Contract # CDPR 99-0223

DEPARTMENT OF PESTICIDE REGULATION
PEST MANAGEMENT GRANTS FINAL REPORT
(Prepared for the California Department of Pesticide Regulation)

Title: Food Stress Interactions between the Argentine Ant (*Linepithema humile*) and Urban Tree Dwelling Arthropods in Relationship to Structural Invasions

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Acknowledgments

Without the help of a number of people, this project would not have been possible. We would like to thank all of the staff of the Dahlsten laboratory for their help on the project: Dave Rowney, Bill Copper, Steve Suoja, Jenny Loda, Bill Suoja and Andrew Lawson. They provided needed logistic support throughout the project including data collection and field support. Dr. Vernard Lewis provided additional field support to the project through the use of his field technician, Gee Chow. Dr. Matt Orr has been instrumental in providing guidance on experimental design and protocol throughout the project. Dave Rowney provided support for statistical analysis using the Systat 7.0 statistical package for personal computers. Arthur J. Slater, of campus Environmental Services, provided the initial data set on which our basic hypothesis for this work is based. In addition, he provided practical insight and direction on the relationships between Argentine ants and other arthropods found in the urban environment.

This report was submitted in fulfillment of DPR contract 99-0223 *Food Stress Interactions between the Argentine Ant (Linepithema humile) and Urban Tree Dwelling Arthropods in Relationship to Structural Invasions* by the University of California under the sponsorship of the California Department of Pesticide Regulation. Work was completed as of February 28th, 2001.

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Introduction

The Argentine ant, *Linepithema humile* (Mayer) was first introduced from Brazil or Argentina into the United States in ca. 1891 and into California in ca. 1905 (Baker *et. al.* 1985). According to Knight and Rust (1990), this ant is the most widespread pest in populated areas of California with a host range that extends from the Mexican border north to Humboldt County and east to the Sierra Nevada mountain range. Colonies of *L. humile* are predominant between the months of May and November, but can be found throughout the year in the San Francisco Bay Area. Their colonies are polygynous (multiple queens) and largely interconnected (polydomous) with no hostility between adjacent colonies (Silverman and Nsimba 2000). Foraging by Argentine ants is temperature-dependant as well as seasonal in nature (Human *et. al.* 1998, Markin 1970). Ants will not forage under extremes of hot or cold and are influenced by fluctuating weather patterns. Throughout the United States, this ant is ranked first among insect pests found in the urban environment where it occurs. Argentine ants commonly invade structures within the urban environment. As a result of this behavior, there is an increased potential for human exposure and environmental contamination from increased pesticide use.

There are several hypotheses describing why Argentine ants invade structures:

- Environmental factors (rainfall, temperature, etc) may drive the ants into structures.
- Food stresses caused by a seasonal reduction in honeydew-producing arthropods may force the ant to forage in structures for alternative food sources.
- A combination of environmental and biological factors.
- Ant invasions are simply a result of random foraging and not related to either environmental or extrinsic biological factors.

The negative influence Argentine ants have on the biological control of arthropods in agricultural settings is well documented (Markin 1970, Way 1963, Bartlett 1961, Flanders 1958, Nixon 1951). In addition to work in agricultural systems, a limited body of work has been done in natural settings. For example, Ward (1987) examined population dynamics and distribution in natural habitats around the University of California at Davis, CA. But, the population dynamics and tropic interactions between Argentine ants and their food sources within urban environments are poorly understood. The concept of Integrated Pest Management (IPM) is based on a thorough understanding of the system and the biology of the pest species.

We have proposed that the best way to control Argentine ants is to solve some of the basic ecological questions still surrounding this species. Our desire was to determine how ant populations increase in the urban environment, with the goal of using the underlying ecological patterns of food stresses (biological and environmental) to develop effective IPM strategies. The overall objectives for this study were:

1.) To determine relationships between food sources, environmental conditions, and home invasions of Argentine ants by surveying trees for honeydew-producing arthropods used by Argentine ants, determining phenology of major honeydew-producing arthropods and their natural enemy complexes.

2.) To develop and refine sampling methods (bole and trail counts, pitfall traps, monitored bait stations, and visual site surveys) for determining population densities and distributions of Argentine ants in urban environments.

3.) To develop and evaluate IPM control strategies for Argentine ants in urban environments.

   a. using natural enemies to control honeydew-producers.
   b. using landscape plantings.
   c. using ant exclusion and baiting technology - including evaluations of bait types (proteinaceous or sucrose), seasonal timing, and placement of insecticidal baits.

