Research Article

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A comparison of insecticide susceptibility levels in 12 species of urban pest ants with special focus on the odorous house ant, *Tapinoma sessile*

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Abstract

BACKGROUND: Many ant species are pests in urban, agricultural, and natural habitats around the world. The primary means of reducing or eliminating ant infestations utilizes chemical control, mainly applications of residual insecticides. Control failures with residual insecticides are common, driven in part by a lack of understanding of basic biological and life history characteristics, including interspecific variation in susceptibility to insecticides. The current study evaluated the susceptibility of 12 species of urban pest ants to three classes of insecticides.

RESULTS: Results show significant variation in susceptibility across species. Contrary to the hypothesis of proportionality, no significant relationship was detected between body mass and median lethal time (LT_{50}) or time to 100% mortality. The odorous house ant (*Tapinoma sessile*) was consistently the least susceptible to all insecticides, as indicated by the highest LT_{50} values and the greatest amount of time required to reach 100% mortality. Comparatively low susceptibility to commonly used spray insecticides may explain why *T. sessile* is such a persistent pest. Broadcast applications of spray insecticides may kill off the most susceptible species, leaving behind *T. sessile*. Lack of competition from other ant species, combined with increased access to nesting and feeding resources may allow *T. sessile* to fill a vacant ecological niche and expand its range.

CONCLUSION: Considering *T. sessile*'s relatively low susceptibility to insecticides, its ability to become established in areas colonized by other invasive ants, and its highly invasive behaviors, it should be watched for by biosecurity programs as it has high potential to become a globally invasive pest.

Keywords: bifenthrin; chlorfenapyr; fipronil; invasive ants; odorous house ant; pest ants

1 INTRODUCTION

Globally, ants are a diverse and expansive group of insects and many species are serious pests in urban, agricultural, and natural environments.[1] Invasive species such as Argentine ant (*Linepithema humile*), big-headed ant (*Pheidole megacephala*), pharaoh ant (*Monomorium pharaonis*), red imported fire ant (*Solenopsis invicta*), and many others thrive in urban environments and continue to spread globally.[2] In the USA, ants consistently rank as the number one household pest and generate an estimated $2.1 billion in service revenue for pest management companies.[3] Forty-one ant species are considered household pests in the USA and include a mixture of native and introduced species.[4] The importance of each pest ant species varies according to geographic location. A 2019 nationwide survey of 169 pest management companies revealed that five ant species accounted for three-quarters of service calls across the USA. They were odorous house ant (*Tapinoma sessile*, 23%), carpenter ants (*Camponotus* spp., 18%), Argentine ant (*Linepithema humile*, 16%), pavement ant (*Tetramorium caespitum*, 9%), and red imported fire ant (*Solenopsis invicta*, 9%).[3]

Management of urban pest ants is primarily achieved through the use of chemical products including residual sprays, baits, and granules.[5–9] Baits are highly effective against a wide range of pest ants and have been used for controlling ants in urban and natural areas.[10,11] Despite some successes,[10,12] toxic baits have a number of disadvantages that limit their use. These include a relatively short life span under field conditions, susceptibility to environmental degradation, potential to cause ecological contamination, lack of effective dispensers, and non-target effects.[8] In addition to toxic baits, recent advances have provided new tools to more effectively manage urban pest ants. These tools include hydrogel baits,[13–16] prey-baiting based on the use of insecticide-treated prey,[17,18] and pheromone-assisted baiting.[19,20] Despite the availability of effective baits and other management approaches, residual insecticide sprays continue to be widely used for ant management. Spray insecticides are typically

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applied as "barrier" or "perimeter" sprays around structures and work by killing ants that trail across the treated areas. When non-repellent, slow-acting insecticides such as fipronil are used, barrier applications are particularly effective because exposed workers continue interacting with nestmates for several hours after exposure and share the insecticides with nestmates via horizontal transfer. Recent studies show that horizontal transfer and the resulting secondary kill can be effectively used to control populations of urban and invasive ants.[21,22]

A current challenge to effective ant control is lack of comprehensive, comparative studies on the susceptibility of different ant species to commonly used insecticides. Information on control is limited to a few species of economic importance such as the Argentine ant[23] and the red imported fire ant.[24] Control failures with liquid spray pesticides are common in urban[23] and natural areas.[25] Hoffmann et al.,[25] analyzed the success of ant eradication campaigns and reported that over 50% resulted in failures. Factors including species, eradication methods, number of treatments, and active ingredients were all important in eradication success, but it was impossible to tease apart their relative contribution because of complex interactions. Ants display extreme variation in life history traits, which may result in differences in susceptibility to insecticides, and consequently substantial differences in the outcome of control or eradication efforts.

