Food and Bait Preferences of *Liometopum occidentale* (Hymenoptera: Formicidae)[1]

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Abstract The velvety tree ant, *Limetopum occidentale* Emery, is commonly found in urban areas throughout the western U.S. and has been reported damaging structures. Foragers prefer sucrose, glucose, and honey sucanat solutions. Solid protein baits containing anchovy also were retrieved by workers. In the early summer, foragers were active both day and night. In the late summer when daytime temperatures exceeded 35°C, workers only foraged at night. Even though workers are polymorphic, they all consumed about 0.25 mg of a 25% sucrose solution and thus providing a mechanism of determining foraging activity by determining sugar water removal from monitoring stations. Liquid bait bases containing 25% sucrose would be effective if suitable toxicants can be identified.

Key Words velvety tree ant, bait preference, sucrose bait-base

The velvety tree ant, *Liometopum occidentale* Emery (Hymenoptera: Formicidae), is commonly found along the coastal regions from southern Washington to northern Mexico (Del Toro et al. 2009, Snelling and George 1979, Hoey-Chamberlain et al. 2013, Dr. Laurel Hansen personal communication). This ant can be found at elevations as low as 7 m in Oregon to over 1700 m in California (Dr. Laurel Hansen personal communication; personal collection). They are the most common and dominant ant in oak and pine forests of southwestern U.S. (Wheeler and Wheeler 1986, Ward 2005, Del Toro et al. 2009). They prefer to nest in the crevices of oaks, alders, elms, cottonwoods, and creosote, in soil, underneath bark of dead trees, and under rotten logs (Cook 1953).

Liometopum occidentale is also commonly found in urban areas of southern California. Structural damage caused by *L. occidentale* has been reported (Wheeler and Wheeler 1986, Merickel and Clark 1994, Gulmahamad 1995, Hedges 1998, Klotz et al. 2008). However, velvety tree ants are often mistaken for carpenter ants (*Camponotus* spp.) or odorous house ant (*Tapinmoa sessile* Say) by homeowners and Pest Management Professionals (PMPs). This mistaken identity is due to morphological and behavioral characteristics they share with carpenter ants, namely polymorphic workers, a smooth convex thoracic profile, and the tendency to excavate wood (Klotz et al. 2008). Confusion with odorous house ants occurs because both ants produce a rotten coconut-like odor. Consequently, their importance as structural pests may be greatly under reported, especially in California, Oregon, and Washington.

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Liometopum occidentale form massive foraging trails over 60 m in length with some trails as long as 145 and 185 m (Conconi et al. 1983a, b, Gulmahamad 1995) and covering areas up to 740 m^2 (Del Toro et al. 2009, Wang et al. 2010). Workers travel mostly underground in very shallow galleries (1 - 2 cm deep), or in the litter (Ramos-Elorduy and Levieux 1992). Once they invade oak trees, they use this resource indefinitely. Foragers forage at temperatures between 24 - 38°C (Tremper 1971). Velvety tree ants forage during the day in great numbers in the spring and early summer, but around midsummer they switch to nighttime foraging, likely due to increasing daytime temperatures. This has been observed, but not scientifically proven. They are opportunistic omnivores (Wheeler 1905) and can often be found tending hemipterans and carrying prey insects back to the nest (Conconi et al. 1987, Gulmahamad 1995, personal observations).

Recently there has been renewed interest in the use of baits as a means of ant control because baits deliver low amount of toxicants directly to target species, are easy to apply, require no mixing by the applicator and can be used against ants that nest in protected harborages and are often unaffected by sprays (Klotz et al. 2000, 2008, 2009, Hooper-Bui and Rust 2000). In addition, conventional perimeter sprays can generate unintended pesticide runoff in urban water ways (Greenberg et al. 2010). Toxic baits are generally considered to be more effective in controlling ant infestations than insecticidal sprays and dusts because they are more likely to eliminate ant colonies by killing queens, brood, and resident workers as well as foraging workers (Williams et al. 1990, Knight and Rust 1991, Williams and Vail 1993). However, baits need to be highly acceptable to ants to compete for the attention of foragers if other food sources are available (Cornelius et al. 1996). To develop an attractive bait, the food preferences of the pest ant must be determined.

