Exposure of Brown Recluse and Brown Widow Spiders (Araneae: Sicariidae, Theridiidae) to a Commercial Sulfuryl Fluoride Fumigation

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ABSTRACT The body of pesticide research on spiders is sparse with most studies using topical or residual applications to assess efficacy. Data on the effects of fumigation on spider survivorship are scarce in the scientific literature. In this study, we exposed adult male and female brown recluse spiders, *Loxosceles reclusa* Gertsch & Mulaik, and female brown widow spiders, *Latrodectus geometricus* C. L. Koch, to a commercial fumigation event using sulfuryl fluoride directed at termite control. General consensus from the pest control industry is that fumigation is not always effective for control of spiders for a variety of reasons, including insufficient fumigant dosage, particularly, for contents of egg sacs that require a higher fumigant dosage for control. We demonstrated that a sulfuryl fluoride fumigation with an accumulated dosage of 162 oz-h per 1,000 ft^3 at 21°C over 25 h ($\approx$1.7× the drywood termite dosage) directed at termites was sufficient to kill adult brown recluse and brown widow spiders. The effectiveness of commercial fumigation practices to control spiders, and particularly their egg sacs, warrants further study.

KEY WORDS *Loxosceles*, *Latrodectus*, Arachnida, pesticide testing, urban entomology

In comparison to the amount of pesticide research on insects, the complementary body of literature on spiders is minor. Most published research has been conducted on spiders of medical importance (widow spiders, *Latrodectus*, and recluse spiders, *Loxosceles*).

Of the published toxicological research involving *Loxosceles* spiders, the greatest amount has been performed with topical or residual applications (e.g., Norment and Pate 1968; Gladney and Dawkins 1972; Sterling et al. 1972; Price et al. 1988, 1989) with most studies involving pesticides that have been banned since these tests were completed (e.g., lindane, dieldrin, and DDT). More recent research showed microencapsulated λ-cyhalothrin to be an efficacious pesticide in bioassays for killing *Loxosceles intermedia* Mello-Leitão in South America (Navarro-Silva et al. 2010). Less is known regarding the effects of commercial fumigation practices on spider survival with little being published in the open scientific literature. The general anecdotal consensus from conversations with members of the pest control industry is that fumigation for adequate termite control cannot guarantee to simultaneously eliminate brown recluse spider populations. From experimental laboratory exposures, Thoms and Scheffrahn (1994) provided a wealth of information on the lethal accumulation dosage (LAD_{99}) on 39 insect species, one tick species, and two spider species. The LAD_{99} is determined by "the target pest, its life stage, and temperature at the site of the target pest" (Thoms and Scheffrahn 1994). One spider that was tested, the brown recluse spider, *Loxosceles reclusa* Gertsch & Mulaik, has an LAD_{99} of 77 oz-h per 1,000 ft^3 at 27°C which converts to 1.6× the drywood termite rate. In comparison, the LAD_{99} mean ± SD for 11 species of termites (discounting one outlier) was 40.8 ± 8.6 oz-h per 1,000 ft^3 (range = 20–51; note: the conversion factor from oz-h per 1,000 ft^3 to g-h per m^3 is 1.0014 so for practical purposes, the numeric value is almost equivalent, i.e., 77 oz-h per 1,000 ft^3 equals 77.11 g-h per m^3).

Widow spiders (*Latrodectus* spp.) are known for being difficult to control with pesticides. These spiders are a recurring problem for the grape industry in regard to consumer concerns when black widows are found in grape bunches or for inspectors vetting exported cargo (Cavanaugh 1992, Reed and Newland 2002). Cavanaugh (1992) details the effective control of the western black widow spider, *Latrodectus hesperus* Chamberlin & Ivie, in grapes in California's Central Valley where SO_2 fumigation was not overly effective until coupled with CO_2. The proposed mechanism for this synergism was that CO_2 is a respiration stimulant (in mammals), and therefore might increase respiration in spiders causing lethal intoxication by fumigants (Cavanaugh 1992). The LAD_{99} with sulfuryl fluoride for the western black widow spider and its egg sacs was 82 and 300 oz-h per 1,000 ft^3 at 27°C, respectively (Thoms and Scheffrahn 1994). This is 1.7× and 6.2× the drywood termite dosage for black widows and their egg sacs, respectively. Invasive brown widow spiders, *Latrodectus geometricus* C. L. Koch, have re-

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cently reached high densities in urban southern California (Vetter et al. 2012) and are a concern to homeowners who frequently request advice for chemical control options.

