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FAILURE OF THE "MOSQUITO PLANT", *PELARGONIUM* × *CITROSUM* 'VAN LEENII', TO REPEL ADULT *AEDES ALBOPICTUS* AND *CULEX QUINQUEFASCIATUS* IN FLORIDA

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ABSTRACT. The efficacy of the "mosquito plant", *Pelargonium* × *citrosum* 'van Leenii', as an area-wide repellent against adult host-seeking *Aedes albopictus* and *Culex quinquefasciatus* females was evaluated. No significant differences ($P > 0.05$) were observed in the number of mosquitoes landing on the forearms of human subjects in locations where plants were present compared with areas without plants. In laboratory cage trials, more *Cx. quinquefasciatus* adults rested on excised leaves of this cultivar compared side-by-side with similar size and shape white paper leaf models.

INTRODUCTION

A variety of botanical substances have been evaluated for their repellency against adult mosquitoes (Christophers 1947, Dethier 1947, Sukumar et al. 1991). In many instances these studies used "essential oils" that were extracts from whole or parts of plants. One of the earliest well-known mosquito repellents (being used as early as 1882) is the essential oil of citronella (Dethier 1947). This substance is currently available in several commercially formulated repellents. As a secondary plant compound, citronella was originally extracted from the citronella or nardus grass, *Cymbopogon nardus* Linn., and found to be composed of a variety of acyclic monoterpenes including borneol, geraniol, citronellol, and citronellal (Christophers 1947, Dethier 1947). Some of these compounds are common repellents found in the alarm substance produced by some ant species (Rodriguez and Levin 1976).

We have seen a variety of garden catalogs and businesses from the USA and Canada advertising a "mosquito plant" also sometimes commonly referred to as "citrosa plant" or "citrosa geranium". These common names refer to *Pelargonium* × *citrosum* 'van Leenii' Voigt *ex* T. Sprague (family: Geraniaceae), a plant that produces citronella oil and that is claimed to "be the only effective mosquito repellent plant in the world". This plant is a cross of an African lemon geranium (*P. crispum*) with an English fingerbowl geranium (*P.* × *limoneum*) hybrid that further incorporated tissue cultures of a southern Asiatic grass that produced citronella oil. This resultant cultivar has been attributed to the efforts of Dutch horticulturist, Dirk Van Leenen. Mosquito repellency of the 'van Leenii' cultivar is implied by vaporization of plant volatiles (i.e., citronella oil) into the surrounding environment and is claimed to provide a barrier of protection against host-seeking mosquitoes within a 3-m-diam area. Our study was initiated to evaluate, in field and laboratory trials, the repellency of *P.* × *citrosum* 'van Leenii', in north Florida against adult host-seeking females of *Aedes albopictus* (Skuse) and *Culex quinquefasciatus* Say, 2 common urban pest mosquitoes.

MATERIALS AND METHODS

Field tests were conducted in a 13.9 × 7.2 × 2.6-m screened enclosure at the John A. Mulrennan, Sr. Research Laboratory, Panama City, FL. At 14-d intervals, 10 *P.* × *citrosum* 'van Leenii' potted plants were placed 0.5 m apart in one end of the enclosure in a 1.6-m-diam circle 30 min before each study began to allow plant volatiles to equilibrate in the immediate area for trials 1–5. At weeks 14 through 18 (trials 6–8), plants remained in the test location for 24 h prior to mosquito release and collections. An area with no plants, 9 m from the nearest 'van Leenii' cultivar (i.e., at the other end of the enclosure), was designated as a control. Fifteen minutes later (after plants had been set out), approximately 500 *Ae. albopictus* and 1,000 *Cx. quinquefasciatus* laboratory-reared 5–6-day-old nonbloodfed females were released in the middle of the screened enclosure before collections commenced. After the 30-min equilibration time 2 people sat in chairs, each at opposite ends of the enclosure in the middle of each test area and mosquitoes that landed on their bare forearms were removed with an aspirator (Hausherr's Machine Works, Toms River, NJ). Four 5-min collection periods exposed each individual twice at each location (i.e., plant vs. control). After these collections, plants were switched to the control area and the previous "treatment" area then became a control. Thirty minutes was allowed to elapse before

Table 1. Total number of *Aedes albopictus* and *Culex quinquefasciatus* females collected from the forearms of 2 human volunteers in areas with and without *Pelargonium* × *citrosum* 'van Leenii', morning tests.

	Control		Plant		
Trial	*Ae. albopictus*	*Cx. quinquefasciatus*	*Ae. albopictus*	*Cx. quinquefasciatus*	*t*-value[1]
1	42	4	39	0	1.18
2	89	1	134	1	2.04
3	73	5	105	13	0.67
4	22	18	29	7	0.21
6	104	44	110	157	0.56
7	11	0	22	0	1.12
8	286	0	239	0	0.71
Total	627	72	678	178	

[1] All *t*-values not significant, $P > 0.05$.

starting the next set of mosquito collections. This allowed any volatiles in the previous treatment area to dissipate and volatiles in the new treatment area with plants to equilibrate.

All mosquitoes collected were identified and the number aspirated from each person was recorded at each time interval. Because of host-seeking differences between the 2 species, the study was conducted during early morning and late evening crepuscular periods. No wind was felt by the investigators during testing. Between test intervals plants were removed from the study area and placed in a 2nd screened enclosure, away from the study site, similar to the first. The study was conducted from August 5 through November 5, 1993. Heights of each plant were recorded on the day of testing. Temperature during morning tests averaged 21.3 ± 1.0°C and for evening tests 26.9 ± 0.8°C.

