General Biology and Current Management Approaches of Soft Scale Pests (Hemiptera: Coccidae)

Ernesto Robayo Camacho and Juang-Horng Chong

Department of Agricultural and Environmental Sciences, Pee Dee Research and Education Center, Clemson University, 2200 Pocket Road, Florence, SC 29506 (crobayo@g.clemson.edu; juanghc@clemson.edu).

Corresponding author, e-mail: juanghc@clemson.edu

J. Integ. Pest Mngmt. (2015) 6(1): 17; DOI: 10.1093/jipm/pvm016

ABSTRACT. We summarize the economic importance, biology, and management of soft scales, focusing on pests of agricultural, horticultural, and silvicultural crops in outdoor production systems and urban landscapes. We also provide summaries on volitism, crawler emergence timing, and predictive models for crawler emergence to assist in developing soft scale management programs. Phloem-feeding soft scale pests cause direct (e.g., injuries to plant tissues and removal of nutrients) and indirect damage (e.g., reduction in photosynthesis and aesthetic value by honeydew and sooty mold). Variations in life cycle, reproduction, fecundity, and behavior exist among congenerics due to host, environmental, climatic, and geographical variations. Sampling of soft scale pests involves sighting the insects or their damage, and assessing their abundance. Crawlers of most univoltine species emerge in the spring and the summer. Degree-day models and plant phenological indicators help determine the initiation of sampling and treatment against crawlers (the life stage most vulnerable to contact insecticides). The efficacy of cultural management tactics, such as fertilization, pruning, and irrigation, in reducing soft scale abundance is poorly documented. A large number of parasitoids and predators attack soft scale populations in the field; therefore, natural enemy conservation by using selective insecticides is important. Systemic insecticides provide greater flexibility in application method and timing, and have longer residual longevity than contact insecticides. Application timing of contact insecticides that coincide with crawler emergence is most effective in reducing soft scale abundance.

Key Words: biological control, chemical control, crawler emergence, cultural control, volitism

Among the scale insects (Hemiptera: Coccoidea), members of Coccidae (the soft scales), Diaspididae (the armored scales), and Pseudococcidae (the mealybugs) are the most common and serious pests in the world (Ben-Dov et al. 2015). Most of the 1,148 soft scale species currently recognized (Ben-Dov et al. 2015) are innocuous herbivores, and a few even produce valuable products. For example, wax from *Eriocerus* and *Ceroplastes* spp. is used to make candles, and as polish for furniture, ornaments, traditional medicine, and human food component in India and China (Qin 1997). The most extensively studied soft scale species are agricultural, horticultural, and silvicultural crop pests (Kosztarab 1996, Ben-Dov and Hodgson 1997). Thirty of the 50 economically important soft scale species listed by Gill and Kosztarab (1997) caused damage on ornamental plants and fruit trees in the United States. Globally, 146 soft scale species are either pests (66 species) or potential threats (80 species) to agriculture in the United States (Miller and Miller 2003). Several exotic soft scale species were introduced to North America and Europe through trade of ornamental plants and fruits (Miller and Miller 2003, Stocks 2013, Pellizzari and Porcelli 2014).

There is an enormous amount of literature on the biology, ecology, and management of soft scale pests. Ben-Dov and Hodgson’s (1997) “Soft Scale Insects. Their Biology, Natural Enemies and Control” remains the most comprehensive collection of information on soft scales. In this paper, we summarize current knowledge most relevant to soft scale management. We also provide summaries of volitism, crawler emergence timing, and predictive models for crawler emergence, which will prove useful in developing appropriately timed insecticide application programs.

Economic Importance

Kosztarab (1997a) estimated that worldwide management costs and losses to soft scale infestations alone reached >US$1 billion annually. The economic importance of soft scale pests is a function of their damage, wide host range, propensity to be introduced to new areas, and wide geographical distribution.

Factors Influencing the Pest Status of Soft Scales

Temperature and humidity are the main abiotic factors limiting the range and abundance of soft scales (Kosztarab 1996). Similar to other insects, developmental rate of soft scales increases with ambient temperature until an optimal temperature is reached, after which the developmental rate declines. The generation times of *Saissetia coffeae* (Walker) were 83, 68, and 49 d at 18, 24, and 30°C, respectively (Abd-Rabou et al. 2009). Li and Su (2002) reported that *S. coffeae* failed to complete development at 30°C. More than 80% of settled *Saissetia oleae* (Olivier) first instars died at temperature >30°C and relative humidity <30% (De Freitas 1972, Pucci et al. 1982). In general, conditions of relatively high temperature and humidity are beneficial to soft scale population growth (Kosztarab 1996). Warmer ambient temperatures due to heat accumulation on paved surfaces in urban areas (i.e., heat islands) increased populations of *Parthenolecanium quebeci* (Fitch) on oak trees in Raleigh, North Carolina (Meinke et al. 2013).

Host plant susceptibility affects infestation level and damage (Vranjec 1997). Susceptibility varies among plant species, varieties, and cultivars (see Host Plant Resistance). Host susceptibility varies in time and space, so outbreaks may occur in one year or one region but not in others (Vranjec 1997). *Ceroplastes sinensis* Del Guercio is a serious pest of citrus in coastal Australia (Beatie and Kaldor 1990, Beatie et al. 1991), but it is only a sporadic pest in Spain, Italy, and Greece (Gill 1988, Stathas et al. 2003a).

Nutrients in the soil and the plant also affect the severity of scale insect infestation (Kunkel 1997). *Coffee* (*Coffea arabica* L.) plants provided with more nitrogen, potassium, and organic compost amendments supported more *Coccus viridis* (Green) than poorly fertilized plants (Fernandes et al. 2012, Gonthier et al. 2013). Similarly, abundance of *Toumeyella parvicornis* (Cockerell) increased after pines...
(Pinus banksiana Lamb.) were fertilized with urea (Smirnoff and Valero 1975). The increased nitrogen and free amino acid concentrations in fertilized plants provided additional resources for C. viridis growth and reproduction, leading to greater abundance (Fernandes et al. 2012, Gonthier et al. 2013). An increase in nitrogen concentration also leads to decreased phytochemical concentrations (Hermes and Mattson 1992). Chlorogenic acid and caffeine stimulate C. viridis crawler movement, consequently reducing their feeding and increasing the risks of predation, on poorly fertilized plants (Fernandes et al. 2012). Fernandes et al. (2012) also suggested that coffee plants fertilized with potassium tolerated more C. viridis because elevated potassium supplies allowed the plants to increase growth and compensate for resources lost to the soft scales.

In urban environments, soft scale populations thrive on trees under physiological stress (such as water or nutrient deficiency; Kosztarab 1988). Environmental stress and pollution also affect soft scale abundance on urban trees (Kosztarab 1988, Xie et al. 1995). Eulecanium giganteum (Shinji) density was positively correlated with air pollutant concentrations (include suspended particles, dust, CO, S, NOx and SO2 produced as a result of automobile traffic) in Taiyuan, China (Xie et al. 1995). Xie et al. (1995) suggested that scale insect density could be used to monitor air pollution on city streets.

**Host Range**

Some soft scale species are polyphagous or monophagous, but most are oligophagous (Kosztarab 1996, Miller and Miller 2003). For example, Eriopelitis and Luzulaspis spp. feed on herbage plants; Parthenolecanium spp. prefer woody plants; Physokermes spp. feed exclusively on conifers; and Toumeyella spp. feed mainly on gymnosperms from the families Cupresaceae, Pineaceae, and Taxaceae (Kosztarab 1996). The majority of introduced species are polyphagous (Miller et al. 2005). Polyphagous species are more likely to become major pests when introduced to new areas because the existing plant species may allow the soft scales to develop and reproduce, thus facilitating the introduced soft scale’s establishment (Mitter and Futuyma 1983, Kosztarab 1996). Polyphagous species often develop host-induced biotypes (i.e., variability in their shape, color, and size depending on the host plant; Kosztarab 1996). Biotype and variable morphology have led to misidentification of pest species such as *Parthenolecanium corni* (Bouché) (Ebeling 1938).