Currently, a number of elementary questions remain unanswered regarding which factors play a role in susceptibility to insecticides and the magnitude of their effects. The objectives for the current study were twofold. The first objective was to evaluate the susceptibility of 12 species of urban pest ants to three different classes of insecticides. The second objective was to perform regression analysis and explore the pairwise relationship between body mass and susceptibility. It is generally assumed that body mass and susceptibility are connected and the hypothesis of proportionality states that arthropods respond to insecticides in direct proportion to their body mass.[26] Indeed, this has been demonstrated in some insects.[27,28] However, the extent to which insecticide susceptibility is dependent on body weight is not well understood and increased tolerance with increased weight cannot be assumed to be a general pattern among all insects.[27,29] Preliminary results revealed that *Tapinoma sessile* was the least susceptible to all insecticides when time–mortality relationships were considered. *T. sessile* is widespread throughout North America[30] and is one of the most notorious pest ants in urban environments.[4,31,32] The implications of greater insecticide tolerance as this relates to the management of *T. sessile* are discussed.

2 MATERIALS AND METHODS

2.1 Ant collections

To examine the relationship between body mass and susceptibility to insecticide, 12 ant species across a continuum of body sizes were collected. All species are common urban pests in the USA.[4] The species included: acrobat ant, *Crematogaster cerasi* (five colonies); Argentine ant, *Linepithema humile* (two colonies); black carpenter ant, *Camponotus pennsylvanicus* (seven colonies); cornfield ant, *Lasius neoniger* (five colonies); field ant, *Formica neogagates* (four colonies); little black ant, *Monomorium minimum* (three colonies); odorous house ant, *Tapinoma sessile* (six colonies); pavement ant, *Tetramorium caespitum* (five colonies); pharaoh ant, *Monomorium pharaonis* (one colony); red imported fire ant, *Solenopsis invicta* (six colonies); thief ant, *Solenopsis molesta* (five colonies); and western harvester ant, *Pogonomyrmex occidentalis* (one colony). Argentine ants were collected in Winston-Salem and Raleigh, NC, harvester ants in Provo, UT, and red imported fire ants in Geneva, FL. All other species were collected in Tippecanoe County, IN. All ants were brought to the laboratory and placed in boxes with artificial nests. Ants were provided with 20% sucrose solution, drinking water, and used in tests within 2 months of collecting. Body mass was recoded to the nearest 0.01 mg using a microbalance (Mettler Toledo AE 100). For each species, 30–40 individuals were weighed, and the mean body mass was used to examine the relationship between body mass and susceptibility to insecticides. For species with polymorphic workers (*Camponotus pennsylvanicus* and *S. invicta*) medium-sized workers were selected for weight measurements.

