

**Winter Activity for Crapemyrtle Bark Scale, an Urban Landscape Pest**

**Erika R. Wright**  
Department of Biochemistry, Molecular Biology, Entomology, and Plant Pathology, Mississippi State University, Mississippi State, MS 39762, USA; and Department of Entomology, The Ohio State University, Columbus, OH 43210, USA

**Kevin D. Chase**  
The R.A. Bartlett Tree Research Lab, Cutbush Lane East, Shinfield, Reading, Berkshire RG2 9AF, United Kingdom

**Caitlin Littlejohn and Amber Stiller**  
Bartlett Tree Research Laboratory, Charlotte, NC 28278, USA

**Samuel F. Ward**  
Department of Entomology, The Ohio State University, Columbus, OH 43210, USA

**Keywords.** crawler, dispersal, emergence, population ecology, scale insect, winter

**Abstract.** Scale insects are some of the most abundant and damaging pests of urban forests in North America. Despite their prevalence, scale insect emergence during the winter dormant season, which could contribute to their population growth and spread and thereby inform management, has not been thoroughly investigated. Crapemyrtle bark scale (CMBS), Acanthococcus lagerstroemiae (Kuwana) (Hemiptera: Eriococcidae), is a nonnative pest of a widely grown landscape tree, crapemyrtle (Lagerstroemia spp.). Now present throughout the Southeast and Mid-Atlantic regions of the United States, CMBS has spread rapidly since its initial detection in Plano, TX, USA, in 2004. The contributions of year-round activity to the insect’s widespread abundance and economic importance are unclear. Here, after infesting crapemyrtles with known numbers of CMBS in Summer 2021, we recorded the presence or absence of CMBS immatures on infested trees from Autumn 2021 to late Winter 2022. We found that active nymphs occurred throughout the entirety of these colder seasons. Additionally, average CMBS density drastically increased from October to March, growing from 28 ± 10 SE insects per plant to 554 ± 133 SE, respectively. Our results highlight previously unknown aspects of year-round crawler emergence by CMBS, which could provide opportunities for landscape managers to use targeted winter applications of less harmful pesticides such as horticultural oils.

In urban forests throughout North America, scale insects are some of the most abundant pests damaging landscape trees (Frank 2019). Crapemyrtle bark scale (CMBS), Acanthococcus lagerstroemiae (Kuwana) (Hemiptera: Eriococcidae), is a nonnative, sap-feeding insect originally from Asia that has severely damaged a popular landscape tree, crapemyrtle (Lagerstroemia spp.), across at least 15 states in the Southeast and Mid-Atlantic regions of the United States (Wang et al. 2016). Since its initial detection in a nursery in Plano, TX, USA, in 2004, CMBS has reduced the aesthetic value and overall health of crapemyrtles in several urban centers by feeding on phloem, leading to colonization by sooty mold, a group of plant fungi commonly in the Ascomycota phylum that feed on the sugary excretions, or honeydew, produced by CMBS on infested trees (Wang et al. 2016; Windbiel-Rojas and Messenger-Sikes 2020).

The primary host tree of CMBS, crapemyrtle, is valued for its hardness, ornamental flowers and bark, and resistance to pests and diseases (Chappell et al. 2012). With an estimated wholesale value of more than $85 million (US Department of Agriculture, National Agricultural Statistics Service 2019) coupled with the costs of insecticide applications for CMBS management (Layton et al. 2022), CMBS is a cause of economic concern. This pest also poses environmental concerns because it has been observed completing its life cycle on native plants such as American beautyberry (Callicarpa americana L.) and St. John’s wort (Hypericum kalmanii L.) in the field and Rubus spp. such as blackberries in feeding trials (Wang et al. 2019a). It has also been found to complete its life cycle on cultivated species like pomegranate (Punica granatum L.) and Chinese hackberry (Celtis sinensis P.) in feeding trials (Wang et al. 2019a) and spirea (Spiraea spp. L.) in the field (Xie et al. 2021). Due to the increased number of hosts that CMBS can feed on in North America, the concern for increased damage to native species such as American beautyberry is significant.