**Damage**

Soft scales are phloem-sucking insects. After settling at a feeding site, the scale insects pierce the host plant tissue with modified stylets until reaching the phloem vessels, from where they suck plant sap. Phloem sap is rich in carbohydrates but poor in soluble nitrogen compounds, so phloem feeders have to ingest large quantities of sap to meet their nutritional requirements (Malumphy 1997). The excess carbohydrate-rich solution, known as honeydew, is excreted through a complex anal apparatus and mechanism unique to soft scales (Williams and Williams 1980). Honeydew is an ideal substrate for saprophytic sooty mold. A sooty mold colony on the leaf surface reduces photosynthetic efficiency through shading photosynthetic cells and interfering with gas exchange through stomata (Kosztarab and Kozár 1988, Mikey 1997, Stauffer and Rose 1997), traps heat from the sunlight (thus potentially scorching the leaf; Gill 1997), and (along with honeydew) reduces the aesthetic and market values of fruits and ornamental plants (Williams and Kosztarab 1972, Katsoyannos 1996, Gill and Kosztarab 1997).

Soft scales damage host directly when their stylets penetrate and injure the vascular and photosynthetic tissues (Gill and Kosztarab 1997, Vranjic 1997). Saliva of some species contains proteinases and cellulases capable of breaking down cells, damaging vascular and photosynthetic tissues in the vicinity of the stylet (Carter 1973). Necrosis produced by individual scale insects is normally localized. Aggregated injury by severe infestations, however, may lead to dieback of twigs and branches (Vranjic 1997).

Feeding by soft scale removes nutrients and carbohydrates from plants, which retards plant growth and recovery (Washburn et al. 1985, Speight 1991). Furthermore, infested host plants are weakened and become more susceptible to attack by other insects and pathogens (Hanson and Miller 1984).

**Life Cycle and Biology**

It is difficult to generalize the life cycle and biology of soft scales because variations exist even among congeners (Kosztarab 1996). Thus, we provide here a brief, but not universal, description of soft scale life cycle. Female life cycle consists of egg (Fig. 1), two or three nymphal instars (depending on species), and adult. In biparental species, males have a derived form of incomplete metamorphosis, which consists of two feeding nymphal instars followed by the nonfeeding “prepupal” (third-instar), “pupal” (fourth-instar), and adult (Marotta 1997).

First instars or “crawlers” disperse actively by crawling away from their mothers (Mendel et al. 1984; Fig. 2), or passively by wind or phoresis (Greathead 1997). Washburn and Frankie (1981) demonstrated that Pulvinariella mesembryanthemi (Vailot) crawlers disperse more readily by wind than through phoresis. Wind can carry crawlers 55 m to >4 km (Quayle 1916, Rabkin and Le Jeune 1954, Hoelscher 1967, Reed et al. 1970, Washburn and Frankie 1981, Mendel et al. 1984, Washburn and Washburn 1984, Yardeni 1987).

First instars generally remain at the feeding site after settling (Fig. 3). They lack a waxy cover or “test,” and consequently are more susceptible to extreme environmental stresses and insecticides (Kosztarab 1996, Marotta 1997). Sexes are indistinguishable among the first instars (Williams 1997).

Second instars are similar in external appearance to, but larger than, the first instars. Sexual dimorphism becomes apparent in older second instars, with the males becoming elongated oval and covered with waxy, translucent plate-like tests or “puparia” (Kosztarab 1996). Males develop through the “prepupal” and the “pupal” instars (both instars characterized by developing wing buds) under the protective tests (Miller and Williams 1990). Adult males have two pairs of wings, but the hind wings are either absent or reduced to halters (or “hamulohalteres”; Giliomee 1997). Adult males emerge from the tests and disperse by flight. The sexual behavior of male soft scales is poorly understood but likely similar to those of armored scales and mealybugs. Adult male armored scales and mealybugs locate females through pheromones (Moreno et al. 1972, Millar et al. 2012, Waterworth and Millar 2012). Being weak fliers, male armored scales only mate with nearby females (Rice and Moreno 1970, Moreno et al. 1972).
Female second instars are broadly oval (Fig. 4). Most species develop through third instar, but some species do not [e.g., E. pela (Qin 1997)]. A female third instar (Fig. 5) looks similar to an adult, and lasts only 2–4 d. As a result, the third instar is not always identified in life cycle studies (Marotta 1997).

Adult females are wingless and neotenic (i.e., resemble the nymphal stage; Fig. 6). An adult female undergoes a series of changes prior to oviposition, such as increase in size, color change, dorsoventral swelling, and formation of either a cavity under the venter (known as the “brood chamber” and occurs in Ceroplastinae, and Coccinae tribe Coccini, Paralecaniini and Saissetiini, Eulecaniinae, and Myzolecaniinae), or a white, waxy ovisac beneath or behind the body (in Filippiinae, Eriopletinae, and the Coccinae tribe Pulvinariini; Marotta 1997).

Most univoltine species overwinter as second instars; others overwinter as adults (Kosztarab 1996). Some species, such as C. sinensis, can overwinter as either third instar or adult (Stathas et al. 2003a). In species where nymphs feed on the foliage, second instars migrate to, and overwinter on, twigs and branches. This migration often coincides with or precedes specific changes in host phenology (Marotta and Tranfaglia 1997), most notably leaf senescence (Michelbacher and Ortega 1958).

Soft scales reproduce either sexually or parthenogenetically (Saakyan-Baranova et al. 1971, Kosztarab 1996). Some species [e.g., P. corni and Pulvinaria vitis (L.)] can reproduce sexually and parthenogenetically (Schmutterer 1952, Canard 1958, Phillips 1963, Pellizzari 1997); the mechanism that regulates the variable mode of reproduction in these soft scale species is poorly understood.
Fecondity varies greatly among species. Per capita fecundity was less than 24 eggs for *Eucalyptus tessellarum* (Signoret) (Vese-Fitzgerald 1940), up to 6,355 eggs for *Ceroplastes destructor* Newstead (Wakgari and Gillomee 2000), and 382–395 crawlers for *Phalacrocorax hoviortoni* Hodges and Hodgson (Amarasekare and Mannion 2011). Fecondity also varies among individuals. Per capita fecundity of *Coccus hesperidum* L. ranged from 70 to 1,000 eggs (Tereznikova 1981) and that of *S. oleae* ranged from 566 to 5,539 off-spring (Beingalea 1969). Fecondity was positively correlated to body volume in *P. corni* (Birijadi 1981), and to weight in *Rhodococcus turalis* (Archangelskaja) (Fan et al. 2013). Host plant, climatic conditions, and altitude may be responsible for variations in sex ratios, parthenogenesis, and fecundity in *C. hesperidum* (Thomsen 1929; Nur 1979, 1980), *E. pela* (Danzig 1980, 1986, 1997), *P. corni* (Thiem 1933a, 1933b; Canard 1958, Saakyan-Baranova et al. 1971), *P. vitis* (Newstead 1903; Schmuterer 1952; Danzig 1959, 1980, 1986; Malumphy 1992), and *S. coffeae* (Thomsen 1929; Nur 1979, 1980).

Among the 70 soft scale species reviewed (almost exclusively agriculturally, horticulturally, and silviculturally pests), 53% are strictly univoltine, 7% are strictly bivoltine, and 4% are strictly multivoltine (Table 1). Some multivoltine species have as many as five generations annually (e.g., *C. hesperidum* in southern California; Gill 1988). No subfamily, tribe, or genus has a higher tendency to include multivoltine species than the others. Many soft scale species exhibit great variations in voltinism depending on host, geographical and climatic conditions (Table 1; Marotta and Tranfaglia 1997). A cosmopolitan soft scale species may develop more generations in a warmer country, or a warmer climatic zone within a country. For example, *Ceroplastes rubens* (Maskell) has one generation in Japan and China (Itioka and Inoue 1991, Xia et al. 2005) and two generations in Australia (Loch and Zalucki 1997). *Ceroplastes destructor* is univoltine in central and southern New South Wales but bivoltine in northern New South Wales, Australia (Qin and Gullan 1994). *Saissetia oleae* is univoltine in the inland regions of Greece where hot and dry summers and cold winters prevail (Argyriou 1963), but bivoltine in the coastal regions of Iberian Peninsula and Israel where high summer humidity and mild winters are common (Peleg 1965, De Freitas 1972).