2.2 Residual exposure assays

The susceptibility of 12 different ant species to applications of three different broad-spectrum insecticide chemistries was tested in residual exposure assays. The chemistries evaluated were: (i) pyrethroid (Talstar One, FMC Corp., 7.9% bifenthrin); (ii) phenylpyrazole (Termidor SC, BASF Corp., 9.1% fipronil); and (iii) halogenated pyrrole (Phantom CS, BASF Corp., 21.5% chlorfenapyr). Insecticide concentrates were diluted in water to label-recommended rates: 0.06% for bifenthrin, 0.06% for fipronil, and 0.5% for chlorfenapyr. The diluted insecticides were sprayed onto a non-porous surface consisting of 15.2 × 15.2 cm glazed ceramic tiles. The applications were made using a fine mist spray bottle atomizer (Specialty Bottles) at the rate of 0.92 ml per tile. This is equivalent to the label-recommended application volume of 4 ml of finished dilution per 1000 cm^2. The required volume of each insecticide dilution was sprayed onto the tile from 3 cm away. The spray bottle was weighed before and after application to ensure that the proper volume of spray solution was applied for each tile. In addition, control tests consisted of tiles treated with water alone. The treated tiles were allowed to dry overnight. The environmental conditions in the laboratory were: 28 ± 2°C, 40 ± 10% relative humidity, and 14:10 h light/dark photoperiod. For each experimental replicate, ten ants randomly selected from stock colonies were transferred to a holding container consisting of a Petri dish (9 cm diameter × 1 cm high). The inner wall of the Petri dish was coated with Fluon™ to restrict the ants to the treated substrate and to prevent escapes. The Petri dish housing the ants was then inverted onto the treated tile. The ants were exposed to the treated tiles continuously. Mortality assessments consisted of the number of ants that were either alive (moving) or dead (no movement when probed). Mortality counts were recorded at different time points depending on the insecticide and species, with no fewer than seven time points per insecticide/species combination. Ten replicates were performed for each insecticide/species combination for a total of 100 ants per insecticide/species combination.

2.3 Data analysis

The median lethal time (LT_{50}) value was calculated for each replicate colony by using probit analysis in R.[33] A goodness-of-fit test was performed for each probit model. To determine which insecticide was more toxic to a particular species the relative tolerance ratio (RT_LR_{50}) was calculated for each insecticide ($RT_LR_{50} = LT_{50}$ of the least toxic insecticide per LT_{50} of the insecticide). Analysis of variance (ANOVA; PROC GLM) was performed in SAS 9.4 for each insecticide to examine the distribution of LT_{50} values across the different species.[34] The ANOVA test was followed by post-hoc Tukey's HSD tests to separate the means. The relationship

TABLE 1. Mean LT_{50} values (in min) and lower and upper 95% confidence limits for 12 species of urban pest ants exposed to 0.06% bifenthrin

Insecticide	Species	$N^{(2)}$	X^2	d.f.	Mean LT_{50} (±SD)	Mean UCL (±SD)	Mean LCL (±SD)	RT_LR_{50}
Bifenthrin	Odorous house	100	3.15	9	78.8 ± 9.3 a	69.4 ± 9.2	87.4 ± 10.2	0.11
Bifenthrin	Harvester	100	1.49	9	47.9 ± 9.0 b	38.0 ± 8.6	56.3 ± 10.5	0.18
Bifenthrin	Acrobat	100	1.74	9	45.0 ± 6.1 b	39.2 ± 6.5	49.4 ± 6.7	0.19
Bifenthrin	Carpenter	100	0.82	9	43.0 ± 3.1 bc	34.8 ± 13.6	46.7 ± 3.0	0.20
Bifenthrin	Fire	100	3.54	9	40.8 ± 6.9 bc	31.2 ± 6.7	49.9 ± 7.8	0.21
Bifenthrin	Pavement	100	8.51	9	39.3 ± 7.4 bc	28.4 ± 15.2	46.3 ± 8.0	0.22
Bifenthrin	Cornfield	100	0.35	9	35.6 ± 5.2 cd	30.0 ± 6.0	39.6 ± 5.5	0.24
Bifenthrin	Little black	100	1.47	9	29.9 ± 6.3 de	21.9 ± 6.4	37.0 ± 7.0	0.28
Bifenthrin	Argentine	100	2.54	9	28.7 ± 5.5 de	21.7 ± 8.8	33.7 ± 5.2	0.30
Bifenthrin	Pharaoh	100	5.16	9	21.8 ± 4.2 ef	15.1 ± 5.7	25.7 ± 4.0	0.39
Bifenthrin	Field	100	1.57	9	16.8 ± 4.1 fg	10.5 ± 3.8	20.3 ± 4.3	0.51
Bifenthrin	Thief	100	3.75	9	8.5 ± 1.6 g	6.4 ± 1.6	10.8 ± 2.4	1.00

Species arranged from least to most susceptible. LT_{50} means followed by the same letter are not significantly different based on Tukey's HSD test ($P \leq 0.05$). $N^{(2)}$, number of insects used; LT_{50}, median lethal time; UCL, upper 95% confidence limits; LCL, lower 95% confidence limits; RT_LR_{50}, relative tolerance ratio.