Two commonly used methods of determining food preference are: (1) to count the number of ants attracted over time to various foods offered simultaneously, or (2) to measure the amount consumed of various foods offered simultaneously and compare the proportions of the total taken. In this study, we used the second method because it provides an estimate of the amount of bait base that is actually retrieved by foragers. For example, Argentine ants are attracted to sucrose gels, however, the handling time of this food is so great due to its consistency that the ants do not consume as much of it as a liquid sucrose solution (Silverman and Roulston 2001). The second approach provides a better estimate of foraging activity over time, especially for species that might only forage sporadically or during specific times during the day.

Control of *L. occidentale* is problematic because of the distance that workers forage and that nests may not be located on the property being treated. Consequently, baits are a reasonable alternative to spraying pesticides if suitable baits could be developed. The objectives of this study were to (1) develop a suitable choice-feeding bioassay, (2) determine if there are daily patterns of foraging behavior, (3) determine if there are preferred foods that might serve as bait bases for toxic baits, and (4) determine an effective monitoring method of estimating foraging activity.

Materials and Methods

Food preference studies. Food preference studies of *L. occidentale* were conducted in the field with choice tests because it was impossible to maintain large natural laboratory populations. During the choice tests, preweighed open vials of different candidate types of food were placed within a foraging arena near the ants' foraging trails. The candidate foods were left out for a fixed time interval then returned to the laboratory and reweighed. An arena designed by Rust et al. (2000) was used for these experiments (Fig. 1). The arena consisted of an aluminum cake pan (20 cm diam. by 4 cm high) with 4 openings set 90° apart. Pieces of glass tubing (7 cm long by 7 mm outer diam.) were inserted through the openings so the ends were flush with the outside of the pan. This directed ants toward the center of the arena. Exactly 5 ml of liquid or 3 g of solid food material were measured into 14.8-ml glass vials with screw cap lids. The vials were opened and placed in a random pattern within the arena. The arena was covered with a piece of transparent mylar plastic and a piece of plywood covered with aluminum foil to provide shade and protection from rodents and other animals. Ant foraging activity was assessed by determining the amount of food removed. The amount of food removed (initial food - final food weight) was corrected by the percent reduction or gain in weight due to evaporation or absorption of water in the control foods placed simultaneously in a protected outdoor location where the ants were unable to forage on them. The amount of bait removed was corrected by the percentage of reduction or gain in weight of the control bait with following formula: (Test $Food_{ai}$)(Evap $Food_a$) – (Test $Food_a$), where Evap $Food_a$ = Evap $Food_i$-Evap $Food_f$/ Evap $Food_i$ in the controls. If Evap $Food_i$-Evap $Food_f$/Evap $Food_i$ < 0, then add 1 to Evap $Food_a$. Data were collected as two sets. Set one was tested on days in July 2010 (5 - 31 July 2010) with temperatures between 19.1 - 27.1°C (66.3 - 80.8°F) during the test period, and nights with temperatures between 16.4 - 24.2°C (61.6 - 75.6°F) during the test period. Data set two was collected on nights in September 2010 and August 2011 (25 - 26 September 2010 and 27 July- 23 August 2011) with temperatures between 18.4 - 28.6°C (65.1 - 83.4°F) during the test period.

A variety of solid and liquid foods that contain sugars, fats and/or proteins was tested in the first test. Six food choices (25% glucose, 25% sucrose, 25% honey sucanat, anchovy granules, roach granules, earthworm granules) were tested during 6 h trial periods during the day (1000 - 1600 h or approx. 4 h after sunrise until approx.