Voltinism also differs among host plant species or cultivars. *Ceroplastes floridensis* is univoltine on *Rhododendron* spp. from Florida to Maryland (Kehr 1972), bivoltine on holly (*Ilex* spp.) in Georgia (Hodges et al. 2001), and multivoltine on citrus and holly in Florida (Johnson and Lyon 1991). *Coccus hesperidum* is univoltine or bivoltine on the “Valencia late” orange variety but multivoltine on citrus in Florida to Maryland (Kehr 1972), bivoltine on holly (*Ilex* spp.) in Georgia (Hodges et al. 2001), and multivoltine on citrus and holly in Florida (Johnson and Lyon 1991). *Coccus hesperidum* is univoltine or bivoltine on the “Valencia late” orange variety but multivoltine on the “Hamlin” variety (Panis 1977a). A higher nutritional quality of certain host plant species or cultivars (Nietner) is usually univoltine with a partial second generation in Australia (Loch and Zalucki 1997). A cosmopolitan soft scale species may develop more generations in a warmer country, or a warmer climatic zone within a country.

**Monitoring**

Soft scale infestations are detected by looking for populations and damage symptoms. Sampling plans typically determine insect density on a prescribed number of leaves or branches, but procedures vary among crop systems (e.g., citrus in Trumble et al. 1995, Grafton-Cardwell et al. 1999, Martinez-Ferrer et al. 2015; olive in Tena et al. 2007; and tea in Naemimani et al. 2014). Scouting should be trained and equipped (with handlens, sticky traps, etc.) to detect cryptic signs and symptoms. Honeydew, sooty mold, and honeydew-seeking ants are general signs of phloem-feeding insect infestations; they can be used to pinpoint the areas where plants may be inspected for the presence of soft scales. Monitoring or matting disruption of soft scales with pheromone baits is not available.

Degree-day models and plant phenological indicators predict crawler emergence and inform scouts and IPM practitioners on when to initiate sampling and treatment (Mussey and Potter 1997, Herms 2004). Only a small number of IPM practitioners implement these predictive models because of the high diversity of pests (and plants) that require management (each may require a unique model, but see Kulhanek 2009), the time needed to learn, calculate and implement the models (LeBude et al. 2012), and the difficulty in interpreting the observed plant phenophase. Few predictive models for soft scales have been published (Table 2), further impeding their adoption.

Crawler presence can be confirmed by looking for the crawlers on the leaves and branches, or by deploying a modified sticky trap. The sticky trap is made of a double-sided tape (or a single-side tape with the adhesive surface facing outward) wrapped around a twig or branch where gravid soft scales are present. The trap is inspected regularly for captured crawlers.

Despite its importance in determining insecticide application timing, crawler emergence period is reported for only 49 soft scale species (Table 3). In the United States, *P. corni* crawlers emerge earlier in the southern states (Hodges and Brannan 2004, Klingeman et al. 2002) than those in the northern states (Asquith 1949, Krischik and Davidson 2003, Herms 2004, Hoover et al. 2011). Crawlers of most univoltine species emerge in the spring through the summer, i.e. April through June in the United States and October through February in the Southern Hemisphere (Table 3).

**Economic Threshold**

On ornamental plants grown in nurseries or landscapes, pest management tactics are often applied whenever scale insect populations or damage becomes noticeable (Bethke 2010). Economic thresholds vary among perennial fruits and nut crops. The economic thresholds of *C. floridensis* in citrus orchards of Egypt are 24.4, 26.6–28.4, and 25.1–27.0 individuals per twig in June, October, and December, respectively (Salem and Zaki 1985, Helmy et al. 1986).

**Cultural Control**

The goal of cultural control is to make the environment less favorable to pest development and reproduction. Proper fertilization, pruning, and irrigation maintain plant vigor, promote plant tolerance to pest damage, and reduce sap-sucking insect population growth (CAST 2003, Dreistadt 2008, Kabashima and Dreistadt 2014). However, few studies have demonstrated the efficacy and underlying mechanism of these cultural management practices. Pruning is effective in removing infested plant tissues and reducing populations of *S. oleae* and *Coccus pseudomagnoliarum* (Kuwana) (Kabashima and Dreistadt 2014). Pruned olive trees harbored 200% fewer nymphs and 50% fewer adult *S. oleae* compared to unpruned trees (Ougas and Chemseddine 2011). Excessive irrigation increased the developmental rate of *C. destructor* (Milne 1993).

**Host Plant Resistance**

It is generally recommended that pest-resistant plant species or cultivars should replace those that are susceptible to pests and damage (Kabashima and Dreistadt 2014). However, few studies investigated resistance or tolerance of various host plant species or cultivars to soft scales in the field. Potter and Redmond (2013) reported that American...
| Subfamily      | Tribe            | Genus | Species               | Host cited in the references          | Location(s)             | Generations per year | Reference(s) |
|---------------|------------------|-------|-----------------------|----------------------------------------|-------------------------|----------------------|--------------|
| Ceroplastinae | Ceroplastini     | Genus | *Ceroplastes*          |                                        |                         |                      |              |
|               | Ceroplastini     | *Ceroplastes* | *alboineatus* | *Pittacaulon praecox* | *Mexico*  | 2 | (Narada and Lechuga 1971) |
|               | Ceroplastini     |       | *ceriferus*            | *Various* | *Italy; Maryland, Virginia, USA* | 1 | (Kostzarab 1996, Mori et al. 2001) |
|               | Ceroplastini     |       | *Citrus*               | *Japan* | *1* | (Ohgushi 1969) |
|               | Ceroplastini     |       | *Burford holly (Ilex cornuta 'Burfordi')* | *Georgia, USA* | *1* | (Hodges and Braman 2004) |
|               | Ceroplastini     |       | *citripediformis*      | *Fruit trees* | *Georgia* | *1* | (Tulashvili 1920) |
|               | Ceroplastini     |       | *Citrus*               | *California, USA* | *1* | (Ben-Dov 1993, Kostzarab 1997b) |
|               | Ceroplastini     |       | *Various*              | *Texas, USA* | *2* | (Johnson and Lyon 1991) |
|               | Ceroplastini     |       | *Guava*                | *Egypt* | *2* | (Bakr et al. 2010) |
|               | Ceroplastini     |       | *Passion fruit (Passiflora edulis)* | *Central coast, Peru* | *3* | (Marín-Loayza and Cisneros-Vera 1996) |
|               | Ceroplastini     |       | *Citrus*               | *New Zealand* | *1* | (Olson et al. 1993, Lo et al. 1996) |
|               | Ceroplastini     |       | *Ceroplastes japonicus* | *Poplar, bay laurel, maple,* | *1* | (Qin and Gullan 1994) |
|               | Ceroplastini     |       | *Citrus*               | *Queensland, Northern New South Wales, Australia* | *2* | (Smith 1970, Qin and Gullan 1994) |
|               | Ceroplastini     |       | *floridensis*          | *Yunnan, China* | *1* | (Yun 1994) |
|               | Ceroplastini     |       | *Rhododendron spp.*    | *Florida to Maryland, USA* | *1* | (Kehr 1972) |
|               | Ceroplastini     |       | *Holly (Ilex spp.)*    | *Georgia, USA* | *2* | (Hodges et al. 2001) |
|               | Ceroplastini     |       | *Citrus*               | *Greece* | *2* | (Argyriou and Kourmadas 1980) |
|               | Ceroplastini     |       | *Citrus*               | *Israel* | *2* | (Yardeni and Rosen 1995, Pellizzari 1997) |
|               | Ceroplastini     |       | *Citrus*               | *Fujian, China* | *1* | (Kaiju 2011) |
|               | Ceroplastini     |       | *Citrus*               | *Queensland, Australia* | *2* | (Smith et al. 1997) |
|               | Ceroplastini     |       | *Citrus*               | *Egypt* | *3* | (Salem and Hamdy 1985, Helmy et al. 1986, Abd-Ehalil Moharum 2011) |
|               | Ceroplastini     |       | *Various*              | *Florida, USA* | *3* | (Johnson and Lyon 1991) |
|               | Ceroplastini     |       | *Orange, Passion fruit (Passiflora edulis)* | *Peru* | *3* | (Marín-Loayza and Cisneros-Vera 1996) |
|               | Ceroplastini     |       | *japonicus*            | *China; Italy* | *1* | (Pellizzari and Camporese 1994, Davis et al. 2005, Yongxiang 2008) |
|               | Ceroplastini     |       | *Various*              | *Croatia* | *1* | (Marten-Milek et al. 2007) |
|               | Ceroplastini     |       | *Citrus*               | *Japan* | *1* | (Ohgushi 1969) |
|               | Ceroplastini     |       | *pseudoceriferus*      | *China; Korea* | *1* | (Park et al. 1990, Wang et al. 2006) |
|               | Ceroplastini     |       | *Lychee, mango*        | *Southern Taiwan, Republic of China* | *3* | (Wen and Lee 1996) |
|               | Ceroplastini     |       | *Various*              | *Shanghai and Kunming, China* | *1* | (Tao et al. 2003, Xia et al. 2005) |
|               | Ceroplastini     |       | *Citrus*               | *Japan* | *1* | (Yasumatsu 1958) |
|               | Ceroplastini     |       | *rusci*                | *Australia* | *2* | (Loch and Zalucki 1997) |
|               | Ceroplastini     |       | *Fig tree (Ficus carica)* | *Mediterranean coast, France* | *1* | (Benassy and Franco 1974) |
|               | Ceroplastini     |       | *Fig tree (Ficus carica)* | *Algeria; Greece; Turkey* | *2* | (Argyriou and Santorini 1980, Oezemen and Akst 2003, Biche et al. 2012) |
|               | Ceroplastini     |       | *Quince*               | *Egypt* | *2* | (Ragab 1995) |
|               | Ceroplastini     |       | *Citrus*               | *Italy; Spain* | *2* | (Inserra 1970, Longo and Russo 1986, Del la Cruz Blanco et al. 2010, Pellizzari et al. 2010) |
|               | Ceroplastini     |       | *sinosis*              | *Southern Vietnam* | *4* | (Vu et al. 2006) |
|               | Ceroplastini     |       | *Soursop (Annona muricata), fig* | *Virignia, USA* | *1* | (Williams and Kostzarab 1972, Kostzarab 1996) |
|               | Ceroplastini     |       | *Citrus*               | *Greece; Italy* | *1* | (Frediani 1960, Stathas et al. 2003a) |
|               | Ceroplastini     |       | *Citrus*               | *Coastal districts, Australia* | *1* | (Snowball 1970) |
|               | Ceroplastini     |       | *Citrus*               | *New Zealand* | *1* | (Cottier and Wellington 1939) |