Materials and Methods

Objective 1.) To determine relationships between food sources, environmental conditions, and home invasions of Argentine ants.

The Alameda County site (UAV) was used to develop and refine honeydew-sampling methods. The 58-acre UAV site has 564 apartments in 61 structures. The apartment buildings on site are designed with inner quads and are surrounded by an irrigated mature landscape (lawn and trees). There are | 700 trees with six major species: one Eucalyptus: Ironbark (*Eucalyptus sideroxylon* (A.Cunn.)); one pine, Monterey pine (*Pinus radiata* (D. Don), one sycamore, London plane tree (*Platanus x acerifolia* (Willd.)); one acacia, Blackwood acacia (*Acacia melanoxylon* (R.Br.)); one cedar, (*Cedrus deodara* (G.Don)); and one elm, Chinese elm (*Ulmus parvifolia* (Jacq.)). Each individual tree on the site has been uniquely numbered. Three of the six major species on the Albany Village site have been selected for bi-weekly monitoring of honeydew production by tree dwelling arthropods: Monterey pine, London planetree, and the Chinese elm. Selection of tree species used for honeydew sampling was based on the complaint database and proximity to the apartment buildings on the site. A total of 41 trees were used for honeydew monitoring (14 Monterey pine, 14 London plane tree, and 13 Chinese elm) on the Albany Village site. All trees were selected at random from on-site populations for each species. Honeydew monitoring was done using yellow water sensitive insecticide spray droplet monitoring cards (7.6 x 5.2 cm cards) on which honeydew produces distinct blue dots. Four cards were placed | 60 cm below terminal branches using a wire hanger in each cardinal direction. The cards were deployed from 10:00 a.m. to 2:00 p.m. every other week during the growing season for Plane trees and during the entire season for elms. On Monterey pine, the monitoring cards were placed | 60 cm from the growth tips of branches using a permanently mounted pulley system. Cards on Monterey pine were deployed starting August 31 though December 1, 2000. On several dates, some of the honeydew cards showed exceptionally high spotting. We believe this to be caused by lawn sprinklers in the area and not honeydew production. For this reason, all values greater than three dots/cm^2 were excluded from the analysis.

To relate honeydew (food source) to ant populations within the trees, each of the trees monitored for honeydew was also monitored for foraging ants using bole counting of trailing ants. The number of ant trails on a given tree was determined before counting, as well as, the cardinal direction (N, S, E, W) of each trail. The total time spent counting ant trails on any one tree was 20 minutes (if the total ant trail number was 4 or less, each trail was counted for five minutes; if ant trail numbers were 5 or greater then each trail was counted for the number of minutes necessary to equal 20 minutes total, e. g. 10 trails at 2 min. each = 20 min. Temperature and humidity were recorded at several tree locations. Bole counting of trailing ants was taken during the period from 10:00 am to 2:00 pm. Trees that had no ant trails were excluded from the analysis. We used the square-root transform on both honeydew and trailing ant values to get distributions closer to normal.

Objective 2.) To develop and refine sampling methods for determining population densities and distributions of Argentine ants in urban environments.

Selected trees from the major tree species on the site were monitored for seasonal changes in trailing ant populations via bole counting on a monthly basis. Foraging ant populations were monitored using bole counting of trailing ants on ten species of trees: Black Acacia (*A. melanoxylon*), white alder (*Alnus rhombifolia* (Nutt.), California buckeye *Aesculus californica* (Nutt.), deodar cedar (*C. deodara*), Chinese elm (*U. parvifolia)*, Ironbark eucalyptus (*E. sideroxylon*), liquidambar (*Liquidambar styraciflua* (L.)), Lombardy poplar (*Populus nigra 'Italica'* (L.)), Monterey pine (*P. radiata*), and London plane tree *(Platanus x acerifolia)* at the University of California Student housing facility (UVA) in Albany, California. There were a total of 40 trees used for monthly ant population monitoring. The number of ant trails on a given tree was determined before counting, as well as, the cardinal (N, S, E, W, SW, SE, NW, and NE) direction of each trail The total time spent counting ant trails on any one tree was 20 minutes (if the total ant trail number was 4 or less, each trail was counted for five minutes; if ant trail numbers were 5 or greater then each trail was counted for the number of minutes necessary to equal 20 minutes total, e. g. 10 trails at 2 min. each = 20 min. Temperature and humidity were recorded at several tree locations. Results from the 1999-2000 season showed that ant trails in the morning were not significantly different from trails in the afternoon, therefore bole counting was taken only once daily (a.m. or p.m.) for a given tree on a given day. Table 1. indicates the trees species, common name, and number of each species selected for surveying. In any given tree species, a maximum of six trees was selected for bole counting of trailing ants and in two species (*A. californica* and *A. rhombifolia*) only one tree was used for bole counting of trailing ants. The number trees present on the site limited the number of trees selected for bole counting in a given species.