In March 2014, a nonresidential building in Riverside, CA, to which we had access for our research, was tarped and treated for drywood termites, *Incisitermes minor* (Hagen), by a nationally recognized commercial fumigation company. We were unaware of any published study that exposed brown recluse or brown widow spiders in a commercial fumigation episode of a large building, although Thoms (2004) reported on the successful fumigation of the Chilean recluse spider, *Loxosceles laeta* (Nicolet) in a structure using 10× the drywood termite dosage. Therefore, we attempted to generate potentially useful information for the pest control industry on the efficacy of fumigation for spider suppression. The paucity of information regarding the efficacy of commercially applied fumigants and spider control is understandable. Homeowners would be very hesitant to participate in an experiment that purposefully deployed sentinel pest species (e.g., brown recluse spiders) in a home in case the spiders escaped and survived the fumigation treatment. Homeowners have occasionally contacted one of us (R.S.V.) requesting information on whether fumigation will rid a house of brown recluse spiders; however, no published data in the readily accessible, open scientific literature were known to us regarding actual field testing upon which to base recommendations for this particular spider species (some information does exist on fumigation of brown recluse spiders in the private sector but it is typically unpublished data and, therefore, not easily accessed). With this study, we provide data on the effectiveness of whole-building fumigation with sulfuryl fluoride on the survivorship rates of adults of two common pest spider species.

Materials and Methods

Spiders. The original stock of brown recluse spiders used in this study was collected from Lenexa, KS, Russellville, AR, and possibly Columbia, MO, although the exact heritage of this colony has not been consistently recorded. Spiderlings from egg sacs were reared communally in a 4-liter plastic jar in the University California–Riverside (UCR) Insectary and Quarantine facility, and were fed mostly western subterranean termites, *Reticulitermes hesperus* Banks, first-instar German cockroaches, *Blattella germanica* (L.) (both prey species are kept in culture at UCR), and, from a compost bin, wild-caught flies, possibly *Drosophila* spp. Recluse spiderlings are not cannibalistic as long as they are well fed (Vetter and Rust 2008). Once spiderlings reached ≈50% adult size, spiders were transferred to individual vials and fed mostly German cockroaches. Other incidentally captured arthropods were randomly offered to spiders as they became available. Brown recluse spiders used in this study were last offered food ≈1 mo before the fumigation event. The spiders had been mature ≈1 yr at the time of testing and all females were virgins; brown recluses can live for several years in captivity (Hite et al. 1966, Horner and Stewart 1967).

Female brown widow spiders were collected the previous summer from multiple southern California locations, were in captivity from 6 to 9 mo, and were used as suppliers of egg sacs in other studies. Female spiders were fed mealworms, *Tenebrio molitor* L., every 10–24 d and fed twice in a 3-d period, 2 wk before the fumigation. Although the brown widow is almost exclusively a peridomestic invader and rarely found inside homes, we included them in this study because they have been observed to infest garages, exterior storage cabinets, porch furnishings, and other items that would be included in a tarped, fumigated residence.

Fumigation Cages. Brown recluse spiders were placed individually inside 40-dram plastic vials (48 mm internal diameter by 86 mm length) with a 45-mm-diameter hole in the bottom of the vial and a 33-mm-diameter hole in the plastic lid. Each hole was covered with household aluminum window screening with spacing of 6 by 6.7 openings per centimeter, affixed with hot glue. A piece of screening, 75 by 50 mm, was placed inside the vial, to give the spider a textured surface to walk on, leaving ≈5 mm of free space on each end to prevent accidental trapping of spiders inside vials. Vials were placed inside 5.7-liter plastic shoeboxes with snap handle locks on two ends of the lid. A 280 by 127 mm rectangle was cut from the box lid where the open space represented ≈65% of the total area of the top opening of the box. The hole in the lid was covered with the same aluminum screening used on the vials. A small layer of petroleum jelly was smeared on the inside wall of the box near the lid to act as an additional barrier and the lid was securely affixed to the container with duct tape.