(continued)
| Subfamily | Tribe | Genus | Species | Host cited in the references | Location(s) | Generations per year | Reference(s) |
|-----------|-------|-------|---------|------------------------------|-------------|----------------------|--------------|
| Coccinae  | Coccini | Coccus | hesperidum | Citrus | Northern Spain | 1 | (Martínez-Ferrer et al. 2015) |
| Coccinae  | Coccini | Coccus | pseudomagnoliarum | Citrus spp. | Various | 3–5 | (Bernal et al. 1998, Charles et al. 2005) |

(continued)
| Subfamily | Tribe | Genus | Species | Host cited in the references | Location(s) | Generations | Reference(s) |
|-----------|-------|-------|---------|-------------------------------|-------------|-------------|--------------|
| **hydrangeae** | | | Conifers, hydrangea, cherry, others | Turkey | Australia; Europe; Japan; California, East Coast, USA | 2 | (Ülgentürk et al. 2004) |
| | | | mango | Mango | India | 1 | (Chatterji and Datta 1974) |
| | | | varius | Various | China | 2–3 | (Peng et al. 1990) |
| | | | citr | Citrus | Taiwan | 3 | (Takahashi 1939) |
| | | | psidii | Guava | Egypt | 2, 3 | (Baker et al. 2012) |
| | | | rhois | Poison oak (Rhus diversiloba), peach, plum, apple and currant (Ribes), prune | California, USA | 1 | (Essig 1958) |
| | | | vitis | Peach, Poplar, alder, beech, willow, hawthorne | Canada, New Zealand | 1 | (Essig 1963) |
| | | | | | Eastern USA | 1 | (Essig 1963) |
| | | | | | Northern California, USA | 2 | (Tassan and Hagen 1995) |
| | | | | | Southern California, USA | 3–4 | (Tassan and Hagen 1995) |
| | | | | | Italy | 1 | (Nuzzaci 1969a) |
| | | | | | Greece | 1 | (Santas 1985) |
| | | | | | Turkey | 1 | (Ecevit et al. 1987) |
| | | | | | France | 1 | (Canard 1958) |
| | | | | | New Zealand | 1 | (Charles et al. 2005) |
| | | | | | Krasnodar, Russia | 1 | (Borchsenius 1957) |
| | | | | | Virginia, USA | 1 | (Day 2008) |
| | | | | | California, USA | 1 | (Kawecki 1958, Madsen and Barnes 1959) |
| **Pulvinariella** | Saissetiini | Parasaessetia | Parthenolecanium | Ficus, Hedera Grapevine (Vitis vinifera) Corylus | California, Florida, USA | 1 | (Tassan and Hagen 1995) |
| | | | | | Italy | 2 | (Nuzzaci 1969a) |
| | | | | | Greece | 1 | (Santas 1985) |
| | | | | | Turkey | 1 | (Ecevit et al. 1987) |
| | | | | | France | 1 | (Canard 1958) |
| | | | | | New Zealand | 1 | (Charles et al. 2005) |
| | | | | | Krasnodar, Russia | 1 | (Borchsenius 1957) |
| | | | | | Virginia, USA | 1 | (Day 2008) |
| | | | | | California, USA | 1 | (Kawecki 1958, Madsen and Barnes 1959) |
| | | | | | Chile | 2 | (Bayer CropScience Chile 2014) |
| | | | | | Hungary | 2 | (Kosztarab 1959) |
| | | | | | Pennsylvania, USA | 2 | (Essig 1963) |
| | | | | | Krasnodar, Russia | 1 | (Borchsenius 1957) |
| | | | | | Hungary | 1 | (Kosztarab 1997b) |
| | | | | | Virginia, USA | 1 | (Kosztarab 1997b) |
| | | | | | Pennsylvania, Illinois, USA | 1 | (Stimmel 1978, Hoover 2006) |
| | | | | | Henan, Shandong, China | 1 | (AQS1Q 2007) |
| | | | | | Henan, Shandong, China | 2 | (AQS1Q 2007) |
| | | | | | Argentina | 1 | (Teran and Guyot 1969) |
| | | | | | Chile | 1 | (Bayer CropScience Chile 2014) |
| | | | | | Israel | 1 | (Ben-Dov 1993) |
| | | | | | USA | 1 | (Kosztarab 1996) |
| | | | | | Australia; Southern Greece | 1 | (Stathas et al. 2003b, Buchanan 2008) |
| | | | | | New Zealand | 1 | (Stimmel 1978, Hoover 2006) |
| | | | | | Former Soviet Union | 2 | (Borchsenius 1957) |
| | | | | | Central Asia | 2 | (Ben-Dov 1993) |
| | | | | | Europe | 1 | (Del-Bene 1991) |
| | | | | | California, USA | 1 | (Michelbacher and Swift 1954) |
| | | | | | Australia | 1 | (Buchanan 2008) |
| | | | | | Virginia, USA | 1 | (Williams and Kosztarab 1972) |
| | | | | | California, USA | 1 | (Swiecki and Bernhardt 2006) |

(continued)
| Subfamily | Tribe | Genus | Species | Host cited in the references | Location(s) | Generations per year* | Reference(s) |
|-----------|-------|-------|---------|-------------------------------|-------------|-----------------------|--------------|
| Cyphococcinae | Cyphococcini | Eulecanini | Didesmococcus | Ruby lannelloides, Quercus rubra | Greece | 1 | (Gounari et al. 2012) |
| Eulecanini | Eulecanini | Eulecanini | Eulecaniinae | Eulecanium carcae, E. cerasorum, E. ciliatum | Various | 1 | (Madsen and Barnes 1959, Kosztarab 1996) |
| | | | | Acer campestre, A. pseudoplatanus, C. lanatus monogyna | California, Maryland, USA | 1 | (Madsen and Barnes 1959, Kosztarab 1996) |
| | | | | Ornamental plants and broadleaved trees | England; California, USA | 1 | (Gill 1988, Alford 2007) |
| | | | | Various | California, USA | 1 | (McKenzie 1951, Husseiny and Madsen 1962) |
| | | | | Quercus frainetto, Q. cerasus, Q. ithaburensis ssp. macrolepis | Greece | 1 | (Gounari et al. 2012) |
| | | | | Various | Bulgaria, Georgia, Russia; California, USA | 1 | (Hadzibedzi 1967, Tzatev 1968, Kosztarab and Kozar 1988) |
| | | | | Abies, Picea | Georgia | 1 | (Hadzibedzi 1967) |
| | | | | Conifers (Abies, Picea) | Germany | 1 | (Kosztarab 1997b) |
| | | | | Greek fir (Abies cephalonica) | Greece | 1 | (Stathas 2001) |
| | | | | Corylus, Juglans regia, Rosaceae | Europe | 1 | (Schmutterer 1952) |
| | | | | Spruce | Germany | 1 | (Schmutterer 1956) |
| | | | | Abies cephalonica, A. borisii regis | Greece | 1 | (Gounari et al. 2012) |
| Subfamily       | Tribe        | Genus   | Species                        | Host cited in the references                                | Location(s)                  | Generations per year | Reference(s)                |
|-----------------|--------------|---------|--------------------------------|-------------------------------------------------------------|------------------------------|-----------------------|--------------------------|
| Pseudopulviniinae |              |         |                                |                                                             | N/A                          | N/A                   |                          |

N/A, not specified.