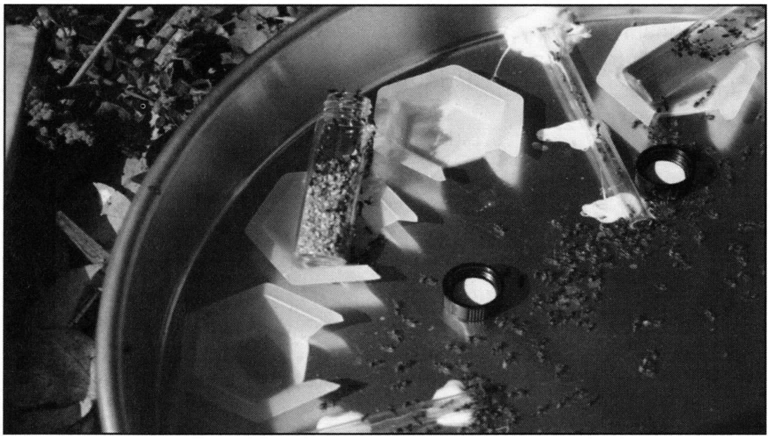

Fig. 1. ***Liometopum occidentale*** **foraging on baits in an uncovered choice arena.**

4 h before sunset; $n = 17$) and at night (1900 - 0100 h or approx. 1 h before sunset and approx. 5 h before sunrise; $n = 18$). In the second test, nine choices (same six as above plus 25% agave nectar, 25% fructose, and water) were tested during 12- h trial periods (1900 - 0700 h or at approx. sunset until approx. sunrise; $n = 24$).

Food preparation. The liquid carbohydrate baits were prepared from sucrose (Fischer Scientific®, Fair Lawn, NJ), D-(+)-glucose (Sigma®, Sigma-Aldrich Co., St. Louis, MO), D-(-)-fructose (Sigma®, Sigma-Aldrich Co., St. Louis, MO); honey sucanat / honey crystals (The Prepared Pantry®, Rigby, ID, a mixture of evaporated sugar cane juice and honey). Twenty-five percent solutions (w/v) were prepared because this concentration was highly preferred by Argentine ants (Baker et al. 1985, Rust et al. 2000) and *Solenopsis invicta* Buren (Greenberg et al. 2004). The liquid agave nectar (Madhava®, Madhava Honey, Lyons, CO) was prepared by measuring 30.5 ml of the syrup (as it already contained 18% water) into a graduated cylinder, and was filled with 69.5 ml distilled water to provide a 25% agave nectar solution. All the solutions were stirred until clear and stored in the refrigerator until needed.

The granular bait bases were prepared by following a prescribed recipe according to (Hooper and Rust 1997). Animal material such as anchovy (packed in oil), American cockroaches, and earthworms were ground up (50 g), and mixed with sugar, salt, water, powdered dry eggs and corn grit (150 g) to produce a paste. The paste was then freeze dried for 24 - 48 h. The bait was then gently loosened into individual granules. The addition of cornmeal and anchovy significantly improved the acceptance of the diet by the southern fire ant, *Solenopsis xyloni* McCook, than those containing mealworms or beef hash. This addition also resulted in more uniform particle size. Also, the addition of powdered dried eggs was found to be attractive to southern fire ant, and reduced the time required to freeze-dry the diets (Hooper and Rust 1997).

Individual consumption. To determine the amount of sucrose solutions consumed by workers, groups of approx. 20 *L. occidentale* workers from 3 different colonies were starved for 72 h in 237 ml (8 oz) polystyrene cups (hi-plas) coated on the inside with Teflon T-30B (E.I. Dupont de Nemours and Co., Wilmington, DE) to prevent them from escaping. Each cup was provided a moist cotton ball and covered with a lid to prevent dehydration. This set-up maintained a relative humidity within the cup of approx. 80%. This is extremely important because ants exposed in open cups during the starvation period died and the few survivors had extremely high intake of 25% sucrose water. Ants were then anesthetized with CO_2, separated into individual ~60 ml salsa cup coated on the interior with Teflon and covered with a lid. The individual ants were then anesthetized with CO_2, weighed to 10 µg using a Satorius M2P balance (Sartorius AG, Goettingen, Germany) and returned to their individual cups. After recovering, they were provided 25% sucrose water for 30 min, anesthetized with CO_2, and weighed again.