Objective 3.) To develop and evaluate IPM control strategies for Argentine ants in urban environments.

No IPM control strategies for Argentine ants were developed or evaluated during this phase of the project.

Results

Objective 1.) To determine relationships between food sources, environmental conditions, and home invasions of Argentine ants.

Honeydew on each of the three tree species increased over the summer months, however, the amount of honeydew/cm^2 was much lower on the London plane trees than on the pines or the elms (Fig. 1, Fig. 2, and Fig. 3). The number of ants observed on the bole counts also increased on each tree species over the summer months. The ant counts on London planes and pines were similar, but considerably less than on Chinese elm (Fig. 1, Fig. 2, and Fig. 3). For each tree species, the highest ant counts were recorded in mid September. Repeated measures analysis of variance found no effect of direction for either honeydew or ants, but both were affected by date (linear, quadratic effects).

There is a positive correlation between foraging ants and honeydew production in Chinese elms (R^2 adj. = 0.3) (Fig 4) with a slightly weaker positive correlation in Monterey pine (R^2 adj. = 0.22) (Fig 5) and a weak positive correlation in London plane (R^2 adj. = 0.028) (Fig 6).

Objective 2.) To develop and refine sampling methods for determining population densities and distributions of Argentine ants in urban environments.

Ant populations were monitored using bole counting of trailing ants on 10 species of trees. Four species showed peaks of ant trails in June (blackwood acacia, Lombardi poplar, ironbark eucalyptus and plane tree), while five species showed peaks in August and September (California buckeye, deodor cedar, liquidambar, Monterey pine and Chinese elm). White alder had two low peaks in May and September. Ant counts were highest on cedar, followed by buckeye, acacia and Monterey pine. Since 1999, several of the selected trees in each species have been remove from the site. The monthly counts clearly show seasonality in the feeding behavior of Argentine ants.

Objective 3.) To develop and evaluate IPM control strategies for Argentine ants in urban environments.

No results were obtained on this objective during this period on the project.

Discussion

This study lays the groundwork for testing the hypothesis that Argentine ant are invading houses in response to food stress caused by seasonal changes in tree-dwelling arthropods. During preliminary samples taken in 1998, the Chinese elms were found to be infested with a soft scale, *Gossyparia spuria*(Modeer). This scale is well known for producing copious amounts of honeydew during the summer and early fall. Our results for Chinese elms showed a positive correlation (r^2 adj. = 0.3) between foraging ants and honeydew production in Chinese elms. Some of the sample trees showed higher levels of honeydew production with lower levels of trailing ants, which suggests that ants might be using alternative pathways to and from the honeydew sources in some cases. These alternative pathways might include buildings or adjacent trees, which would cause trailing ant numbers to be underestimated on sample trees.

Results for Monterey pine show a weaker correlation ($r^2 = 0.22$) with ant counts. This correlation might improve when additional data is collected throughout a complete season. The honeydew data for August 31st was high on several trees in the north and south directions. This could be related to sprinkler drift from the adjacent sports grounds. The Monterey pines are infested with the irregular pine scale, *Toumeyella insignicola* (Ferris). The landscape surrounding building complexes with the largest number of ant complaints are heavily planted with small groves or rows of Monterey pines.

Results for London plane trees show a very weak correlation ($r^2 = 0.028$) with ant counts. Ant numbers did not correlate very well with honeydew production in London plane trees. However, there maybe several reasons for the weak correlation. Even though ant counts on London planes increased in September by | 100%, the foliage on the plane trees becomes heavily infected with powdery mildew by early September. This may have affected homopteran populations late in the season. Also in the London plane trees, ants may be feeding on/tending insects found within the nodules on the pollarded trees. Ants were seen trailing on plane trees in January during monthly counts when there is no foliage present on the trees. The current placement of the honeydew cards would not have allowed for measurement of honeydew produced from insects within these nodules. Placement of the honeydew collecting within the canopy may have affected our results. A preliminary sampling of foliage showed significantly more homopterans in the upper crown vs. the lower crown. The placement of the cards in the lower canopy may have underestimated the amount of honeydew produced in the overall canopy.