between LT_{50}, body weight, and time to reach 100% mortality was examined using simple linear regression (CORR PROCEDURE) in SAS 9.4.[34]

3 RESULTS

All three insecticides resulted in 100% mortality in all ant species. However, the species had significant differences in susceptibility among the different insecticide classes at the rates evaluated in the study. Species had a significant effect on LT_{50} values for bifenthrin (ANOVA: $F_{108,119} = 86.31$, $P < 0.001$), chlorfenapyr (ANOVA: $F_{108,119} = 31.09$, $P < 0.001$), and fipronil (ANOVA: $F_{108,119} = 53.85$, $P < 0.001$). LT_{50} values for bifenthrin, chlorfenapyr, and fipronil are presented in Tables 1–3, respectively. Bifenthrin was the fastest-acting insecticide as indicated by the lowest LT_{50} values (Table 1). Bifenthrin also showed the greatest range in toxicity values, with an almost tenfold difference between the least susceptible and the most susceptible species. LT_{50} values ranged from 78.8 min in odorous house ants to 8.5 min in thief ants. Odorous house ants were significantly less susceptible to bifenthrin relative to all other species (Tukey's HSD test, Table 1). The LT_{50} value for odorous house ants, 78.8 min, was more than double the mean LT_{50} value across all test species, 36.3 min. As expected, chlorfenapyr was substantially slower relative to bifenthrin but resulted in 100% mortality in all species (Table 2). LT_{50} values ranged from 331.1 min in odorous house ants to 107.9 min in thief ants. Odorous house ants were again the least susceptible of all species (Tukey's HSD test, Table 2). The mean LT_{50} value across all test species was 227.8 min and the difference in LT_{50} values between the least susceptible and the most susceptible species was approximately threefold. LT_{50} values for fipronil ranged from 416.6 min for odorous house ants to 216.3 min for little black ants (Table 3). The odorous house ant was the least susceptible of all species, but not significantly different from carpenter or cornfield ants (Tukey's HSD test, Table 3). The mean LT_{50} value across all test species was 297.1 min and the difference in LT_{50} values between the least susceptible and the most susceptible species was approximately twofold.

TABLE 2. Mean LT_{50} values (in min) and upper and lower 95% confidence limits for 12 species of urban pest ants exposed to 0.5% chlorfenapyr

Insecticide	Species	$N^{(2)}$	X^2	d.f.	Mean LT_{50} (±SD)	Mean UCL (±SD)	Mean LCL (±SD)	RT_LR_{50}
Chlorfenapyr	Odorous house	100	10.92	9	331.1 ± 44.9 a	282.7 ± 44.6	382.0 ± 51.1	0.33
Chlorfenapyr	Cornfield	100	2.65	9	307.1 ± 31.8 b	289.5 ± 32.9	383.5 ± 142.2	0.35
Chlorfenapyr	Harvester	100	6.65	9	273.0 ± 16.7 bc	210.7 ± 79.5	308.2 ± 16.6	0.40
Chlorfenapyr	Acrobat	100	12.23	9	265.9 ± 29.8 bcd	218.1 ± 37.1	289.7 ± 23.7	0.41
Chlorfenapyr	Fire	100	5.54	9	246.6 ± 35.9 cd	197.7 ± 63.0	278.5 ± 35.7	0.44
Chlorfenapyr	Pavement	100	2.66	9	237.4 ± 48.1 cd	194.7 ± 56.7	265.7 ± 48.6	0.45
Chlorfenapyr	Carpenter	100	1.71	9	235.7 ± 51.9 cde	229.1 ± 78.3	259.7 ± 51.0	0.46
Chlorfenapyr	Argentine	100	2.23	9	215.5 ± 20.4 def	190.4 ± 18.8	236.5 ± 23.3	0.50
Chlorfenapyr	Pharaoh	100	6.24	9	181.3 ± 34.4 efg	162.4 ± 34.8	199.0 ± 35.4	0.60
Chlorfenapyr	Field	100	13.56	9	173.3 ± 66.3 ef	118.3 ± 33.2	178.2 ± 58.5	0.62
Chlorfenapyr	Little black	100	2.42	9	157.2 ± 10.8 gh	138.9 ± 11.7	174.3 ± 10.7	0.69
Chlorfenapyr	Thief	100	2.10	9	107.9 ± 11.9 h	98.1 ± 11.8	116.6 ± 13.7	1.00