To determine the effects of starvation and holding ants without water, several groups were tested. Group one consisted of ants from 1 of the 3 laboratory colonies that were starved for 72 h without a lid on the cup, and fed for the 30-min period. Test group 2 consisted of ants from colony one that were starved for 72 h but not fed during the 30-min period between measurements. Group 3 consisted of ants from colony one that were not starved (taken directly from the colony box) and held with 25% sucrose water for 30 min. Lastly, group 4 were ants from colony one that were not starved (taken directly from the colony box) and not fed during the 30 min 'feeding' period.

Statistical analyses. Data for each food within each arena were converted into proportions of total take from each arena to adjust for potential differences in the size of ant colonies. The data from these choice tests were analyzed using the Friedman's test of rank sums and multiple comparisons using SYSTAT. To be effective, choice feeding studies require relatively large samples. At least 3 times as many replicates as choices was recommended by Williams and Titus (1988) after simulating the study stability of variable loadings in linear discriminant analysis (which is structurally similar to multivariate analysis of variance). Roa (1992) then extended these recommendations to both parametric and nonparametric analyses of multivariate food-preference such as Friedman's test of rank sums. Nonparametric approaches usually need more replicates than the parametric procedure because of the reduction in statistical power inherent in using ranks instead of raw data. Furthermore, the statistic T only approximates the F distribution, and as it does improve as the sample size increases.

The mean weights before and after feeding, and weight gain (after feeding weight-before feeding weight= consumption) were analyzed with an ANOVA. To determine the relationship between body size and sucrose consumption, Pearson's correlation coefficient was used to compare their initial weight and their weight gained after feeding (consumption) of the 3 experimental colonies pooled together. Statistics were performed using R version 2.14.1 (Copyright© 2011 The R Foundation for Statistical Computing).

Results

Food consumption. In the July trials, cockroach and earthworm granules were the least consumed bait bases by *L. occidentale* during daytime, and consumption was significantly less than the liquid carbohydrates (Fig. 2). The consumption of solid anchovy bait base and the glucose and sucrose solutions was not significantly different. The liquid sugar solutions were the most consumed. During the nighttime trials in July, the cockroach and worm granules were the least consumed bait bases, with the consumption of cockroach granules being significantly different from that of the carbohydrates and worm granules being significantly different from carbohydrates with the exception of honey sucanat (Fig. 3). Granular anchovy bait base was the most consumed protein bait base during nighttime and daytime foraging, and was not significantly different from liquid carbohydrate bait bases during nighttime foraging time (Fig. 3). Overall, *L. occidentale* consumed more liquid bait bases containing sucrose, glucose, and honey

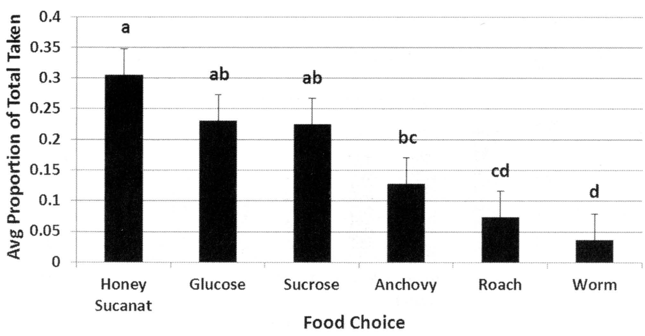

Fig. 2. Average proportion of the total food taken for each bait type during daytime trials on cool July days in 2010. Error bars represent standard error. Bars with the same letter are not significantly different at *P* < 0.05.

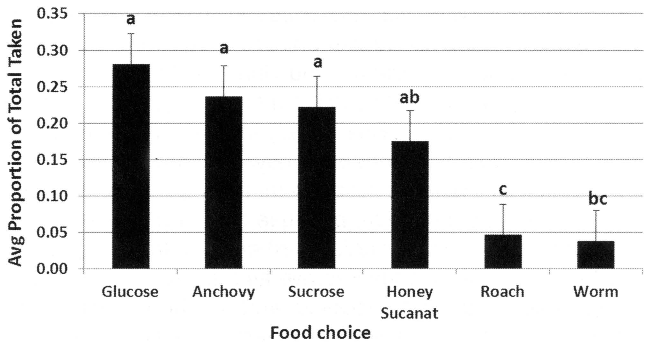

Fig. 3. Average proportion of the total food taken for each bait type during nighttime trials on cool July nights. Error bars represent standard error. Bars with the same letter are not significantly different at $P < 0.05$.