All three species of sample trees had some variation in honeydew production within species. This may be due to a patchy distribution of homopteran populations, or possibly related to factors such as temperature, wind effects, and watering regimes. Some of the sample trees are sheltered from exposure to wind and direct sun exposure that could indirectly affect arthropods producing honeydew via frost dieback and solarization. Some sample trees were watered on a regular schedule while other trees were only watered intermittently. Additionally, ant trailing on all species of trees appears to precede any marked increases in honeydew production in the early spring. Homopteran populations could be very low in the early spring and may require sometime before populations reach a critical mass where honeydew production exceeds the capacity of the Argentine ant to consume it. Ant numbers in the Chinese elms increased between February and March 2001 by 1.4 fold while honeydew increased by 3.8 fold. However during the following month, ant numbers increased by eight fold while honeydew production only doubled. The London plane trees had similar type increases but with reduced numbers. Argentine ants are also known to protect food sources from natural enemies and lags between protection and parasitism in late fall and winter might account for some of these discrepancies in the early spring months that appear to be evident in Figures 1, 2, and 3.

The species complex of arthropods feeding on trees are known to be different for any given tree species. For example, aphid lifecycles can be very complex with several morphological changes within a species. Many aphid species have primary and secondary hosts and in some cases, their taxonomic identification is based on the host tree species. In addition, the differential relationships of trailing ants to honeydew production for our selected species of tree may be due to differences in the quality of honeydew produced. Studies have reported that difference in honeydew quality can affect the growth and abundance of epiphytic microorganism, beneficial and incidental arthropods (James *et. al.* 1999, Moya-Raygoza and Nault 2000, Stadler and Muller 2000), and foraging preferences of certain ant species (Kaakeh and Dutcher 1992).

The seasonal changes in the number of trailing ants on common landscape tree species could be used to increase the effectiveness obtained with currently available ant baits. Control of homopterans early in the season is important to reducing pesticide use. The homopterans could be controlled with very limited applications of a systemic insecticide such as imidacloprid. They could also be controlled using cultural techniques such as limiting the access of the ants to the honeydew sources. Products like Tanglefoot or Stickem around the base of smooth barked trees will limit access to honeydew sources. Rough barked trees could be banded with a rope impregnated with certain semiochemicals. Sisk *et. al.* (1996) showed that Argentine ants foraging could be disrupted using compounds like farnesol . Natural sources of carbohydrates such as honeydew can have negative effects on ant baiting via competition and through early trail establishment on trees with honeydew producing arthropods. Ants trailing to a natural source would be less likely to shift to a bait material because of strong trail following pheromones. In addition, Argentine ants preferentially feed on carbohydrate or proteins depending on the time of year. This preferential feeding could be used to effectively reduce pesticide use. Protein based baits should be used early in the season prior to the establishment of trailing on landscape trees. Carbohydrate based baits should be used in late spring and the summer. However, Argentine ants continue to include protein sources in their diets throughout the summer months (Markin 1970). Throughout the duration of this study, Argentine ants were observed carrying other arthropods down the trunks of trees. This can be interpreted as perhaps seeding new trees with honeydew producing arthropods in the early spring or as sources of protein for use by the colony. Good results with any baiting material is dependant on controlling "natural" food sources.

Summary and Conclusions

Ant counts on Chinese elm, Monterey pine, and London plane peaked in mid-September. There was a significant positive correlation between ant counts and honeydew for Chinese elm and Monterey pine, while only a weak positive correlation for London plane. The lack of a strong relationship in London plane may be due to placement of the honeydew cards or possibly a preference by the ants for honeydew of a certain quality. Ants counted on ten species of tree throughout the year showed ant counts peaked in June for four species while five species peaked in August and September. These differences in seasonal peaks for trailing ants could be related to seasonal changes in the lifecycles of the arthropods producing the honeydew.

This study lays the groundwork for testing the hypothesis that Argentine ant are invading houses in response to food stress caused by seasonal changes in tree-dwelling arthropods. Results from this study showed a positive correlation between honeydew production and trailing ants on landscape trees. These seasonal changes in the number of trailing ants on common landscape tree species could be used to increase the effectiveness obtained with currently available ant baits.