Brown widows were tested in 163-ml plastic food cups containing a Y-shaped piece of cardboard (2.5 mm width with two arms of 35-mm length and one arm of 52-mm length) used as a support structure to which they attached silk. A 45-mm-diameter hole was cut in the lid and a piece of aluminum screening similar to above was hot glued over the hole.

In addition, 10 drywood termites were placed in each of two 20-ml scintillation vials with a piece of balsa wood and a 14-mm hole in the lid covered with screen.

Fumigation. The fumigation occurred in a stucco-faced building, originally constructed in 1931 and consists of two levels with ≈956 m^2 (5,140 square feet) of total area and ≈3,800 m^3 (134,000 cubic feet) of total volume for the two floors.

Four vials individually containing brown recluse spiders (two males and two females) were placed on their sides in each box, with the orientation of the lid alternating in opposite directions in case the size of the opening and directional flow of fumigant was affected by vial orientation. A set of four boxes was placed in each of the three rooms, one with south-facing and west-facing windows, one with south-facing windows, and the last with north-facing windows. Fumigation boxes were placed at three heights: low, near the floor

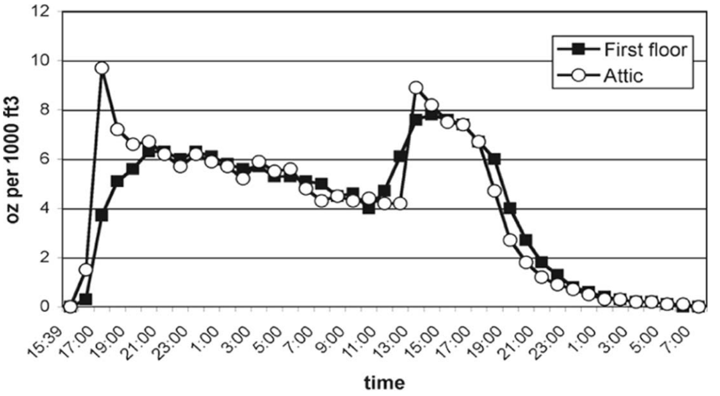

Fig. 1. Progression of fumigation in oz per 1,000 ft^3 from monitors placed on the first floor and in the attic of the building.

inside a cupboard or under a desk (<0.33 m above the floor); medium, on a shelf 1–1.5 m off the floor; and high, on top of a bookshelf 2.5–3.5 m off the floor. Brown recluse spiders were deployed at different heights to verify unpublished studies that sulfuryl fluoride, after reaching equilibrium, does not stratify within a room. A fourth fumigation test box of four brown recluses was set up in each room as a control, placed inside a Nylofume bag (Dow AgroSciences LLC, Indianapolis, IN) that was secured with a rubber band at the top, and then placed inside a second Nylofume bag also secured with a rubber band at the top, as per the instructions from the fumigation company for any item not to be excluded from the fumigated air space. We monitored temperature and relative humidity during fumigation with Hobo data loggers (Onset Computer Corporation, Bourne, MA) in each of the three rooms, and in one room, a data logger was also placed inside a Nylofume bag. An additional set of 12 brown recluse spiders, six of each sex, was kept in their usual maintenance vials in the UCR insectary to function as another untreated cohort to measure naturally occurring mortality. In total, 36 brown recluse spiders were exposed to fumigation with 24 additional recluses serving as controls.

A set of five female brown widows was deployed next to the brown recluse spiders at each of the three heights and within the protective Nylofume bagged controls in the room with north-facing windows. An additional set of five female brown widows was kept in the insectary as an untreated control. In total, 15 brown widow spiders were exposed to fumigant with 10 brown widows serving as controls. A vial of termites was deployed at the lowest level with the spiders in the same room and a second termite vial was used as a control in the insectary.