Management of CMBS is challenging due to its cryptic life history consisting of life stages that are minute in size. Male and female CMBS emerge from eggs as tiny mobile crawlers, hereafter referred to as “active crawlers,” after which they settle to molt and begin feeding. Males eventually develop wings, whereas females remain wingless (Wang et al. 2019a). Depending on the region, CMBS may have two to four generations per year with increased voltinism at warmer latitudes (Gu et al. 2014). As a multivoltine species with females that produce 114 to 320 eggs per ovisac (Wang et al. 2016), this pest exhibits a high potential for rapid population growth.

Crapemyrtle bark scale is thought to overwinter primarily in the settled crawler stage (Wang et al. 2019b, 2019c), but ovisac development, egg hatch, and associated crawler activity in the field during plant dormancy have not yet been evaluated. Our study objective was to characterize activity of CMBS crawlers, such as when they are crawling, during autumn and winter and define the roles of temperature and heat accumulation. Understanding crawler activities in winter will provide guidance for winter management of CMBS, encouraging timely pesticide applications when scale numbers may be lower than in spring and summer; in turn, this could help reduce the likelihood of populations increasing to damaging densities in the following spring or moving between plants in nursery settings. This work also contributes to a broader understanding of the winter biology of scale insects, elucidating the potential for winter population growth and spread.

**Materials and Methods**

In Summer 2021, we collected CMBS populations from urban trees in Charlotte, NC, USA, by cutting twigs from infested crapemyrtle branches. We zip tied twigs with zero, one, two, three, or four settled CMBS crawlers onto upper branches of Lagerstroemia indica × 'Natchez' saplings planted in 26.5-L pots (crapemyrtle; n = 34, ~0.6 m in height). A microscope was used to determine that the proper number of crawlers remained on each twig fragment after copper scrubbings (Chore Boy®) were used to scrape away excess scales on the twigs. Care was taken to ensure that nonmoving settled crawlers were used for artificial infestation, but exact instars were not determined. Twigs were zip-tied to the upper portion of plants so that twigs were nearly flush.
with the branch to which they were attached. Infested plants were then placed into a field at the Bartlett Tree Research Laboratory in Charlotte, NC, USA (35.078820, −81.005866; USDA Hardiness Zone 8a) in a grid formation with 2 m of space between each plant. Plants were not pruned or maintained to be in any particular shape and were allowed to grow freely within the pots; thus, multiple branches developed on all plants. The presence of active crawlers (i.e., first or second instar mobile nymphs) on each tree was recorded through visual observation of the whole tree, and crawlers were considered active if there was at least one moving crawler on a given tree (0 = no active crawlers on the tree, 1 = at least one active crawler on the tree); counts of crawlers were not performed. Crawlers were not disturbed and were only observed with the naked eye; hand lenses were not required to see crawlers. Crawler activity, or the presence of active crawlers, was recorded weekly from Nov 2021 until early Mar 2022 for a total of 14 sampling dates. Maximum and minimum daily temperatures were extracted from a Davis EnviroMonitor® weather station (Hayward, CA, USA) ~0.3 km away from the study site and paired with crawler data to observe potential relationships between temperature and crawler activity.

Additionally, the total number of intact, undisturbed female ovisacs, male cocoons, and settled crawlers per plant was recorded at the end of Oct 2021 and at the beginning of Mar 2022; destructive sampling of all plants was done in Mar 2022. Destructive sampling consisted of removing plants from pots and cutting branches from the main stem. Through counts of all individuals of each life stage of CMBS present were then performed, excluding counts of active crawlers. The number of individuals of these life stages were summed as a per plant metric of CMBS density. The difference in per plant densities between October and March were then compared as a metric of CMBS population change arising from winter activity. The number of individuals of each life stage per plant in October and March are also shown graphically. Densities of each life stage in October and March are displayed graphically. Densities were transformed to ensure modeling assumptions of normality and homogeneity of variances were met. Data supporting results are available on Zenodo (Wright et al. 2023).