Future studies will include ant exclusion trials and monitoring of adult arthropods via sticky traps and foliage sampling. Ant population monitoring will be conducted to determine population densities and distributions of Argentine ants. The information gained from this and future studies may help to reduce the levels of insecticides used for Argentine ant within the urban environment. However, by correctly timing ant baiting and through the elimination of natural food sources such as honeydew, we believe that the levels of pesticides currently used for the control of Argentine ants could be reduced without additional research being required.

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Appendices

Table 1. Number of Trees at Albany Village Site Selected for Bole Counting of Argentine Ant (*Linepithema humile*) Populations [*].

Common Names [a]	Scientific Name [b]	Number of Trees Selected [c]
Blackwood acacia	*Acacia melanoxylon*	3
White alder	*Alnus rhombifolia*	1
California buckeye	*Aesculus californica*	1
Deodar cedar	*Cedrus deodara*	3
Chinese elm	*Ulmus parvifolia*	6
Ironbark eucalyptus	*Eucalyptus sideroxylon*	6
Liquid amber	*Liquidambar styraciflua*	4
Lombardy poplar	*Populus nigra 'Italica'*	4
Monterey pine	*Pinus radiata*	6
Plane tree	*Platanus x acerifolia*	6

[*] Trees were randomly selected from the overall population of trees with trailing ants at the University of California Student's housing facility (UVA) in Albany, CA.

[a] Common names of trees are based on the Sunset Western Garden Book.

[b] Tree species were identified by Dr. Joe McBride at the University of California, Berkeley.

[c] The Number of trees in each species selected for bole counting was base on the overall number of that species of tree on the Albany Village site with six trees being the maximum number.

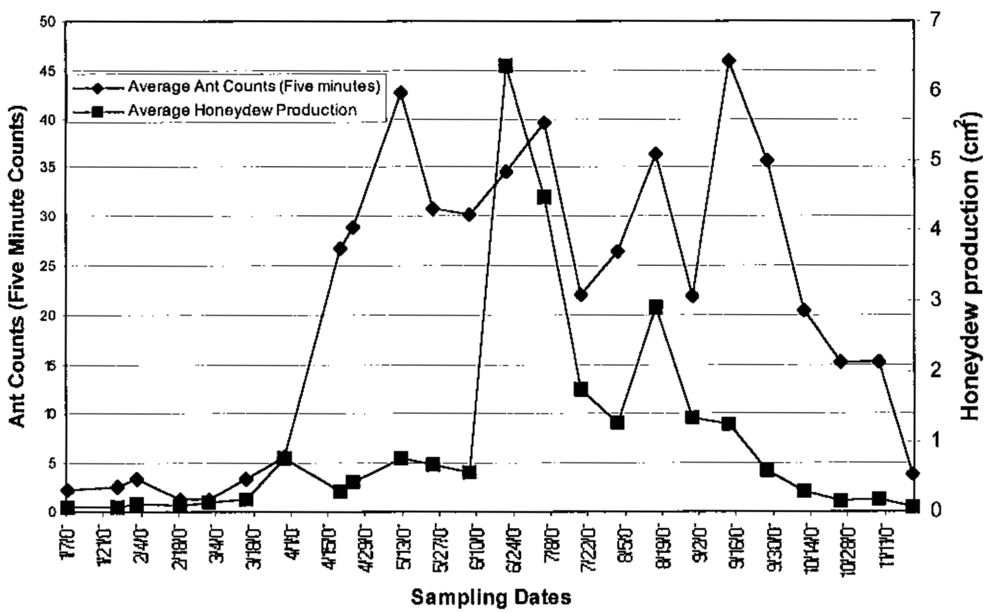

Figure 1. Average Honeydew Production and Ant Counts on Selected Dates for *Ulmus parvifolia* at the University of California Student Housing Facility (UVA) in Albany, California.