Species arranged from least to most susceptible. LT_{50} means followed by the same letter are not significantly different based on Tukey's HSD test ($P \leq 0.05$). $N^{(2)}$, Number of insects used; LT_{50}, median lethal time; UCL, upper 95% confidence limits; LCL, lower 95% confidence limits; RT_LR_{50}, relative tolerance ratio.

TABLE 3. Mean LT_{50} values (in min) and upper and lower 95% confidence limits for 12 species of urban pest ants exposed to 0.06% fipronil

Insecticide	Species	$N^{(2)}$	X^2	d.f.	Mean LT_{50} (±SD)	Mean UCL (±SD)	Mean LCL (±SD)	RT_LR_{50}
Fipronil	Odorous house	100	2.34	9	416.6 ± 15.0 a	394.0 ± 17.0	467.7 ± 15.3	0.52
Fipronil	Carpenter	100	5.12	9	407.6 ± 43.3 ab	368.6 ± 35.2	429.1 ± 53.4	0.53
Fipronil	Cornfield	100	10.27	9	388.9 ± 18.6 ab	363.0 ± 21.1	420.5 ± 40.3	0.56
Fipronil	Acrobat	100	3.25	9	361.8 ± 56.5 bc	309.7 ± 53.7	462.1 ± 159.0	0.60
Fipronil	Fire	100	8.40	9	319.6 ± 30.7 c	276.2 ± 35.5	360.2 ± 28.1	0.68
Fipronil	Pavement	100	2.02	9	263.9 ± 31.6 d	227.9 ± 29.0	296.4 ± 37.9	0.82
Fipronil	Argentine	100	1.39	9	260.3 ± 57.7 d	193.4 ± 81.2	290.5 ± 40.9	0.83
Fipronil	Harvester	100	4.65	9	250.4 ± 19.9 d	220.6 ± 24.5	278.4 ± 19.1	0.86
Fipronil	Field	100	2.80	9	230.8 ± 25.3 d	203.9 ± 28.1	251.6 ± 25.0	0.94
Fipronil	Pharaoh	100	6.17	9	225.8 ± 28.4 d	197.0 ± 36.3	252.0 ± 32.5	0.96
Fipronil	Thief	100	3.05	9	223.7 ± 17.3 d	192.8 ± 25.2	247.1 ± 17.3	0.97
Fipronil	Little black	100	1.24	9	216.3 ± 15.7 d	186.2 ± 17.3	240.7 ± 19.4	1.00

Species arranged from least to most susceptible. LT50 means followed by the same letter are not significantly different based on Tukey's HSD test ($P \leq 0.05$). $N^{(2)}$, Number of insects used; LT_{50}, median lethal time; UCL, upper 95% confidence limits; LCL, lower 95% confidence limits; RT_LR_{50}, relative tolerance ratio.

Mean time to reach 100% mortality values for all species and insecticides are presented in Figure 1. Species displayed significantly different times to 100% mortality for bifenthrin (ANOVA: $F_{108,119} = 130.98$, $P < 0.001$), chlorfenapyr (ANOVA: $F_{108,119} = 107.61$, $P < 0.001$), and fipronil (ANOVA: $F_{108,119} = 90.31$, $P < 0.001$). For bifenthrin, the mean time to reach 100% mortality averaged across all test species was 66 ± 29 min and ranged from 28 ± 11 min in thief ants to 132 ± 9 min in odorous house ants. The mean time to reach 100% mortality for chlorfenapyr was 340 ± 91 min and ranged from 189 ± 23 min in thief ants to 548 ± 30 min in odorous house ants. For fipronil, the mean time to reach 100% mortality was 408 ± 31 min and ranged from 318 ± 15 min in pharaoh ants to 568 ± 41 min in odorous house ants. Odorous house ants were consistently the least susceptible to all insecticides as indicated by the greatest amount of time required to reach 100% mortality. Species ranking, based on the cumulative amount of time required to reach 100% mortality across all species and insecticides, is shown in Figure 2.