Results

Observing CMBS crawler activity throughout autumn and winter revealed a statistically clear increase in crawler activity with higher degree-day accumulation, and densities of CMBS suggest that population growth can occur throughout winter. Crawlers were found on at least one plant during every sampling period, even when daily minimum temperatures reached as low as −3.3°C. There remain some key unknowns, however, as we did not differentiate between hatching of new crawlers from eggs (i.e., physiological development) vs. resumption of activity by crawlers that had hatched previously, both of which could have contributed to increased as daily maximum temperature increased, with 17%, 19%, and 21% of trees having active crawlers when maximum temperatures reached 10°C, 15°C, and 20°C, respectively (Fig. 2A). However, accumulation of degree days between successive sample days did have a statistically significant effect on crawler activity ($X^2 = 4.45, P = 0.0349; Fig. 2B$), with an increase in per plant crawler activity as accumulated degree days increased. For example, according to our model, 10 growing degree days were associated with 16% of plants having activity whereas 50 growing degree days were associated with 31% activity on the ensuing sample day (Fig. 2B). In total, 263 growing degree days were accumulated during the study period between late October and early March.

Densities of CMBS significantly increased between October and March, growing from 28 ± 10 scale insects in October to 554 ± 133 in March (Fig. 3; $t_{15} = 10.95, P < 0.0001$). Three plants with CMBS populations in October fell to zero by March (Fig. 3). Additionally, two plants had CMBS populations that grew between October and March but never had observed active crawlers during winter.

Discussion

Throughout the study period, the lowest temperature recorded was −3.3°C and the highest was 22.2°C, with 32% of plants having active crawlers on the coldest day and 44% on the warmest day (Fig. 1). The lowest percentage of individual plants with crawlers was 3%, observed on a day with a maximum temperature of 15.6°C and a minimum temperature of 0.0°C (Fig. 1). There was no statistically clear effect of daily maximum temperature on crawler activity ($X^2 = 1.00, P = 0.31; Fig. 2A$). Despite a lack of statistical significance, crawler activity generally increased as daily maximum temperature increased, with 17%, 19%, and 21% of trees having active crawlers when maximum temperatures reached 10°C, 15°C, and 20°C, respectively (Fig. 2A). However, accumulation of degree days between successive sample days did have a statistically significant effect on crawler activity ($X^2 = 4.45, P = 0.0349; Fig. 2B$), with an increase in per plant crawler activity as accumulated degree days increased. For example, according to our model, 10 growing degree days were associated with 16% of plants having activity whereas 50 growing degree days were associated with 31% activity on the ensuing sample day (Fig. 2B). In total, 263 growing degree days were accumulated during the study period between late October and early March.

Densities of CMBS significantly increased between October and March, growing from 28 ± 10 scale insects in October to 554 ± 133 in March (Fig. 3; $t_{15} = 10.95, P < 0.0001$). Three plants with CMBS populations in October fell to zero by March (Fig. 3). Additionally, two plants had CMBS populations that grew between October and March but never had observed active crawlers during winter.
activity. Resumption of activity could have been a function of chill coma recovery (MacMillan and Sinclair 2011), for example, if crawlers emerged from sheltered areas such as bark crevices when temperatures warmed above a given threshold. Likewise, a portion of active bark crevices when temperatures warmed above crawlers emerged from sheltered areas such as Millan and Sinclair 2011), for example, if been a function of chill coma recovery (Mac-
activity. Resumption of activity could have
Fig. 2. (A) Predicted proportions of crapemyrtle plants with crapemyrtle bark scale (CMBS) crawlers between Nov 2021 and Mar 2022 based on daily maximum temperatures ($\chi^2 = 1.00, P = 0.31$). (B) Predicted proportion of crapemyrtle plants with active CMBS crawlers between Nov 2021 and Mar 2022 in response to degree days (DD) accumulated since the previous sample day ($\chi^2 = 4.45, P = 0.0349$).