All arthropods were placed in position on 25 March 2014. Tarping of the building was initiated on 27 March 2014, chloropicrin was introduced, and fumigation with Vikane gas fumigant (99.8% sulfuryl fluoride, Dow AgroSciences LLC, Indianapolis, IN) commenced at 1539 hours. The fumigant exposure period was ≈25 h, and fumigant aeration was initiated at 1700 hours on 28 March 2014. The initial target fumigant dose for building treatment for drywood termites was 9.8 oz per 1,000 ft^3. The target accumulated dosage of 117 oz-h per 1,000 ft^3 based on a soil temperature of 18.3°C, representing the coldest temperature in wood which could be infested with drywood termites. An RDA Fumiscope (Key Chemical and Equipment Co., Clearwater, FL) with air sampling locations placed on the first floor and in the attic of the building monitored the progression of the procedure. In a normal experimental fumigation, air samples would have been taken at each location with the spiders; however, we wanted to run the assay without the pest control company's knowledge to ensure that they proceed with their normal treatment. Hence, monitors were only in two locations as determined by the fumigation company. Following aeration using the California Aeration Plan, the tarps were removed from the building on 29 March 2014. Spiders were first assessed for survival on 30 March 2014. To determine survivorship, spiders were checked every day for 5 d until the last spider was dead.

Results

The progression of the fumigation is presented for hourly (Fig. 1) and cumulative (Fig. 2) readings. A second introduction of fumigant was apparently applied on the second day as can be seen by the increase in Fig. 1. The reported accumulated oz-h per 1,000 ft^3 dosages for the first floor of the building and the attic were 166 and 162, respectively. The ambient air temperature was 21.7°C where the spiders were positioned. The drywood termite target dosage for 21.7°C is 94.5 oz-h per 1,000 ft^3, so spiders in bioassays were exposed to 1.8× (first floor) and 1.7× (attic) the drywood termite dosage. Temperature and humidity are displayed in Fig. 3 with temperature means, SEs, minimums, and maximums listed in Table 1.

Spider survival data for the three heights were pooled as there were no obvious differences among them, verifying no stratification of fumigant impacting efficacy occurred. The first check for spider mortality

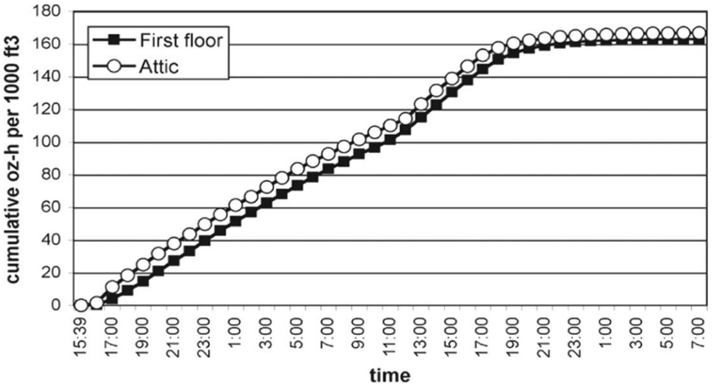

Fig. 2. Cumulative progression of fumigation in oz-h per 1,000 ft^3 from monitors placed on the first floor and in the attic of the building.

occurred ≈30 h after the building was cleared for reentry. All brown recluse males exposed to the fumigant were dead, whereas 72% (13 of 18) of brown recluse females were dead with the remaining five being moribund (i.e., immobile but weakly responsive to gentle probing). All brown recluse females were dead 1 wk after fumigation. All 15 brown widow spiders and 10 termites exposed to fumigation were dead upon the first posttreatment check. All spiders inside the Nylofume bags survived, as did all untreated spiders kept in the insectary. No spiders escaped from the fumigation vials.