Our study used a cross-over experimental design similar to that used by Schreiber et al. (1991) utilizing the statistical analysis of Cochran and Cox (1957). This design recognized 2 main sources of variation: 1) bloodfeeding activity of host-seeking female mosquitoes fluctuates through time, and 2) rate of attack varied from human subject to human subject. Briefly, 2 individuals (A, B) were subjected to treatments C and P (control [i.e., no plant] and plant, respectively) at 2 locations (R, S). The 4 5-min test periods exposed each individual to each treatment in each location using the following order of rotation: C-R, P-R, C-S, R-S for subject A and P-S, C-S, P-R, C-R for subject B. Differences in the total number of mosquitoes collected for each species in control (no plant) vs. plant sites were determined using a *t*-test. Differences were considered significant at $P \geq 0.05$.

Laboratory cage tests of excised *P.* × *citrosum* 'van Leenii' leaves were conducted to evaluate short-range repellency to adult *Cx. quinquefasciatus*. On the day before testing, approximately 100 5-day old adult females were placed in each of 4 42 × 42 × 42-cm screened cages having 2 opposite sides of clear Plexiglas®. One mature leaf (leaf area = 183.9 ± 24.4 cm²) was excised from each of 4 plants and the severed end of the petiole sealed with paraffin wax. The upper surface of each leaf was taped to a 15-cm-diam Whatman #4 filter paper disc and fastened to the screen surface at the back of each cage. A similar shaped and sized filter paper model (designated as a control), to mimic the 'van Leenii' leaf, had been previously cut out of the same quality filter paper, taped to another 15-cm-diam filter paper disc and immediately fastened to the back of the cage. Excised leaves and paper models were approximately 12 cm from each other on the screen surface in the same cage and were about 38 cm from the cage floor. In previous tests, no difference in the number of mosquitoes landing on green vegetable-dyed filter paper leaves placed on a 15-cm-diam filter paper disc occurred when compared with similarly presented uncolored (white) filter paper leaves. Therefore, uncolored filter paper served as a control. Total number of mosquitoes resting on leaves and controls in each cage were recorded every half hour (at 3 1-min intervals) for 8 h. All plants for this study were obtained locally from a commercial hardware/garden shop.

RESULTS AND DISCUSSION

The total number of mosquitoes, regardless of species, that landed on persons in the screened enclosure was not significantly lower in locations where *P.* × *citrosum* 'van Leenii' was present

Table 2. Total number of *Aedes albopictus* and *Culex quinquefasciatus* females collected from the forearms of 2 human volunteers in areas with and without *Pelargonium* × *citrosum* 'van Leenii', evening tests.

	Control		Plant		
Trial	*Ae. albopictus*	*Cx. quinquefasciatus*	*Ae. albopictus*	*Cx. quinquefasciatus*	*t*-value[1]
1	42	18	27	66	0.40
2	22	8	18	9	0.13
3	58	139	77	116	1.29
4	21	101	19	187	1.41
5	15	105	11	232	1.09
6	104	44	110	157	0.56
7	13	426	10	186	0.18
8	0	123	2	294	3.65
Total	275	964	274	1,247	

[1] All *t*-values not significant, $P > 0.05$.

compared with controls in morning (Table 1) or evening tests (Table 2). Literature accompanying commercial advertisements of this cultivar states that one plant should be able to provide enough volatile chemicals to repel mosquitoes within a 3-m^2 area. Our study used 10 times the number of plants in an area of this size with no significant reduction in the number of host-seeking mosquitoes. In addition, plant height (i.e., size) did not affect repellency during the study. Plant height at the beginning of the tests averaged 28.7 ± 1.9 cm and at the end of the test averaged 63.7 ± 3.2 cm. Individual area of mature leaves sampled from these plants ranged from 133.9 to 351.6 cm^2 (mean 245.7 ± 13.9 cm^2). During field tests we observed that several mosquitoes had landed on the plants and used them for resting sites. In laboratory cage tests a significantly greater number of female mosquitoes rested on excised leaves (81) compared with paper leaf model controls (13).

Although the 'van Leenii' cultivar smelled like it emitted citronella, no mosquito repellency was observed as a result of volatiles emitted from these plants. Citronellal (one of the repellent components in oil of citronella) has been reported to be sufficiently volatile to keep mosquitoes at a distance (Sarkaria and Brown 1951). However, only the purified form of this compound was used for this observation and not citronella-producing plants themselves. As stated earlier, oil of citronella (as extracted from plants) contains a complex of components of which geraniol and citronellal are the chief active agents (Christophers 1947, Dethier 1947). Though considered as an olfactory deterrent (Garson and Winnike 1968), contact or gustatory repellency may exist. Citronellol, another component of oil of citronella, has also been reported to deter oviposition by the sweetpotato whitefly (*Bemisia tabaci* (Gennadius)) via contact (Butler et al. 1989).

Evidently in our study the volatiles that are produced from *P.* × *citrosum* 'van Leenii' were either not intrinsically repellent or not released in sufficient quantity to evoke a repellent response to create a barrier against host-seeking *Ae. albopictus* and *Cx. quinquefasciatus* females. It is quite probable that the leaves of this cultivar may have to be crushed or rubbed on the skin to release the volatile components of citronella oil as a phytophagous insect would release these bioactive components upon feeding.

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