Higher level taxonomy is based on Hodgson (1994) and Ben-Dov et al. (2015).
Table 2. Degree-day and plant phenological indicator models for soft scale pests

| Soft scale species                  | Celsius degree-day, DDC (Fahrenheit degree-day, DDF) | Base temperature | Host plant authors | Location | Reference(s) |
|------------------------------------|------------------------------------------------------|------------------|--------------------|----------|--------------|
| Ceroplastes ceriferus              | 843–930 DDC                                          | 12.78°C (55°F)   | Burford holly (Ilex cornuta) | Athens, GA | (Hodges and Braman 2004) |
| Eulecanium cerasorum               | 1028 DDC (1851 DDF)                                  | 1.7°C (35°F)     | Sweetgum (Liquidambar styraciflua) | Lexington, KY | (Mussey and Potter 1997) |
|                                    | 748 DDF                                              | 10°C (50°F)      | N/A                | Wooster, OH | (Hodges 2004) |
|                                    | 818 DDC                                              | 4.4°C (40°F)     | Hackberry (Celtis occidentalis); Norway maple (Acer platanoides) | Lexington, KY | (Hubbard and Potter 2005) |
| Neolecanium corni parvum           | 1938 DDF                                             | 10°C (50°F)      | N/A                | Wooster, OH | (Hodges 2004) |
| Neopulvinaria innumerabilis        | 898–1321 DDC                                         | 10.56°C (51°F)   | Red oak (Quercus falcata) | Athens, GA | (Hodges and Braman 2004) |
| Parthenolecanium corni             | 1100–1582 DDC                                        | 10.56°C (51°F)   | Pin oak (Quercus palustris); willow oak (Quercus phellos); red maple (Acer rubrum) | Athens, GA | (Hodges and Braman 2004) |
|                                    | 1198–1263 DDC                                        | 12.78°C (55°F)   | Pin oak; willow oak; red maple | Athens, GA | (Hodges and Braman 2004) |
|                                    | 1073 DDF                                             | 10°C (50°F)      | N/A                | Midland, MI | (Hodges 2004) |
|                                    | 767 DDF                                              | 10°C (50°F)      | N/A                | Wooster, OH | (Hodges 2004) |
| Parthenolecanium fletcheri         | 844 DDF                                              | 10°C (50°F)      | N/A                | Midland, MI | (Hodges 2004) |
| Pulvinaria acerola                 | 1044 DDC (1879 DDF)                                  | 4.4°C (40°F)     | Red maple          | Lexington, KY | (Mussey and Potter 1997) |
|                                    | 892–1229 DDC                                         | 10.56°C (51°F)   | Red maple          | Athens, GA | (Hodges and Braman 2004) |
|                                    | 1422–1941 DDC                                        | 10.56°C (51°F)   | Burford holly      | Athens, GA | (Hodges and Braman 2004) |
|                                    | 851 DDF                                              | 10°C (50°F)      | N/A                | Wooster, OH | (Hodges 2004) |
| Physokermes piceae                 | 1154 DDF                                             | 10°C (50°F)      | N/A                | Midland, MI | (Hodges 2004) |
|                                    | 894 DDF                                              | 10°C (50°F)      | N/A                | Wooster, OH | (Hodges 2004) |
| Toumeyella lirioidendri            | 532–616 DDC                                          | 10.56°C (51°F)   | Tulip poplar (Liriopendra tulipifera) | Athens, GA | (Hodges and Braman 2004) |
| Toumeyella pini                    | 783 DDF                                              | 10°C (50°F)      | N/A                | Wooster, OH | (Hodges 2004) |

Plant phenological indicator models

| Soft scale species                  | Plant species authors | Phenophase | Location | Reference(s) |
|------------------------------------|-----------------------|------------|----------|--------------|
| Eulecanium cerasorum               | Northern catalpa (Catalpa speciosa) | First bloom | Lexington, KY | (Mussey and Potter 1997) |
|                                    | Washington hawthorne (Craetaegus phaenopyrum) | 50% bloom | Lexington, KY | (Mussey and Potter 1997) |
|                                    | Washington hawthorne | Full bloom | Wooster, OH | (Hodges 2004) |
| Pulvinaria innumerabilis           | Tulip poplar          | Beginning to bloom; 50% bloom | Athens, GA | (Hodges and Braman 2004) |
|                                    | Northern catalpa      | Full bloom | Athens, GA | (Hodges and Braman 2004) |
|                                    | Oakleaf hydrangea     | Full bloom | Athens, GA | (Hodges and Braman 2004) |
| Parthenolecanium corni             | American elder (Sambucus canadensis) | First bloom | Midland, MI | (Hodges 2004) |
|                                    | Washington hawthorne  | Full bloom | Wooster, OH | (Hodges 2004) |
| Parthenolecanium fletcheri         | American elder | First bloom; 95% bloom | Athens, GA | (Hodges and Braman 2004) |
|                                    | Littleleaf linden (Tilia cordata) | Full bloom | Athens, GA | (Hodges and Braman 2004) |
|                                    | Oak leaf hydrangea (Hydrangea quercifolia) | Full bloom | Athens, GA | (Hodges and Braman 2004) |
| Physokermes piceae                 | American elder | First bloom | Midland, MI | (Hodges 2004) |
|                                    | Littleleaf linden ‘Greenspire’ | Full bloom | Midland, MI | (Hodges 2004) |
|                                    | American elder | Full bloom | Wooster, OH | (Hodges 2004) |
|                                    | Bumalda spirea (Spirea x bumalda) | Full bloom | Wooster, OH | (Hodges 2004) |
| Toumeyella lirioidendri            | Honeysuckle (Lonicera sp.) | Full bloom | Athens, GA | (Hodges and Braman 2004) |
|                                    | Flowering dogwood (Cornus florida) | Full bloom | Athens, GA | (Hodges and Braman 2004) |
|                                    | Snowball viburnum (Viburnum macrocephalum) | 50% bloom | Athens, GA | (Hodges and Braman 2004) |
| Toumeyella pini                    | Washington hawthorne | Full bloom | Wooster, OH | (Hodges 2004) |

The models predict crawler emergence or egg hatch. Starting date of the degree-day models was 1 January. Degree-day approximation method used by Herms (2004) was not specified, whereas that used by the other studies was single-sine or sine-wave method.

* N/A, not specified.

E. ulmus (Ulmus americana L.) cultivars supported a larger population of *P. corni* and *Neopulvinaria innumerabilis* (Rathvon) than Asian elm (*U. parvifolia* Jacq. and *U. propinqua* Koidz.) cultivars. Kozár (1972) found that 10 peach (*Prunus persica* (L.) Stokes) varieties were highly susceptible to infestation by *P. corni*, whereas nine were either lightly infested or not infested. Host plant resistance to scale insects is likely conferred by an interaction between plant genetic, physiology, and biochemistry (McClure 1985).