Discussion

When we initiated this study in early March 2014, publications regarding control of brown recluse spiders in buildings did not mention fumigation as a potential control method (Sandidge and Hopwood 2005, Sandidge 2009, Hedges and Vetter 2012; although see comments below). Brown recluses have been known to survive fumigation events (S. Hedges, personal communication). Target pests survive fumigation events because an insufficient dosage was attained based on the temperature and pest species and life stages to be controlled. The dosage of sulfuryl fluoride required for control of the brown recluse adults, but not the egg stage, has been reported (Thoms and Scheffrahn 1994). Therefore, fumigators may be selecting a dosage that is less than that needed for control of the brown recluse egg stage. The accumulated fumigant dosage was ≈163 oz-h per 1,000 ft^3 at 21.7°C (Fig. 2), which is consistent with the laboratory data for fumigant dosage to control brown recluse and black widow spiders (1.6× and 1.7× drywood termite dosage, respectively) as reported by Thoms and Scheffrahn (1994) at 27°C.

Although we exposed female brown widow spiders to the fumigation, this was more of an academic than an applied exercise because these spiders would not be likely candidates for a long-term effective fumigation. Brown widows are not often found in homes, although they do make webs in house eaves and on patios (Vetter et al. 2012), which are places that would be covered by tarpaulins and exposed to fumigants. The elimination of their populations would only be temporary because 1) fumigation offers no residual control and 2) young spiderlings would continuously

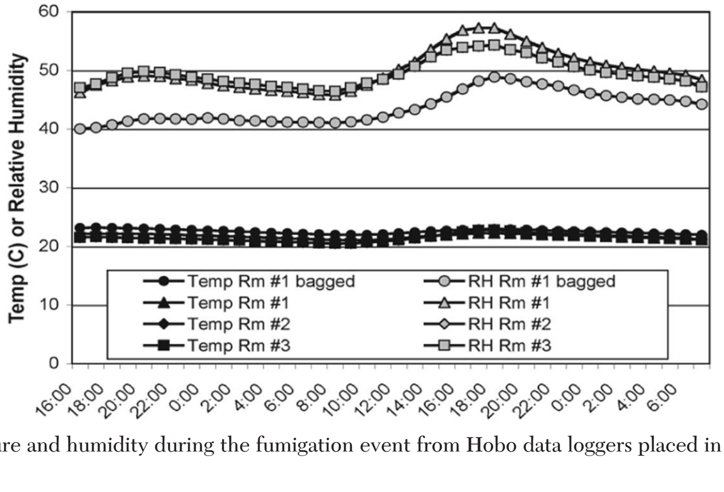

Fig. 3. Temperature and humidity during the fumigation event from Hobo data loggers placed in the three rooms with the spiders.

Table 1. The mean, SE, minimum, and maximum temperatures (°C) from monitors positioned in the four rooms containing spiders

Temp	Room 1 (inside bags)	Room 1	Room 2	Room 3
Mean	22.56	21.70	21.47	21.49
SE	0.06	0.06	0.05	0.10
Min.	21.94	21.03	20.87	20.48
Max	23.18	22.25	22.03	22.82

balloon in from adjacent areas afterward to start a new infestation.

The results of this study provide potentially important information for pest control professionals and indicate that fumigation should be assessed more thoroughly for brown recluse spider control. Fumigation at 10× the drywood termite rate has been shown to be effective for control of brown recluse spiders in two American infestations (E. T., unpublished data) and, as this manuscript was being written, an online narrative article was published describing the successful use of fumigation to control brown recluse spiders in homes (Richardson 2014), although without the quantitative data as we document here. Given the paucity of fumigation data on live spiders in the readily retrievable, open scientific literature, in addition to the pest control industry, other professions such as the real estate industry may benefit where a brown recluse spider infestation can be a severe obstacle in the selling of properties. If fumigation has to be undertaken, the target pest life stage, in addition to spiders, is the hard-to-find egg sac contents that require a higher fumigant dosage for control (Thoms and Scheffrahn 1994). This study validated a field-applied dosage of sulfuryl fluoride for control of adult brown widow and brown recluse spiders, but additional research is needed to determine the dosage of sulfuryl fluoride required to control brown recluse spider eggs.