Body mass varied greatly across the species, from 30.9 ± 4.2 mg in carpenter ants to 0.21 ± 0.02 mg in thief ants. No significant relationship was detected between body mass and LT_{50} values (Figure 2A, Pearson's correlation, $r = 0.09$, $P = 0.28$). Similarly, no significant relationship was detected between body mass and time to 100% mortality (Figure 2B, Pearson's correlation, $r = 0.02$, $P = 0.68$). A significant correlation was detected between LT_{50} values and time to 100% mortality (Figure 2C, Pearson's correlation, $r = 0.96$, $P < 0.001$).

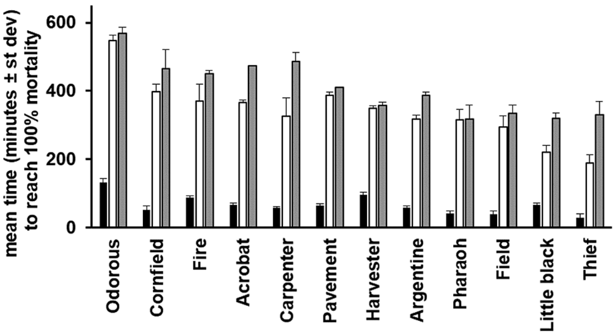

FIGURE 1. Susceptibility of urban pest ants to bifenthrin (black bars), chlorfenapyr (white bars), and fipronil (gray bars). Species are ranked from least susceptible to most susceptible based on cumulative median lethal time (LT_{50}) values across all three insecticides.

4 DISCUSSION

The current study is a comprehensive examination of insecticide susceptibility in the most common urban pest ants, including four widely distributed invasive species. Results demonstrate wide interspecific variation in susceptibility. Previous studies have largely focused on testing the performance of different insecticide products against a single species. The main goal of such studies was to identify the most effective tools for controlling a specific target species. Control failures with residual insecticides are common and are driven by multiple factors including lack of information on insecticide susceptibility for specific target species. The results of the current study merit adjustments in insecticide treatment regimens depending on the species being treated. To achieve satisfactory control, species that have particularly low sensitivity to insecticides might require higher application rates, more frequent application intervals, or both.

Contrary to the hypothesis of proportionality, which states that insects respond to insecticides in direct proportion to their body weight,[26] no significant relationship was detected between body mass and either LT_{50} value or time to 100% mortality. It is generally assumed that body weight and susceptibility in insects are connected. However, increased tolerance with increased weight cannot be assumed to be a general pattern among all insects.[27,29]

In this study, ants had a wide range of body weights with the heaviest, carpenter ant (*Camponotus pennsylvanicus*, mean body weight = 30.900 mg) weighing almost 150 times more than the lightest, thief ant (*Solenopsis molesta*, mean = 0.217 mg). The smallest ant evaluated in the study, thief ant, was highly susceptible to all three insecticides. However, relatively large ants such as field ant (*Formica neogagates*, mean = 7.720 mg) or harvester ant (*Pogonomyrmex occidentalis*, mean = 14.620 mg) were also highly susceptible and not significantly different from thief ants. Results show that in Formicidae, body weight is not a good predictor of susceptibility to insecticides. The extent to which insecticide susceptibility is dependent on body weight is not well understood