**Biological Control**

Many hymenopteran parasitoids of soft scale are members of Aphelinidae, Encyrtidae, Eulophidae, and Pteromalidae (Hayat 1997, Prinsloo 1997, Viggiani 1997, Kapranas and Tena 2015). Major predators of soft scales include beetles [Coccinellidae, Anthribidae (*Anthribus* spp.), and Nitidulidae (*Cybocephalus* spp.); Ponsonby and Copland 1997, Hodek and Honěk 2009] and neuropterans (*Chrysopidae, Hemerobiidae, Coniopterygidae*, and *Raphidiidae;*)
| Species                   | Time of the year                                      | Location                          | Host cited in the references | References                                      |
|---------------------------|------------------------------------------------------|-----------------------------------|------------------------------|------------------------------------------------|
| Ceroplastes albolineatus  | Mar. (1st generation) Sept. (2nd generation)         | Mexico D.F., Mexico               | Pittocaulon praecox          | (Narada and Lechuga 1971)                       |
| Ceroplastes ceriferus     | Late-April                                          | Texas, USA                        | Various                      | (Johnson and Lyon 1991)                        |
|                          | Late-May to mid-June                                | Athens, Georgia, USA              | Burford holly (Ilex cornuta  | (Hodges and Braman 2004)                       |
|                          | June to mid-July                                    | Pennsylvania, USA                 | ‘Burfordii’)                 |                                                 |
|                          | June                                                 | Maryland, Tennessee, USA          | Various                      | (Hoover et al. 2011)                           |
|                          |                                                      |                                   |                              | (Smith et al. 1971, Klingeman et al. 2002)     |
|                          |                                                      |                                   |                              | (New Jersey Department of Agriculture [NJDA] 2006) |
|                          |                                                      |                                   |                              | (Lai 1993)                                     |
| Ceroplastes cirripediformis | Mid-June Early Sept. to mid-Oct. Early-Feb. (1st generation) Late Feb. to early-Mar. | New Jersey, USA Northern Guizhou, China Peru | N/A                          | (Marín-Loaya and Cisneros-Vera 1996)           |
| Ceroplastes destructor    | Early-April                                         | Palmira, Valle del Cauca,        | Passiflora edulis flavicarpa | (Bayer CropScience Chile 2014)                 |
|                          | Late Apr.                                           | Colombia                          |                              | (Kondo Rodríguez 2009)                         |
|                          | Late-April                                          | Texas, USA                        | Various Seminole tangelo (Citrus | (Johnson and Lyon 1991)                        |
|                          | Late-Dec.                                           | Kerikeri, New Zealand            | paradisi x C. reticula       | (Olson et al. 1993)                            |
|                          | Nov.                                                 | New South Wales, Australia        | Citrus (Citrus spp.)         | (Snowball 1969)                                |
|                          | Mid-Oct. (1st generation) Early-April (2nd generation) Mid-Nov. | Queensland, Australia             | Citrus                        | (Smith 1970)                                  |
|                          |                                                      | Cape Province, South Africa       |                             | (Wakgari and Giliomee 2000)                    |
| Ceroplastes floridensis   | Early-June Early-Jan. (1st generation)              | Daegu, South Korea Perú           | Persimmon Orange, passion fruit (Passiflora edulis) | (Han and Lee 1964)                            |
| Ceroplastes japonicus     | Early-May (2nd generation) Early-Oct. (3rd generation) | Egypt                             | Banana                        | (Abd-EIhalim Moharum 2011)                     |
|                          | Early Feb. (1st generation) Mid-Aug. (2nd generation) | May (1st generation) Aug. (2nd generation) | Mango                        | (Swirsik and Greenberg 1972)                   |
|                          |                                                      | Israel                            |                              |                                                 |
|                          | April–May (1st generation) July–Aug. (2nd generation) Oct.–Nov. (3rd generation) | Florida, USA                      | Avocado, citrus, crape myrtle, deodar cedar, elm, holly, Indian hawthorn, loblolly pine, oak | (Johnson and Lyon 1991)                        |
|                          |                                                      |                                   |                              |                                                 |
| Ceroplastes pseudoceriferus | May–June (1st generation) Nov. (2nd generation) Late April–May (1st generation) Late July–Aug. (2nd generation) | Tifton, Georgia, USA              | 1lex spp.                        | (Hodges et al. 2001)                           |
| Ceroplastes sinensis      | June–July (2nd generation) | Texas, USA | N/A | (Drees et al. 2005) |                                                 |
| Ceroplastes japonicas     | Aug. (2nd generation) April (1st generation) Aug. (2nd generation) | Fujian Province, China Korea Italy | Cinnamomum japonicum          | (Kaiju 2011)                                  |
| Ceroplastes sinensis      | Mid-May Early-June June                               | Croatia                           | Various                       | (Masten-Milek et al. 2007)                     |
|                          |                                                      | Korea                             | N/A                           | (Davis et al. 2005)                            |
|                          |                                                      | Italy                             | Bay laurel and maple          | (Pellizzari and Camporese 1994)                 |
|                          |                                                      |                                   | Persimmon Lychee, mango       | (Park et al. 1990)                             |
|                          |                                                      |                                   |                              | (Wen and Lee 1986)                             |
| Ceroplastes pseudoceriferus | Mid-June Late-Jun. (1st generation) Late-Sept. (2nd generation) Late-Mar. (3rd generation) | Korea Southern Taiwan, Republic of China | Persimmon Lychee, mango       | (Park et al. 1990)                             |
| Ceroplastes rubens        | Late-June Early-July Nov. June–July (2nd generation) | Japan Queensland, Australia M. A. | Citrus, persimmon            | (Itoika and Inoue 1991)                        |
|                          | June, July                                          |                                   | Various                       | (QDAFF 2014)                                  |
| Ceroplastes rusci         | Mid-Sept. (1st generation) Feb. (2nd generation) Aug. (2nd generation) Late May to Early-June (1st generation) Late Aug. to early Sept. (2nd generation) | Italy Extremadura, Spain Fig tree | Fig tree                                      | (De la Cruz Blanco et al. 2010)                |
| Ceroplastes sinensis      | Feb. Late-June Early-July Nov June–July (2nd generation) | Northland, New Zealand Virginia, USA Central Greece New South Wales, Australia Northern Spain Chile | Citrus 1lex spp. Citrus sinensis Citrus Citrus reticulata, C. sinensis Various fruit trees | (Lo et al. 1996) (Kosttarab 1996) (Stathas et al. 2003a) (Snowball 1970) (Martinez-Ferrer et al. 2015) (Bayer CropScience Chile 2014) (Dreidstadt) |
| Ceroplastes sinensis      |                                                      | Davis, California, USA            | Chinese hackberry (Celtis sinensis) | (Dreidstadt 2004) |