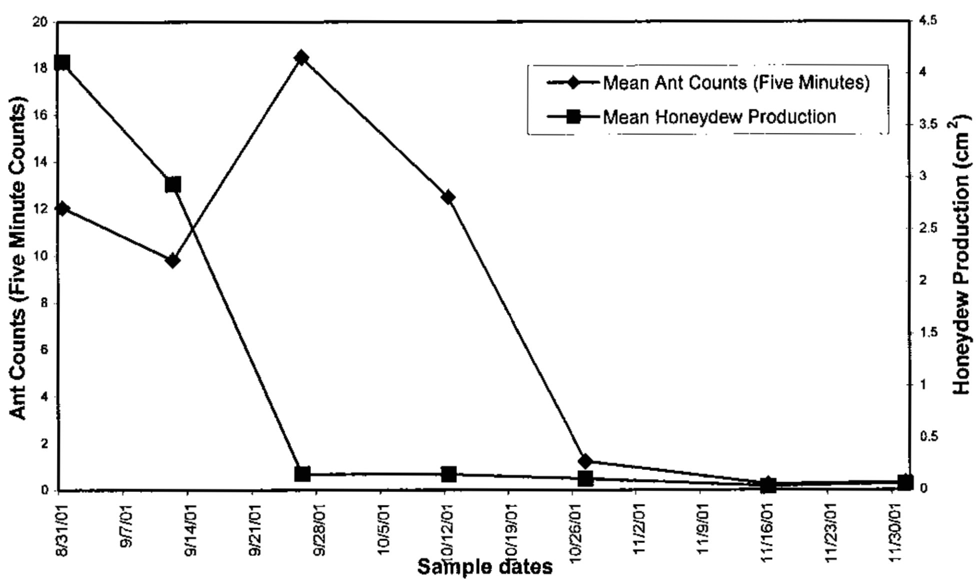

Figure 2. Average Honeydew Production and Ant Counts on Selected Dates for *Pinus radiata* at the University of California Student Housing Facility (UVA) in Albany,California.

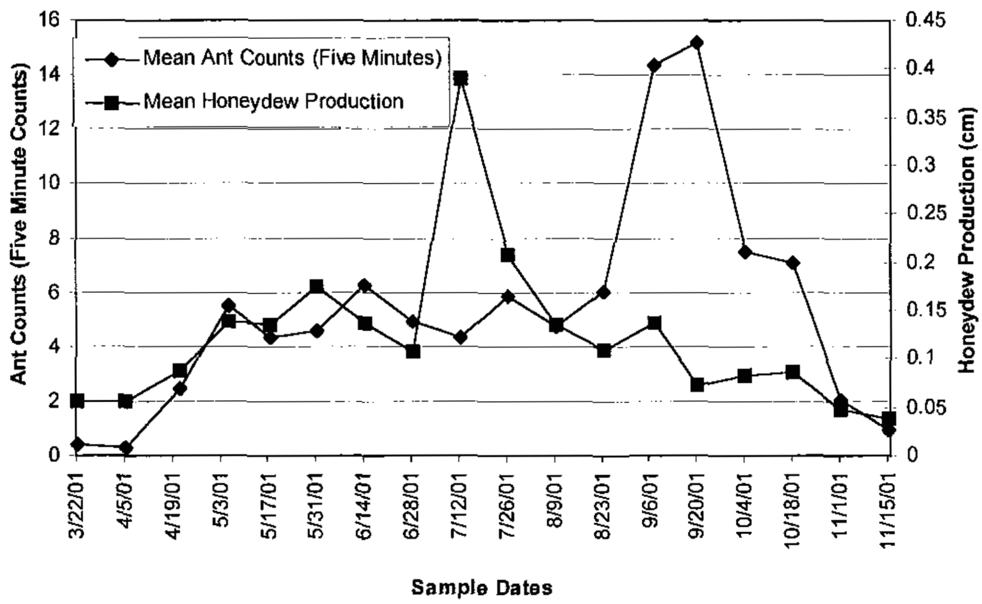

Figure 3. Average Honeydew Prodution and Ant Counts on Selected Dates for *Platanus x acerifolia* at the University of California Student Housing Facility (UVA) in Albany, California.