CMBS October and March, while dots represent mean densities of CMBS October and March, which had already hatched when they were counted in autumn. Because these plants also had only oviparous in autumn and no settled crawlers or male cocoons, the potential that the oviviscs present in autumn are more difficult to detect than high densities. For the Figure 3. Changes in the density (ln-transformed) of crapemyrtle bark scale (CMBS) on crapemyrtle plants between October and March ($t_{18} = 10.95, P < 0.0001$). Bars represent mean densities of CMBS October and March, while dots represent per plant densities of CMBS. Lines connecting the dots represent the change in CMBS densities on individual plants between October and March, providing insight into the potential for winter population growth. For plants that had the same densities and the same change in densities between October and March, there may be multiple plants represented by the same dot and line.

tation suggests that insect development, rather than solely behavioral responses to warm temperatures (i.e., resumption of activity beyond a temperature threshold), drove winter activity. CMBS is thought primarily to overwinter as settled crawlers (Wang et al. 2019b, 2019c). However, given that CMBS can produce multiple overlapping generations per year (Gu et al. 2014), it is likely that various life stages of CMBS, including mature oviviscs, were present in high densities on study trees at the start of autumn. It appears that winter degree-day accumulation fostered development of these life stages and resulted in crawler emergence throughout winter. Crawlers necessarily move for a short period after hatching from eggs to find feeding sites; however, the absence of crawlers does not indicate that development was entirely arrested because other life stages could have still been developing. There were two infested plants that did not have active crawlers at any point during winter; however, in October, they harbored four and 17 individual CMBS, respectively and had settled crawlers in March. This finding may indicate that some CMBS individuals go dormant for the entirety of winter and resume development early the following spring or that our sampling failed to detect some active crawlers; we assume the latter mechanism is highly likely, given the minute size and sometimes cryptic coloration of active crawlers coupled with low scale densities in October, with low densities of crawlers being more difficult to detect than high densities. For the three plants that harbored CMBS populations in autumn but subsequently reduced to zero scale insects in March, it is possible that these populations had a lower survival rate throughout winter due to their low initial population densities in autumn. Because these plants also had only oviviscs present in autumn and no settled crawlers or male cocoons, the potential that the oviviscs had already hatched when they were counted in autumn exists (Fig. 4). Recording the abundance of different life stages throughout winter would provide insight into how CMBS populations change during winter in future sampling efforts.

Our findings that colder temperatures likely inhibit winter population growth suggest that spread and damage may be reduced in colder regions. Reduced CMBS population growth in winter is further supported by findings of higher rates of cold-driven mortality of CMBS beyond 43°N (Wang et al. 2019b). Although CMBS settled crawlers can alter water and lipid concentrations to survive exposure to cold
temperatures (Wang et al. 2019b), our study indicates that active crawlers remain present throughout winter. This result suggests that various life stages may overwinter. If so, variation in cold tolerance of different life stages could influence survival, as has been documented in other insects (Bentz et al. 1991; Gamarra et al. 2020). As our study site was located in Charlotte, NC, USA, it is likely that CMBS populations in North Carolina and surrounding states in the southeastern United States where CMBS infestations are prevalent may also experience population growth during winter.

Because the plants in our study were placed 2 m apart, it is possible that crawlers may have dispersed between plants during winter by crawling or potential movement by wind or animal vectors. Indeed, evidence of CMBS crawlers being blown from infested trees onto sticky cards exists (Cornish 2021), and other scale insects as well as insects with similar life histories have been found to disperse via wind and animal vectors (Magsig-Castillo et al. 2010; McClure 1976; Washburn and Frankie 1981). Thus, it is possible that CMBS population growth as well as dispersal between adjacent trees can occur in winter.

Additionally, these findings support the use of reduced-risk chemical controls such as insecticidal soaps (potassium salts of fatty acids) and horticultural oils labeled for winter applications on CMBS crawlers, which are the most susceptible life stage to these applications. Caution needs to be taken when applying dormant oil and soap treatments in winter because applications in temperatures less than 4°C can cause phytotoxicity. There does not appear to be a single phenological window in which most crawlers emerge to limit application timing for chemical interventions, as our results showed crawler activity throughout winter. However, because crawlers showed increased activity during warmer winter days, less lethal product applications should be applied on warmer winter days when respiration rates are higher. Targeted pesticide applications when temperatures are warmer during winter may help to prevent CMBS populations from building up to high densities in spring, allowing for more effective use of augmentative natural enemy releases.

References Cited


Cornish A. 2021. Seasonality, distribution, and biological control of crapemyrtle bark scale; a new invasive threat in Tennessee. University of Tennessee, Knoxville, USA.