(continued)
Table 3. Continued

| Species                  | Time of the year         | Location               | Host cited in the references | References                     |
|--------------------------|--------------------------|------------------------|------------------------------|--------------------------------|
| Coccus viridis           | June                     | Greece                 | Citrus (Argyriou and Ioannides 1975) | (Argyriou and Ioannides 1975)  |
|                          |                          |                        |                              |                                |
| Didesmococcus unifasciatus | Early June               | Central Asia           | Stone fruits (Babayan 1973)  | (Babayan 1973)                 |
| Eulecanium caryae        | Mid-May to mid-June      | Ohio, USA              | N/A (Klingeman et al. 2002)  | (Klingeman et al. 2002)        |
|                          | Late-June                | Michigan, USA          | Beech, willow birch (Persoon 1973) | (Persoon 1973)                |
|                          | May                      | Tennessee, USA         | Sweetgum (Liquidambar styraciflua), hackberry (Celtis occidentalis), sugar maple (Prunus serotina), Norway maple (Acer platanoides), honeylocust (Prunus serrulata) | (Persoon 1973)               |
| Eulecanium cerasorum     | Late-May                 | Kentucky, USA          | Apple, buckeye, dogwood, elm, locust, maple, pear (Madsen and Barnes 1959) | (Madsen and Barnes 1959) |
|                          | Late-May to early-June   | California, USA        | Pear (Klingeman et al. 2002)  | (Klingeman et al. 2002)        |
|                          | June to early-July       | Pennsylvania, USA      | Crabapple, dogwood, elm, maple, honeylocust, Japanese zelcova, pear, sweetgum, Wisteria spp. (Klingeman et al. 2002) | (Klingeman et al. 2002)       |
| Eulecanium kunoense      | Early to mid-May (females) | Walnut Creek, California, USA | Various (Simanton 1916, Hoover et al. 2011) | (Simanton 1916, Hoover et al. 2011) |
|                          | March (males)            |                        |                              |                                |
| Eulecanium tiliae        | Late-May to Mid-June     | Armenia, Eurasia       | Apple, pear, plum; broad-leaved trees and shrubs (Babayan 1976) | (Babayan 1976)                |
| Lichtensia viburni       | Early to mid-June (1st generation) | Mediterranean basin | Olive, Pistacia lentiscus, Hedera helix (Pellizzari 1997) | (Pellizzari 1997)             |
| Mesolecanium nigrofasciatum | Mid-May to mid-June     | Ohio, USA              | Various (Meyer et al. 2001)  | (Meyer et al. 2001)            |
|                          | Late-May to early June   | North Carolina, USA    | Blueberry (Shetlar 2002)     | (Shetlar 2002)                 |
|                          | June                     | Pennsylvania, USA      | Peach, sycamore (Simanton 1916, Hoover et al. 2011) | (Simanton 1916, Hoover et al. 2011) |
| Neolecanium corniparvum  | June                     | New Jersey, USA        | N/A (Klingeman et al. 2002)  | (Klingeman et al. 2002)        |
|                          | May.                     | New Jersey, USA        | Magnolia spp. (Herrick 1931) | (Herrick 1931)                |
|                          | Late-July to early-Aug.  | Ohio, USA              | Magnolia spp. (Herrick 2004) | (Herrick 2004)                |
|                          | Late-Aug.                | Pennsylvania, USA      | Magnolia spp. (Klingeman et al. 2002) | (Klingeman et al. 2002)       |
|                          | Late-Aug. and Sept.      | Michigan, USA          | Magnolia spp. (Wallner 1969) | (Wallner 1969)                |
|                          | Early-Sept.              | Virginia, USA          | Magnolia spp. (Klingeman et al. 2002) | (Klingeman et al. 2002)       |
| Neopulvinaria innumerabilis | May                     | Tennessee, USA         | Alder, ash, beech, boxwood, dogwood, elm, lilac, linden, locust, maple, oak (Klingeman et al. 2002) | (Klingeman et al. 2002)       |
|                          | Mid to late-May          | Athens, Georgia, USA   | Red oak (Hodges and Braman 2004) | (Hodges and Braman 2004)       |
|                          | Early-June               | Virginia, USA          | Various (Day 2008)            | (Day 2008)                     |
|                          | Mid-June                 | Colorado, New Jersey, USA | Various hardwoods (Cranshaw et al. 1994, NDA 2006) | (Cranshaw et al. 1994, NDA 2006) |
|                          | Mid-June to mid-July     | Pennsylvania, USA      | Maple, pear (Klingeman et al. 2002) | (Klingeman et al. 2002)       |
|                          | Mid-June to early-July   | Midwestern USA         | Maple, honey locust, linden (Tilia spp.) | (Klingeman et al. 2002)       |
| Parasaizsetia nigra      | Dec. and Jan.            | California, USA        | Various (Smith 1944)          | (Smith 1944)                  |
| Parthenolecanium comi    | May (partial 2nd)        | Tennessee, USA         | Fruit trees and ornamental plants (Klingeman et al. 2002) | (Klingeman et al. 2002)       |
|                          | Late-May to mid-June(1st generation) | Athens, Georgia, USA | Pin oak (Quercus palustris), red maple (Acer rubrum), willow oak (Q. phellos) (Hodges and Braman 2004) | (Hodges and Braman 2004)       |
|                          | Early autumn (2nd generation) |                     |                              |                                |
|                          | Late May to early-July   | California, USA        | Broom (tribe Genistaeae) (Birjandi 1981) | (Birjandi 1981)               |
|                          | Early-June               | Virginia, USA          | Various (Klingeman et al. 2002) | (Klingeman et al. 2002)       |
|                          | June and July            | Midwestern USA         | Various (Klingeman et al. 2002) | (Klingeman et al. 2002)       |
|                          | Mid-June                 | New Jersey, USA        | N/A (Klingeman et al. 2002)  | (Klingeman et al. 2002)       |
|                          | Mid-June to mid-July(1st generation) | Pennsylvania, USA   | Various (Klingeman et al. 2002) | (Klingeman et al. 2002)       |
|                          | Mid-Aug. (2nd generation) |                         |                              |                                |
|                          | Mid-July                 | California, USA        | Pear, elm (Asquith 1949, Hoover et al. 2011) | (Asquith 1949, Hoover et al. 2011) |
|                          | Oct. to early-Nov. (1st generation) | Chile                  | Grapes (Essig 1915, Madsen and Barnes 1959) | (Essig 1915, Madsen and Barnes 1959) |
| Parthenolecanium fletcheri | Early-June              | Virginia, USA          | Arborvitae, yew, pachysandra, eastern red cedar (Asquith 1949, Hoover et al. 2011) | (Asquith 1949, Hoover et al. 2011) |

(continued)
Table 3. Continued

| Species | Time of the year | Location | Host cited in the references | References |
|---------|------------------|----------|------------------------------|------------|
| Parthenolecanium fletcheri | June | Pennsylvania, USA | Arborvitae (Thuja spp.), yew | (Hoover 2006) |
| | Mid to late-June | Midwestern USA | Various | (Krischik and Davidson 2003, Herms 2004) |
| | Late June | Central Europe | Cupressus, Juniperus, Platycladus, Thuja, Tsuga | (Malumphy et al. 2011) |
| Parthenolecanium orientale | July, mid-Aug. | New Jersey, USA | Grapevine (Vitis vinifera) | (Li 2004) |
| Parthenolecanium persicae | Mid-May | Southern Greece | Grapevine | (Stathas et al. 2003b) |
| | Early-May | Ohio, USA | Various | (Shettar 2002) |
| | Mid-May to mid-June | Henrico County, Virginia, USA | Barberry | (Kosztarab 1996) |
| | Late-July | Chile | Fruit trees | (Bayer CropScience Chile 2014) |
| | Mid-Nov. | | | |
| Parthenolecanium pruinosum | Late-May to June | California, USA | Walnut | (Michelbacher 1955) |
| Parthenolecanium querciflexus | Late-May | Virginia, USA | Oaks, hickory, birch | (Schultz 1984) |
| Physokermes piceae | Mid-May | Greece | English oak (Quercus robur) | (Raini and Pellizzari 2009) |
| | Late-May to June | Wooster, Ohio, USA | N/A | (Gouni and Pellizzari 2012) |
| | Late-June | Colorado, USA | Spruce | (Cranshaw et al. 1994) |
| | May (males) | Florida, USA | Avocado | (Moznette 1922) |
| Pulvinaria acericola | Mid-May to early-June | Virginia, USA | Maple, dogwood, holly, andromeda, gum | (Day 2008) |
| | June to early-July | Pennsylvania, USA | Azalea | (Hoover et al. 2006) |
| | June 8 to 14 | Lexington, Kentucky, USA | Red maple | (Hoover et al. 2006) |
| Pulvinaria amygdali | June | New York State, USA | Peach, plum, quince | (Mussey and Potter 1997) |
| Pulvinaria floracifera | Late-May | Pennsylvania, USA | Holly, ivy, Taxus spp. | (Harman 1927) |
| | Late-June | Virginia, USA | Camellia, holly, Taxus spp., rhododendron, hydrangea, maple, English ivy | (Hoover et al. 2006) |
| | Mid-May to late-June | New Jersey | Various | (Klingeman et al. 2002) |
| | June | Athens, Georgia, USA | Burford holly, Bradford pear | (Westcott 1973) |
| | Mid-June | Tennessee, USA | Callicarpa spp., Camellia spp., holly, hydrangea, maple, yew | (Haliastri-Sani et al. 2012) |
| | Late-June to early-July | Connecticut, Rhode Island, USA | Various | (Klingeman et al. 2002) |
| | Mid-July to late-June | Guilan and Mazandaran provinces, Iran | Citrus, Taxus baccata, Pittosporum tomentosa, Ilex aquifolium, Camellia sinesis | (Haliastri-Sani et al. 2012) |
| Pulvinaria hydrangeae | July | Europe; Australia; New Zealand; USA | Various | (Baker et al. 2008) |
| Pulvinaria polygonata | March | India | Mango, citrus | (Chatterji and Datta 1974) |
| | Early-May (1st generation) | Egypt | Guava | (Baker et al. 2012) |
| Pulvinaria psidii | Early-June to early-July (2nd generation) | California, USA | Prune, apple, peach, plum | (Essig 1915) |
| | Early-June to mid-Sept. (3rd generation) | Germany; former Soviet Union | Various | (Schmutterer 1952, Borchsenius 1957) |
| Pulvinaria rhois | Mid-Aug. | Ontario, Canada | Peach | (Phillips 1963) |
| Pulvinaria vitis | Mid-May | Pacific Northwest USA | Grape | (Hollingsworth 2014) |
| | July–Aug. | Oakland, California, USA | Ice plant (Carpobrotus sp.) | (Washburn and Frankie 1981) |
| Pulvinariella mesembrianthemi | Sept.–Nov. (partial 2nd generation) | Eastern Spain | Stone fruits | (Babayan 1986) |
| Rhodococcus turanicus | June to July (for 1 generation) | | Citrus, olive | (Bibolíni 1958, Argüerio 1963, Peleg 1965, Nuzzaci 1969b, De Freitas 1972) |
| | Mar. to Oct. (for 2 generations) | Eastern Spain | Citrus, olive | (Briales and Campos 1986, Nogueria et al. 2003, Tena et al. 2007) |
| | Oct.–Nov. | Eastern Spain | Various fruit trees | (Simmonds 1951, Garcia 1969, González and Lamborot 1989) |
| Sphaerolecanium prunastri | Mid-May to mid-June | Ohio, USA | Various | (Shettar 2002) |
| | June | Pennsylvania, USA | Purpleleaf plum, Pyracantha spp. | (Hoover et al. 2011) |
| Toumeyella liriodendri | Aug. | New Jersey, Pennsylvania, Tennessee, USA | Tulip tree, magnolia, linden | (Dong and Cai 2002, Hoover et al. 2011) |
| | Sept. | Virginia, USA | Tulip tree, magnolia | (Ferri et al. 2001) |
| | Late Aug. to Sept. | Midwestern USA | Tulip tree, magnolia, basswood, buttonbush, hickory, lilac, redbud, walnut | (Klingeman et al. 2002, NJDA 2006, Hoover et al. 2011) |