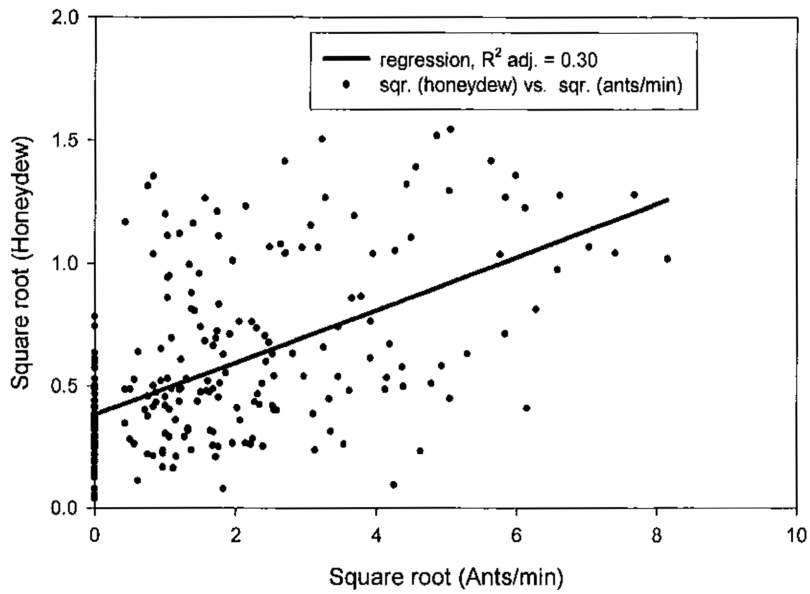

Figure 4. Honeydew vs ants per min (both with square root conv.) traveling down trunks of Chinese elms (*Ulmus parvifolia*) from late winter to fall 2000 in Albany Village, Albany, California.

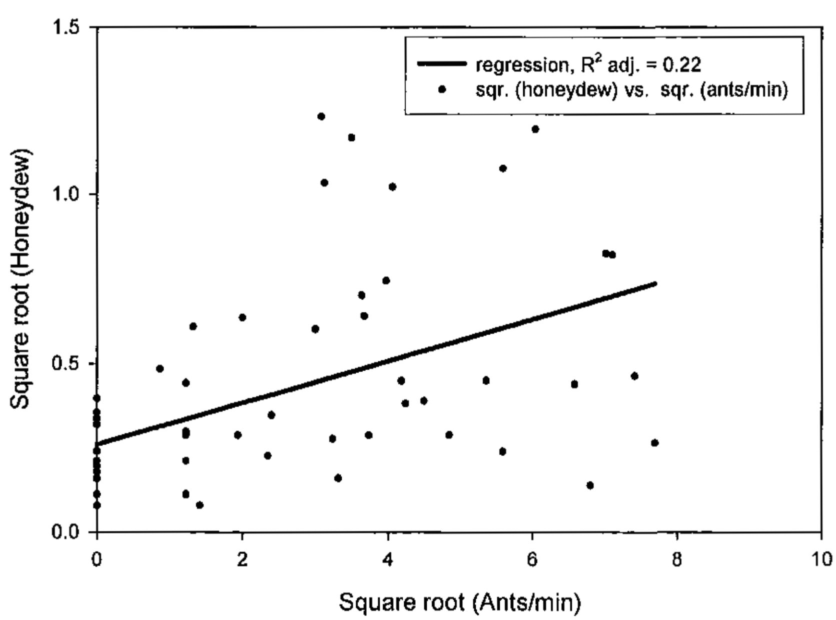

Figure 5. Honeydew vs ants per min (both with square root conv.) traveling down trunks of Monterey pines (*Pinus radiata*) from mid-summer to fall 2000 in Albany Village, Albany, California.

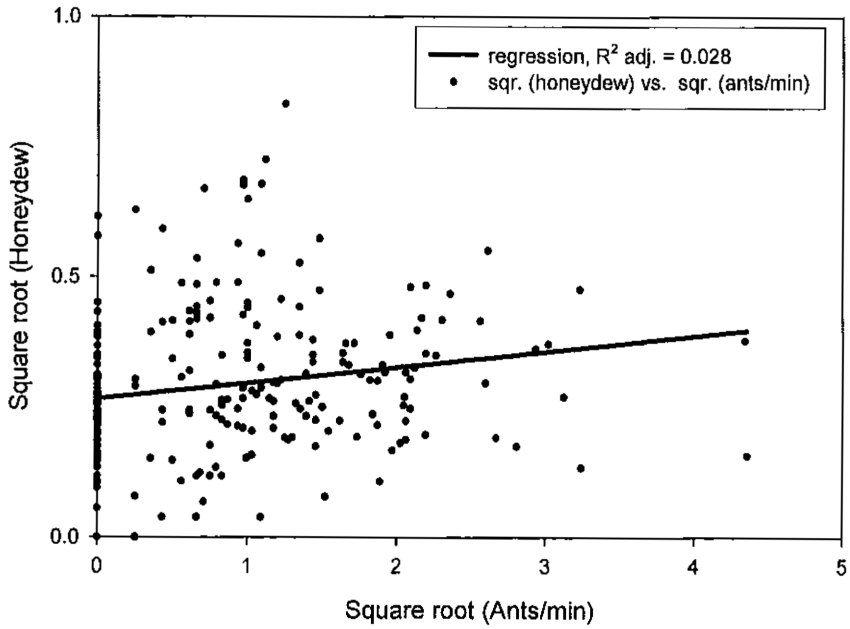

Figure 6. Honeydew vs ants per min (both with square root conv.) traveling down trunks of plane trees (*Platanus x acerifolia*) from late winter to fall 2000 in Albany Village, Albany, California.