sucanat, with the exception of anchovy granules at night, and did not show a significant difference in consumption based on time of day (Kruskal-Wallis: chi-square (1) = 1.412, $P = 0.2348$). When there is only a small difference between certain bait bases, it takes a lot of replicates to provide clear separation.

During the September trials, the ants were moving around during the hottest periods of the day, but would not enter the arenas; therefore all trials were conducted at night. Water was also added as a choice to act as a control to determine if the consumption of the liquid carbohydrates was due to the sugars and not just the water used to dissolve them. *Liometopum occidentale* showed the similar consumption of carbohydrates during these trials as was seen during the July trials (Fig. 4).

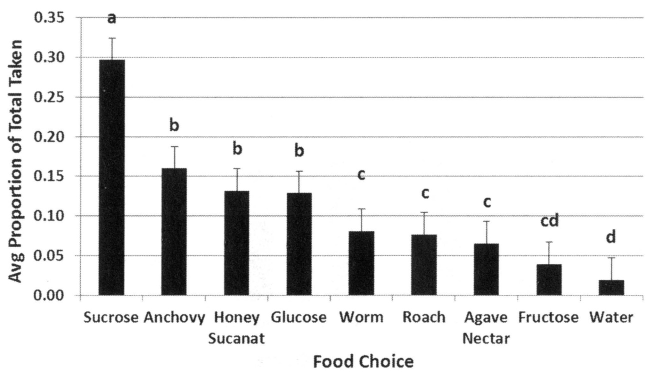

Fig. 4. Average proportion of the total food taken for each bait type during September 2010 / August 2011 trials with error bars representing standard error. Bars with the same letters are not significantly different at $P < 0.05$.

When the proportions from all the carbohydrate solutions consumed were pooled together and the same is done with the proteins, the results showed that *L. occidentale* consumed significantly more of liquid carbohydrate solutions than proteins both during the day and at night (Paired *t*-test: July Day: t=4.93, P = 0.0002; July Night: t =2.49, P = 0.0233). When this same procedure was used for the September trials, *L. occidentale* also consumed more of liquid carbohydrate solutions than both proteins and water (Friedman's test: X^2 (8, 23) = 81.636, P < 0.0001). The consumption of carbohydrates was significantly different from that of the proteins (t = 3.801, P = 0.00042) and water (t =8.638, P < 0.0001). The consumption of the protein bait bases was also significantly different from that of water (t =4.837, P < 0.0001).

Individual consumption. *Liometopum occidentale* workers are polymorphic and their weights are normally distributed (Fig. 5, Shapiro-Wilk Normality Test, P = 0.9749). However, not all colonies had the same size distributions.

Starving ants for 72 h in a cup without a lid and then feeding them for 30-min period resulted in high mortality during the starvation period (only colony 3 contained enough live ants to weigh for this experiment) and very high sugar consumption during the feeding period. When comparing ants held in cups without lids to those with lids, the mortality of the ants in cups with lids was significantly lower than ants with cups without lids. The high mortality was most likely due to desiccation.

The mean consumption of ants starved for 3 d is 0.258 ± 0.0528 (mean ± standard error) mg of 25% sucrose water. The mean weights of the three colonies before feeding were statistically different ($F_{2, 42}$ =6.920, P = 0.0025) and therefore cannot be pooled together for further analysis. The mean weights after feeding of the three colonies were also statistically different ($F_{2, 42}$ =5.010, P = 0.0104) and, therefore, cannot be pooled together for further analysis. However, the mean weight gain or consumption per ant ($F_{2, 42}$ =1.533, P = 0.2277) of the 3 colonies were not statistically different; therefore, the colonies were pooled together in further analyses of the data.

