acclimatized prior to the periodic winter cold snaps (sudden short periods of cold weather) that occur in Florida (Witt 2010) at the northern edge of the treehopper's range.

A replicate of a single exposure to freezing and sub-freezing temperatures (Table 1) consisted of 10 field collected adults, 5 females and 5 males pooled from several aggregations, that were placed in a 20 × 100 mm diam plastic petri dish. Prior to testing, the insects were held at 22 °C for 1 h. The tests were done in a Tenny Junior Temperature Cabinet (Thermal Product Solutions, Riverside, Michigan) (Cherry 1979a) with an accuracy of ± 0.1 °C. The exposure duration was 3 h, because Cherry (1979a,b) had established that durations of the daily high and low temperatures in southern Florida were no longer than 3 h. After exposure, the treehoppers were placed on a caged *Calliandra* plant and held at 23 ±1 °C. Mortality was assessed 25 h post exposure.

We tested the effects of multiple exposures to freezing and sub-freezing temperatures on the survival of adults. For these tests the *U. crassicornis* adults were exposed to the test temperatures (Tables 1 and 2) with the second exposure occurring 25 h after the first to mimic a multi-day

Table 1. Mortality of *Umbonia crassicornis* adults at 25 hours after a single 3-hour exposure to various freezing and sub-freezing temperatures.

Exposure Temperature °C	Number Replicates	Total Number *U. crassicornis* Treated[2]	Mean Percent Mortality[1]
0	10	100	3.1 ± 5.9
-5	18	180	15.8 ± 9.0
-7	16	160	17.0 ± 7.8
-9	4	40	77.5 ± 31.8
-10	6	60	95.0 ± 4.1

[1]Mean + SEM; mean calculated from % mortality of each replicate.
[2]Males and females in a 1:1 ratio in each replicate; no significant difference in survival between the sexes. Test test (T < 1).

TABLE 2. MORTALITY OF *UMBONIA CRASSICORNIS* ADULTS FROM TWO 3-HOUR EXPOSURES TO VARIOUS FREEZING AND SUB-FREEZING TEMPERATURES. THE EXPERIMENT WAS REPLICATED EITHER 2 OR 3 TIMES DEPENDING ON THE TEMPERATURE AND AVAILABILITY OF ADULTS.

Initial Exposure Temperature °C	Second Exposure Temperature ºC		
	0	-5	-7
0	20% (2/20)[1]	10% (2/20)	38% (2/39)
-5	35% (2/40)	25% (3/59)	45% (3/57)
-7	40% (2/50)	26% (2/38)	5% (2/40)

[1]Number of replicates/number individuals tested in ().

cold snap (Table 2) (Witt 2010). Prior to testing the insects were held at 22 °C for 1 h. After exposure, the treehoppers were placed on a caged *Calliandra* plant and held at 23 ±1 °C. Mortality was assessed 25 h post exposure.

Differences in the survival of males versus females were evaluated using a *t*-test (Little & Hills 1978). The relationship between survival and a single cold temperature exposure was evaluated using a polynomial regression equation (Statview, BrainPower, Inc. Calabassas, California).

The mortality of the adults increased with decreasing temperature (Table 1). Mortality rapidly increased between -7 and -9 °C with over 90% mortality at -10 °C. There was no difference between the survival of males and females ($t < 1$ for all temperatures). The polynomial regression $Y = 8.43X + 1.758X^2 + 4.295$ ($r = 0.974$; $F = 18.754$; df = 4; $P = 0.05$) describes the relationship between percent mortality (Y) and a single cold temperature exposure (X). Multiple exposures to freezing or sub-freezing temperatures increased mortality by 1.7 to 12.3 fold compared to a single exposure (Table 2).

On the night of 2 Mar 1980, the air temperature at a test plot, where we were following the survival of marked *U. crassicornis* females, dropped to -1.67 °C with a wind of 24 km/h. That night 33 of 53 marked females disappeared (assumed dead). We believe that the lost females died rather than dispersed from the test area, because *Umbonia crassicornis* females do not desert their offspring (Wood & Dowell 1984). Females guarding their offspring will remain on cut branches that are put into plastic boxes (Wood 1976). Females removed from their offspring and which had their eyes covered with black ink will remain with their offspring after being put back on a branch with them (Wood 1976).The average daily mortality in the preceding days had been 4 females (< 0.05%) lost per day, and low temperatures in the test area before the freeze ranged from 5.5 to 17.2 °C (Dowell & Wood unpublished data). The freeze caused the death of an additional 20/53 or 37.7% of the exposed females. Putting -1.67 °C into the regression equation above, we expected to lose 23.3% (= 13 females) of the marked females.

Central Florida, the northern limit of *U. crassiciornis* in Florida, experienced 54 freezes with temperatures of 0 °C or lower over a 100 yr period (Witt 2010). Twelve of these freezes had minimal temperatures of 0 °C to -1.67 °C; 28 had temperatures of -2.2 to -4.4 °C and 14 had temperatures of -5 °C or lower (Witt 2010). Many of these colder temperatures were during freezes of 2 or more days. For example, Winter Haven, Florida experienced temperatures of -5.0, -4.4 and -6.7 °C respectively on the nights of 18-20 Jan 1977 and temperatures of -7.2, -6.7 and -6.7 °C, respectively, on the nights of 1-23 Jan 1985 (Weather Channel 2009). As one goes north of central Florida the frequency of freezing temperatures increases and the minimum low temperatures decrease (Weather Channel 2009).

At the northern edge of its range in Florida, *U. crassicornis* face lethal cold temperatures about every other yr with moderately severe freezes every 4 yr, and severe freezes every 7 to 8 yr (Witt 2010). Based on our data, these regular freezing episodes are an effective barrier that limits the insect's northern movement in Florida in the same manner that they limit other insects including *Aleurocanthus woglumi* (Ashby) (Hemiptera: Aleyrodidae), *Aleurodicus dispersus* (Russell) (Cherry 1979a,b) and *Cryptotermes brevis* (Walker) (Scheffrahn 2013).

SUMMARY

Umbonia crassicornis mortality in single cold temperature exposures increased with decreasing temperature, and the equation, $Y = 8.43X + 1.758X^2 + 4.295$, describes the relationship between mortality (Y) and cold temperature (X). Multiple exposures to freezing temperatures increased mortality by 1.7 to 12.3 fold. Periods of freezing temperature occur every other year at the insect's northern limit of its range in Florida and are one factor responsible for limiting its distribution in the state.

Key Words: cold snap, distribution, freezing temperatures, multiple exposures, polynomial equation, thorn bug,

RESUMEN

La mortalidad de *Umbonia crassicornis* aumentó con la disminución de la temperatura, y la ecuación, $8.43X + 1.758X^2 + 4.295$, describe la relación entre la mortalidad (Y) y la temperatura fría (X). Exposiciones múltiples a temperaturas bajas aumentó la mortalidad en un 1.7 a 12.7 veces. Los períodos de temperaturas de congelación que suceden cada otro año en el límite norte de los insectos de la Florida es uno de los factores responsables de la limitación de su distribución en el estado.

Palabras Clave: ola de frío, distribución, temperaturas de congelación, exposiciones múltiples, ecuación polinómica, insecto de espina.

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