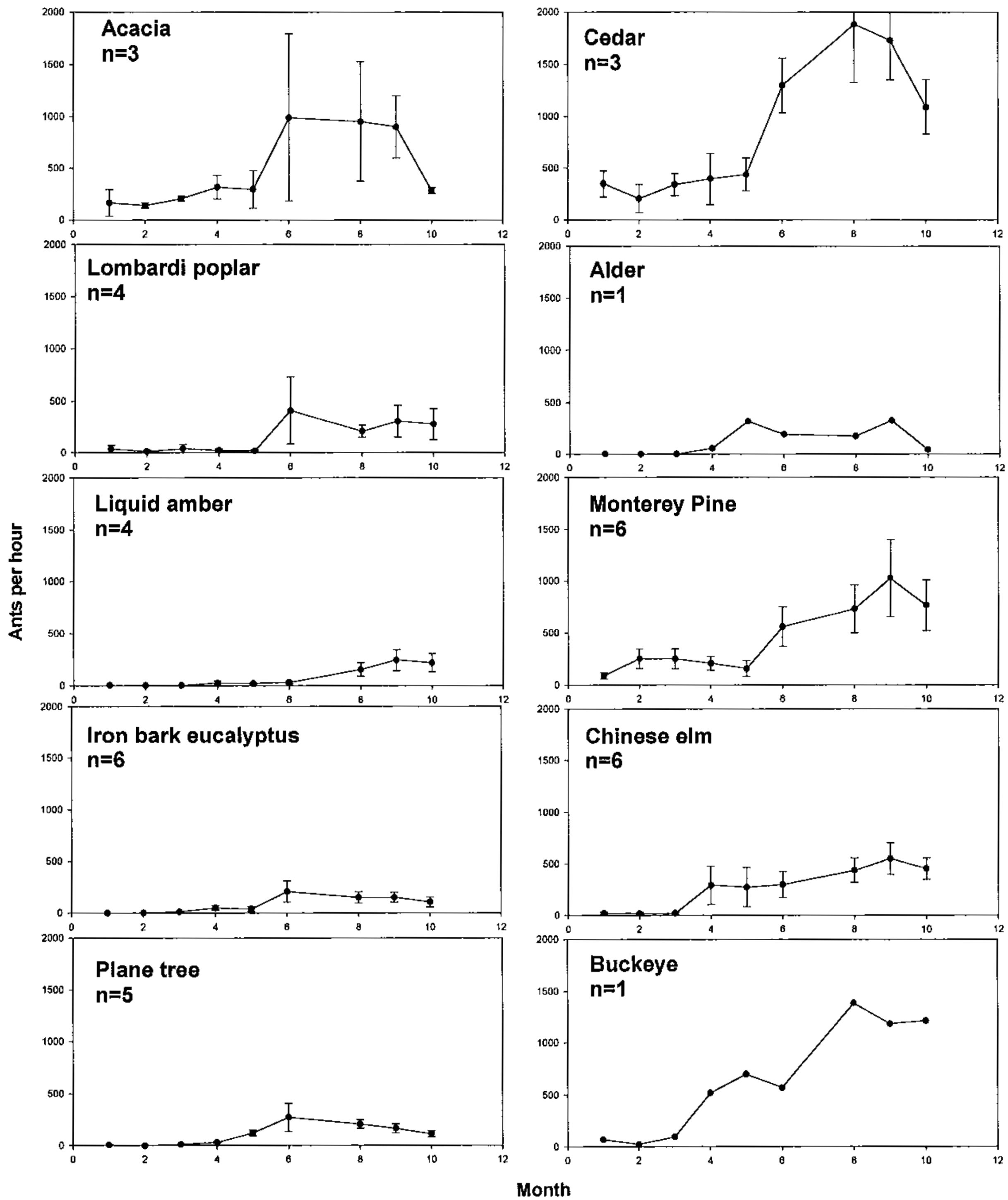

Figure 7. Mean ants per hour (± std. error) traveling down trunks of eight tree species in Albany Village, Albany, California by month in 2000.