There was no relationship between the ant's initial weight before feeding and the amount of 25% sucrose water consumed (t = -1.422, df = 43, P = 0.1623, R= -0.2119, Fig. 6). All *L. occidentale* workers, regardless of their initial weight ("size") consumed the same amount of 25% sucrose water (Table 1).

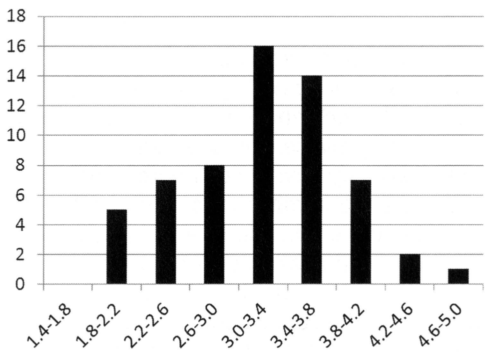

Fig. 5. Histogram of the weight (mg) of 60 ants (from 3 different colonies) that were starved for 72 h.

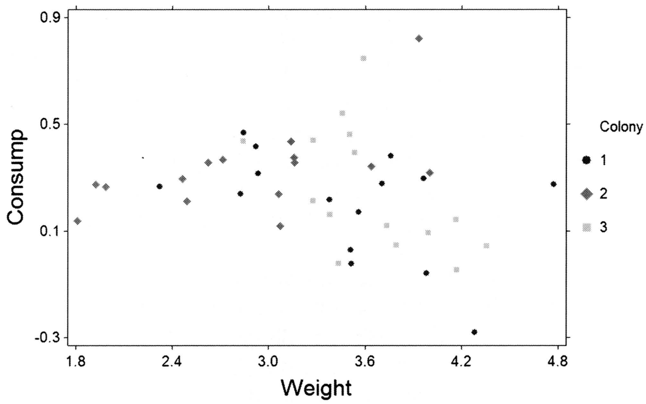

Fig. 6. Weight of 25% sucrose water consumed compared with the ant's initial weight. Each colony is represented by a different shape.

Discussion

The choice feeding assay developed by Rust et al. (2000) to test food preference of Argentine ants was effectively modified to determine the food preferences for *L. occidentale*. As long as the choice pan was placed on or very near an ant trail, the ants readily entered and foraged inside the pan. As was the case with Argentine ants, large numbers of replicates were needed to provide clear separation between acceptable foods, typically at least 3 times the number of choices being provided. Once workers find acceptable foods, they initiate recruitment to that particular food source. The quantity of food removed is dictated by the quality and the ease at which workers can handle or process that particular food item. Silverman and Roulston (2001) found that *L. humile* removed greater amounts of liquid sucrose compare with the same amount of sucrose in gel form because of a shorter handling time. Similarly, Hooper and Rust (1997) found that particle sizes of diet of 840 - 2000 µm resulted in the largest amount of diet removed by *S. xyloni* foragers.

Liquid and solid bait bases were tested because they are used by different members in the colony. Liquids are consumed by workers or returned to the nest by storing it in their crop (Klotz et al. 2008) and then regurgitating the food to other workers, larvae or the queen, via trophallaxis. Ant foragers are not capable of swallowing solid food particles because they have a constricted pharynx and a filter consisting of ridges and hairs that line the infrabuccal cavity that prevent particles beyond a certain size from passing into the gut. The threshold size of particles that cannot be ingested by adults varies among species (Klotz et al. 2008), but are always extremely small. For example, *Camponotus pennyslvanicus* (DeGeer) ingest particles smaller than 100 µm in diam (Klotz et al. 2008), whereas *S. invicta* filter out particles as small as 0.88 µm (Glancey et al. 1981). Solid baits with particles larger than the threshold size for ingestion by workers are collected and fed to the larvae that have the ability to digest solids (Klotz et al. 2008). Therefore, the targets of these foods are usually only the larvae.

Table 1. Mean values ± SE of weights (mg) before and after feeding, weight gain/loss, and the proportion of weight gained or lost in mg.