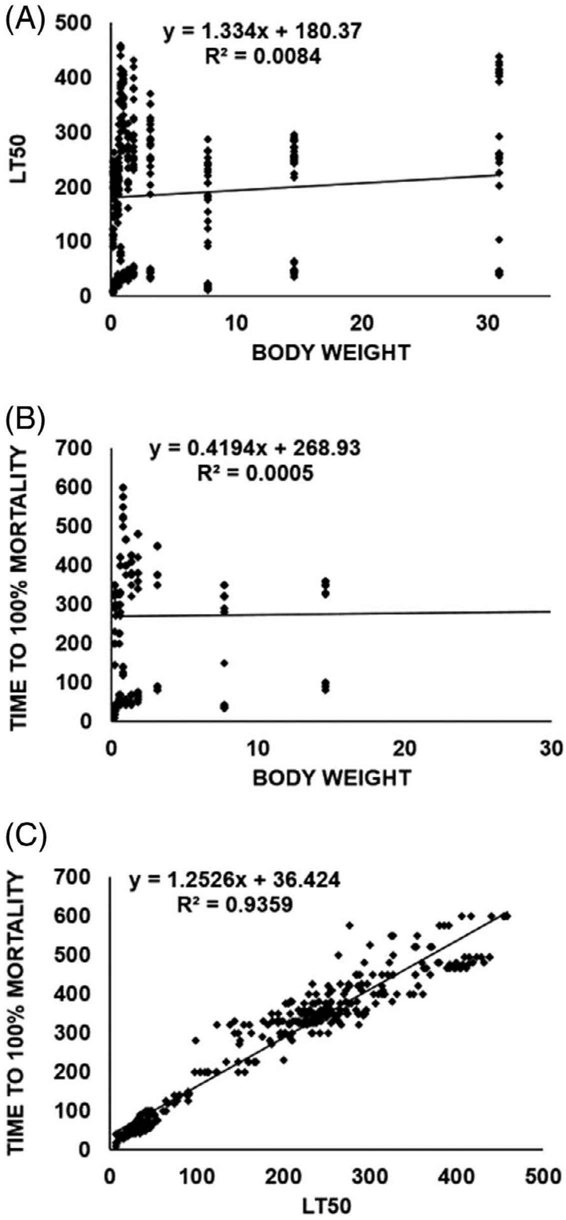

FIGURE 2. Results of regression analysis between: (A) body weight and median lethal time (LT_{50}) values; (B) body weight and time to reach 100% mortality; and (C) LT_{50} values and time to reach 100% mortality.

because various genetic, biological, and operational factors can potentially affect susceptibility. For example, differences in cuticle thickness could lead to differences in insecticide penetration and sequestration, differences in enzyme levels could affect insecticide metabolism, target site (receptor) physiology could affect interactions with specific insecticides, and behavioral differences could lead to differences in exposure levels. These individual factors, and their potential interactions, make it difficult to discern the importance of any single factor.

Results of the current study show that at label-prescribed rates, the odorous house ant, *T. sessile*, is significantly less susceptible to all insecticides relative to all other ant species. Comparatively low susceptibility may explain why *T. sessile* is such a persistent pest and so difficult to control. *T. sessile* is widespread throughout North America and has the widest geographic range and the greatest ecological tolerance of any ant in North America.[30] It is very opportunistic and in urban areas it is classified a pest species.[31] Colonies range from small, single-queen, single-nest colonies in natural habitats to large, multi-nest, multi-queen supercolonies in urban areas.[32,35] In urban areas, *T. sessile* exhibit extreme polygyny and polydomy, and often becomes a dominant invasive pest.[36–38] Additionally, *T. sessile* is invasive in Hawaii where it is showing behaviors common to other globally invasive ants such as supercolony behaviors, extreme polydomy and polygyny, generalist nesting and feeding habits, and the ability to survive in new environments.[39] *T. sessile* had especially low sensitivity to bifenthrin, a pyrethroid insecticide. Pyrethroids are one of the most commonly used insecticides for urban pest management.[9] They dominate the marketplace and are the active ingredient in most insecticides available to consumers for residential use in the USA.[40] Future work should examine whether low susceptibility to pyrethroids is one of the factors why *T. sessile* is so difficult to control in urban situations.