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References Cited

Cavanaugh, P. 1992. Black widow defense set. Grape Grower 8: 4–5.

Gladney, W. J., and C. C. Dawkins. 1972. Insecticidal tests against the brown recluse spider. J. Econ. Entomol. 65: 1491–1493.

Hedges, S. A., and R. S. Vetter. 2012. Pest control technology field guide for the management of urban spiders. GIE Media, Cleveland, OH.

Hite, J. M., W. J. Gladney, J. L. Lancaster, and W. H. Whitcomb. 1966. Biology of the brown recluse spider. University of Arkansas Agriculture Experimental. Station Bulletin #711: 26.

Horner, N. V., and K. W. Stewart. 1967. Life history of the brown spider, *Loxosceles reclusa* Gertsch and Mulaik. Texas J. Sci. 19: 334–347.

Navarro-Silva, M. A., J.E.L. Duque, E. N. Ramires, C.F.S. Andrade, E. Marques-da-Silva, F. A. Marques, C. E. Delay, J. D. Fontana, A.C.S. Silva, and G. M. Fraguas. 2010. Chemical control of *Loxosceles intermedia* (Araneae: Sicariidae) with pyrethroids: field and laboratory evaulation. J. Med. Entomol. 103: 166–171.

Norment, B. R., and T. L. Pate. 1968. Residual activity of diazinon and lindane for control of *Loxosceles reclusa.* J. Econ. Entomol. 61: 574–575.

Price, R., L. Blevins, and K. Pinkston. 1988. Laboratory bioassay: Brown recluse spider, *Loxosceles reclusa* Gertsch & Mulaik. Insecticide Acaracide Tests 14: 368–369.

Price, R., L. Blevins, K. Pinkston, and M. Bell. 1989. Laboratory bioassay: Brown recluse spider, *Loxosceles reclusa* Gertsch & Mulaik. Insecticide Acaracide Tests 15: 381.

Reed, C., and S. Newland. 2002. MAF Biosecurity pest risk assessment: Spiders associated with table grapes from United States of America (State of California), Australia, Mexico and Chile. MAF Biosecurity Authority, Wellington, New Zealand.

Richardson, B. 2014. [Spider control] making a difference. http://www.pctonline.com/pct0314-brown-recluse-spiders-treatment.aspx.

Sandidge, J. S. 2009. Brown recluse spiders: A knowledge based guide to control and elimination. BRS Pest Control, McLouth, KS.

Sandidge, J. S., and J. L. Hopwood. 2005. Brown recluse spiders: A review of biology, life history and pest management. Trans. Kansas Acad. Sci. 108: 99–108.

Sterling, H. R., R. G. Price, and K. O. Furr. 1972. Laboratory evaluation of insecticides on various surfaces and at various intervals for control of the brown recluse spider. J. Econ. Entomol. 65: 1071–1073.

Thoms, E. M. 2004. Vikane® gas fumigant (sulfuryl fluoride) for eradicating structural infestations of exotic or unusual arthropod pests, pp. 49–50. *In:* T. Sutphin, D. Miller and R. Kopanic (eds.), Proceedings, National Conference on Urban Entomology, 20 May 2004, Phoenix, AZ.

Thoms, E. M., and R. H. Scheffrahn. 1994. Control of pests by fumigation with Vikane gas fumigant (sulfuryl fluoride). Down to Earth 49: 23–30.

Vetter, R. S., and M. K. Rust. 2008. Refugia preferences by the spiders *Loxosceles reclusa* and *Loxosceles laeta* (Araneae: Sicariidae). J. Med. Entomol. 45: 36–41.

Vetter, R. S., L. S. Vincent, D.W.R. Danielsen, K. I. Reinker, D. E. Clarke, A. A. Itnyre, J. N. Kabashima, and M. K. Rust. 2012. The prevalence of brown widow and black widow spiders (Araneae: Theridiidae) in urban southern California. J. Med. Entomol. 49: 947–951.

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