Treatment	N	Before	After	Gain/Loss	Proportion
Starved w/ lid; fed	60	3.3342 ± 0.1712	3.5925 ± 0.1681	0.2583 ± 0.0528	0.0831 ± 0.0158
Starved w/out lid; fed	15	2.9331 ± 0.2039	3.5106 ± 0.2479	0.5775 ± 0.0967	0.2245 ± 0.0408
Starved w/ lid; not fed	15	2.8403 ± 0.1063	2.8122 ± 0.1029	−0.0281 ± 0.0117	−0.0094 ± 0.0040
Not starved; fed	15	3.3046 ± 0.1240	3.2594 ± 0.1247	−0.0452 ± 0.0042	−0.0141 ± 0.0015
Not starved; not fed	15	3.1095 ± 0.1901	3.0630 ± 0.1885	−0.0465 ± 0.0037	−0.0152 ± 0.0012
Total	120				

A variety of food bait bases have been tested against various species of ants, and we_selected several of the more attractive and preferred foods. Twenty percent sucrose and honey solutions were particularly attractive to *Tapinoma indicum* (Forel) and of the proteinaceous foods tested tuna was preferred (Chong and Lee 2006). They did not feed on oils. Choice tests with white-footed ants, *Technomyrmex albipes* (F. Smith), found that 25% sucrose solutions and an artificial nectar-honeydew were highly preferred (Warner and Scheffrahn 2004). Tinti and Nofre (2001) found that *Lasius niger* L. preferred melezitose > sucrose = raffinose > D-glucose = maltose = sorbitol. *Linepithema humile* prefer 25% honey water and sucrose over solid sugars and other solid foods with protein content (Rust et al. 2000, Baker et al. 1985). Foods that have been tested on *Ochetellus glaber* (Mayr), *Paratrechina longicornis* (Latreille), and *Pheidole megacephala* (F.) include but are not limited to canola oil, corn oil, olive oil, peanut oil, safflower oil, soybean oil, fructose, glucose, maltose, melezitose, sucrose, and trehalose (Cornelius et al. 1996). *Ochetellus glaber* significantly preferred sucrose over maltose, but showed no preference for the different oils. *Paratrechina longicornis* did not show a preference for different sugars or different oils. *Pheidole megacephala* showed a significant preference for melezitose over glucose, maltose, and trehalose, but not over fructose and sucrose, and also showed a preference for olive oil (Loke and Lee 2004). Results indicated that this species preferred protein-rich food (peanut butter and dead cockroaches) to those containing only sugar or lipid. There also appeared to be some changes in their preference between peanut butter and dead cockroaches. The results of these studies indicate that the food type preference of ants in the subfamily Myrmicinae varies greatly from species to species, and even within species, whereas members of the subfamily Dolchoderine prefer liquid sugar diets.

Liometopum occidentale showed only a slight food preference change between day and night trials; however, overall food type preference (carbohydrate, protein, or lipid) did not change. Ants preferred liquid carbohydrates over solid proteins during both day and night trials. This preference persisted in the late summer trials even with the addition of a few more food choices. The exception to this carbohydrate preference was the anchovy granules that appeared to be preferred during both night trials. This may be due in part to the fact that this food was a mixture of 2 food types, proteins and oils, as the anchovies were packed in oil.

The foraging and feeding preferences of *L. occidentale* are similar to the other North American species *L. apiculatum*. *Liometopum apiculatum* are opportunistic carnivores and granivores (Shapley 1920), feeding on crustaceans, annelids, mollusks, dead vertebrates, animal droppings, and extrafloral nectar (Velasco et al. 2007). However, hemipteran exudates can make up the bulk of their diet in some habitats (Conconi et al. 1983b).

Some ant species such as *Monomorium pharaonis* (L.) and *S. invicta* varied their preference for certain foods with time, weather, caste composition, colony age, long-term feeding history, stage and presence of brood (Edwards and Abraham 1990, Stein et al. 1990). On the other hand, ants such as the *L. humile* and *T. indicum* did not alternate their preference between food classes (Rust et al. 2000, Chong and Lee 2006). For example, *L. humile* preferred carbohydrate solutions over a 1-year period even when proteinaceous foods were provided (Rust et al. 2000).