In the USA, ants consistently rank as the number one household pest and the number one revenue generator for pest management companies.[3] In 2019, ants accounted for over 24% of the structural pest management market. According to a survey of 169 pest management firms, *T. sessile* represents the largest percentage of service calls (23% of responders) and is the most difficult ant to control (22% of responders).[3] Additionally, *T. sessile* is considered the number one "call-back" ant. A "call-back" occurs when an insecticide is applied to control ants, but control is not achieved and the customer requests additional service. The results of the current study may help explain why *T. sessile* is such as a persistent urban pest and why it is so difficult to control. *T. sessile* was consistently the least susceptible species across multiple classes of insecticide chemistries. The study utilized a continuous exposure where the ants were confined to the treated substrate to assure that 100% mortality was reached across all species. In field situations, insecticides are typically applied to areas where the ants are expected to trail, and exposure is intermittent. Ants are exposed either directly when they visit the treated areas or indirectly by contact with nestmates that have visited the treated areas and returned to the nest. Field-realistic exposure levels are likely to be relatively low and sublethal, which may further accentuate differences among species. As a result, broadcast applications of perimeter sprays to control pest ants may kill off the most susceptible species leaving behind less susceptible species such as *T. sessile*. Less susceptible species may survive the treatments, necessitating retreatment. Furthermore, applications of spray insecticides may lead to secondary pest outbreaks which are common in agricultural situations. Secondary pest outbreaks occur when the use of a pesticide to reduce the densities of an unwanted target pest triggers subsequent outbreaks of another pest. Perimeter treatments targeting urban pest ants may eliminate relatively common yet highly sensitive species, leaving behind less common, less susceptible species to populate the treated areas.

T. sessile is present in every state in the continental USA and its pest status has been well-documented since the early 20th century.[41] It is thought by many to be undergoing a range expansion[6,32,35,42] and has been increasingly encountered in urban areas. The low susceptibility of *T. sessile* to commonly used barrier spray insecticides may also help explain why it is becoming such a prevalent pest in urban areas. A study by Scharf et al.,[6] evaluated the effectiveness of perimeter treatments of fipronil, imidacloprid, and cyfluthrin again perimeter-invading ants. All treatments led to substantial reductions in ant counts relative to untreated controls. The authors did not find *T. sessile* in their study plots before the treatments were applied. However, a comparison of ant species composition between treated and control plots 8 weeks after the treatment revealed an increase in frequencies of *T. sessile* in treated plots only. The authors interpreted this as indicative of invasive-like characteristics of *T. sessile* and its ability to rapidly colonize areas with vacant resources. The results of the current study may help explain those observed by Scharf et al.[6] It is plausible that highly susceptible ant species were eliminated by the insecticide treatments which created a vacant ecological niche. Scharf et al.[6] reported that pavement ants (*Tetramorium caespitum*) were the most abundant ant at the study site. Relative to *T. sessile*, *Tetramorium caespitum* are significantly more susceptible to bifenthrin (LT_{50} of 39 versus 79 min), chlorfenapyr (LT_{50} of 237 versus 331 min), and fipronil (LT_{50} of 264 versus 417 min). Elimination of *Tetramorium caespitum* and other ant species may have allowed *T. sessile* to move into areas that offered nesting and food resources previously occupied by other species. In turn, access to resources, may have fueled the growth of *T. sessile* colonies in a snowballing effect, leading to the formation of supercolonies frequently observed in urban[32,35,37] and natural areas.[39]

T. sessile belongs to the subfamily Dolichoderinae which includes many globally widespread and extremely successful tramp species such as Argentine ants (*Linepithema humile*), ghost ants (*Tapinoma melanocephalum*), white-footed ants (*Technomyrmex albipes*), and difficult ants (*Technomyrmex difficilis*). The Argentine ant represents the most widespread and damaging of these invaders and is especially difficult to control.[8,25] Current results indicate that relative to *T. sessile*, *Linepithema humile* is significantly more susceptible to all insecticides including bifenthrin (LT_{50} of 29 versus 79 min), chlorfenapyr (LT_{50} of 216 versus 331 min), and fipronil (LT_{50} of 260 versus 417 min). Despite being more susceptible, *Linepithema humile* is notoriously difficult to eradicate with a failure rate of 64%.[25] A previous study showed that *T. sessile* is capable of long-distance jump-dispersal and is capable of becoming established in areas previously invaded by *Linepithema humile* and other invasive ant species.[39] Considering *T. sessile*'s relatively low susceptibility to insecticides, its ability to become established in areas colonized by other invasive ants, including both tropical and temperate areas, and its highly invasive behaviors, it should be watched for by biosecurity programs as it has high potential to become a globally invasive pest.

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