The types of toxicants that can be used in liquid and solid baits are determined by the solubility of the toxicants. Aqueous sugar solutions require that toxicants such as boric acid, imidacloprid or thiamethoxam (Rust et al. 2004). Oil-based foods can only be used as baits when incorporated with oil soluble toxicants such as hydramethylnon, methoprene, or pyriproxyfen. Solid protein baits can incorporate toxicants such as fipronil. The anchovy granular bait base is a viable option as a dry proteinaceous bait, because velvety tree ants showed a strong preference for it. To use this food as bait, toxicants that are soluble in oil could be incorporated into the bait. These baits would likely be used to target the larvae and queens.

Foragers typically return to the nest with liquid foods (Klotz et al. 2008), so it has been speculated that liquid baits may be more effective at delivering toxicant to the ants than solid baits (Krushelnycky and Reimer 1998). For an ant bait to be effective it must consist of an attractive food base and a toxicant with delayed action over a range of concentrations (Stringer et al. 1964). However, the definition of delayed toxicity may need some modification to accommodate baits such as proinsecticides (insecticides that are not toxic until they are metabolically activated within the insects body), as well as sweet liquid baits. Proposed modifications consist of the inclusion of the time required to kill 50% of the population within 1 - 4 d (Rust et al. 2004) and concentrations required to kill 50% of the population in 3 - 8 d (Klotz et al. 1997). Taking all this into consideration, a liquid sugar solution would meet the criteria of an attractive food base, and the new modifications account for its properties and the properties of any water soluble toxicant incorporated into it. Sucrose is readily available, relatively inexpensive, and is used in many commercial ant baits with an added toxicant, such as boric acid, making ideal for such a purpose.

The consumption of sugar solutions is also a method of monitoring foraging activity of *L. humile.* Workers imbibe an average of 0.3 mg sugar water per visit, essentially doubling their weight (Reierson et al. 1998). In arid environments, this technique has also been used to estimate foraging activity of *S. invicta* (Greenberg et al. 2004). Even though *L. occidentale* are polymorphic and much larger ant than *L. humile*, they consumed smaller amounts of sucrose solution, 0.258 ± 0.0528 mg ($\bar{X}$ ± SD). Lower consumption may be explained by the possibility that *L. occidentale* do not have expandable crops. This simplifies estimating the number of ant visits to monitoring stations, a methodology that has been reliably used to quantify the efficacy of ant control treatments with Argentine ants (Reierson et al. 1998, Klotz et al. 2000, Suoja et al. 2000).

One benefit of monitoring ant foraging activity with a large quantity of a food left at a location for an extended period of time (hours or days) is that it reflects long-term foraging patterns and does not depend on single momentary observations which may vary greatly with time of day and environmental conditions. This type of monitoring with sugar water vials is a good way to quantify the activity of Argentine ants (Reierson et al. 1998), and perhaps *Liometopum*, as well.

A study by Alder and Silverman (2004) compared 4 sampling methods for Argentine ants: trailing activity, ant counts at baits, sucrose consumption, and pitfall trap collections. Pitfall provided greatest daily variation and was most time consuming. Sampling variation for the other methods was similar. These researchers recommended worker counts at baits because they required the least amount of time to assess. However, this method only samples the ant population at a short time interval and must be conducted when the ants are most active.

Suoja et al. (2000) found that the variation in the number of ants observed based on visual estimates (trail counts) was much lower than those estimated using consumption-based estimates. However, visual counts recorded much fewer ants and had to be extrapolated to estimate daily ant numbers. Nevertheless, these authors concluded that consumption estimates are unreliable. One reason the authors may have seen such variation in ant numbers using consumption-based estimates is that they used a 10% sucrose solution as their bait, which is significantly less attractive to Argentine ants than 25% sucrose solution (Baker et al. 1985, Rust et al. 2000). Relative worker numbers on different foods are not always consistent with actual consumption levels, and researchers should be cautious about sole reliance on worker residence at baits as an indicator of bait performance (Silverman and Roulston 2001).

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