(continued)
Miller et al. 2004, Ben-Dov et al. 2015, Oswald 2014). Other beetles, hemipterans, flies, caterpillars, mites, and spiders are occasional or opportunistic predators of soft scales (Clausen 1978, Kosztarab 1996, Harris 1997, Ponsonby and Copland 1997, Hodges and Braman 2004, Rakimov et al. 2015).

Resident natural enemies kill many soft scales in the outdoor environment. Two encyrtid, two pteromalid, and one aphelinid parasitoid species were responsible for 10–60% mortality in P. quercifex population (Schultz 1984). Three aphelinid, nine encyrtid, one eucoilid, and one pteromalid species contributed up to 37.5 and 4.5% mortality in nymph and adult Eulecanium cerasorum (Cockerell), respectively, whereas Hyperaspis sp. (Coccinellidae) reduced crawler abundance by 47.6% (Hubbard and Potter 2005). Anthribus nebulosus (Forster) (Anthrhidiae) reduced Physokermes inopinatus Danzig and Kozár population by 55% and Physokermes piceae (Schrank) population by 59% (Kosztarab and Kozár 1983), whereas Anthribus niveovariegatus Reolofo reduced E. pela population by 75% (Deng 1985). Where spiders were left undisturbed, C. floridensis population was below damaging levels (Mansour and Whitecomb 1986). Parasitoids, predators, entomopathogenic fungi, leaf abscission, and rainfall resulted in 96% mortality in C. viridis populations (Rosado et al. 2014). Insecticide treatment against P. corni on fruit trees in California's Central Valley can be omitted if a large (but unspecified) number of scale insects are parasitized in the summer (Bentley and Day 2010).

Conserving existing natural enemy populations is an important strategy in managing soft scale pests. Studies are needed to assess the mechanism, adoption, and effectiveness of habitat manipulation, which include provision of alternative food sources, alternative prey or hosts, shelter and favorable microclimatic conditions (Landis et al. 2000), for soft scale management. In the only relevant study to date, Paredes et al. S. oleae etation diversity and natural enemy shelter, did not reduce shelter and favorable microclimatic conditions (Landis et al. 2000), for an extent scale insect abundance was reduced by the insecticides, the timing of application, the mode of contact with the insecticide residue, and the sublethal effects of these insecticides on the pests and the natural enemies; these are largely unknown for soft scale pests and their natural enemies.

Ants can interfere with foraging and reproductive behaviors of natural enemies through direct attack or incidental disturbance (Bartlett 1961, Bach 1991, Buckley and Gullan 1991, Itioka and Inoue 1996a, 1996b). Ant-exclusion increased predator abundance and reduced soft scale abundance (Vanek and Potter 2010).

Natural enemies, especially parasitoids, are successful in many classical and augmentative biological control programs (Kapranas and Tena 2015). The introduction of Anictus beneficus Ishii and Yasumatsu (Encyrtidae) achieved successful control of C. rubens in Japanese citrus orchards within 2.5 yr (Yasumatsu 1951, 1953, 1958, 1969; Smith 1986; Takagi 2003). The introduction of Metaphycus rutaevius (Timberlake) and Metaphycus helvolus (Compere) reduced C. pseudomagnoliarum populations in southern California (Bartlett 1978), but it was unsuccessful in the San Joaquin Valley (Gressit et al. 1954, Bartlett 1978, Kennett 1988, Kennett et al. 1995) because of mismatch of the natural enemy species with local environmental conditions (Bernal et al. 2001). Suppression of some soft scale populations may require a complex of native and introduced natural enemy species (Schweizer et al. 2002).

Although formulation and high production cost limited earlier adoption, recent advances have allowed greater use of entomopathogenic fungi in crop production (Evans and Hywel-Jones 1997). The efficacy of entomopathogenic fungi depends on appropriate environmental conditions (Evans and Hywel-Jones 1997). In humid tropical regions, Verticillium lecanii (Zimmermann) Viegas is the main mortality factor of C. viridis (Murphy 1997). Efficacy of entomopathogenic fungi also depends on pest species. More C. destructor died from V. lecanii and Fusarium spp. infections than C. sinensis on citrus in Northland, New Zealand (Lo and Chapman 1998).

### Chemical Control

Insecticides registered for soft scale management can be broadly categorized into contact and systemic insecticides. Systemic insecticides, which include members of organophosphates, neonicotinoids, tetramic acid derivatives, and diamides, function as contact insecticides when applied as topical sprays directly on the scale insects. When applied as soil drench, soil injection, basal trunk spray, trunk injection, granular broadcast, and pellet broadcast, systemic insecticides are absorbed by plant tissues and translocated to the canopy. Their application flexibility and efficacy make systemic insecticides the preferred management tool against scale insect pests on large trees, in sensitive areas and in the urban landscape.

| Species | Time of the year | Location | Host cited in the references<sup>a</sup> | References |
|---------|-----------------|----------|--------------------------------------|------------|
| *Toumeyella parvicornis* | June to early-July (in 1 generation) | Colorado and Nebraska, USA | *Pinus* spp. | (Clarke 2013) |
| | May to late-July (in 2 generations) | Maryland, Virginia, North Carolina, USA | *Pinus* spp. | (Clarke 2013) |
| *Toumeyella pini* | Late May to Early-June | Colorado, USA | *Pinus sylvestris*, *Pinus mugo*, *Pinus edulis*, *Pinus nigra* | (Cranshaw et al. 1994) |
| | Mid-June to mid-July | Pennsylvania, USA | *Pinus* spp. | (Hooier et al. 2011) |
| | June 20 | Wooster, Ohio, USA | *Pinus* spp. | (Herm's 2004) |
| | Feb. | Southern California, USA | *Pinus* spp. | (Dreistadt 2004) |
| | Mid-April to mid-May, Late April | San Mateo Co., California, USA | *Pinus* spp. | (Kattoulas and Koehler 1965) |
| | Aug. (males) | San Francisco Bay area, California, USA | *Pinus* spp. | (Dreistadt 2004) |
| | | San Mateo Co., California, USA | *Pinus* spp. | (Kattoulas and Koehler 1965, Gill 1988) |

<sup>a</sup> N/A, not specified.
Systemic insecticides have longer residual efficacy than contact insecticides. Some ornamental plant growers and landscape care professionals use systemic insecticides to prevent infestation and damage by certain recurring pests, such as soft scales (Chong, personal observations). Systemic insecticides provide sufficient population suppression of certain scale insect species with only one application per year (Frank 2012; Chong, unpublished data). Typically, the application is made just before crawler emergence to ensure the highest concentration of active ingredients in the plant tissues. Although systemic insecticides have the benefits of greater flexibility and residual longevity, recent studies suggest that neonicotinoids should be used carefully because of their potential impact on pollinator health (Cowles et al. 2014, Pisa et al. 2014, Johnson and Corn 2015) and their implication in spider mite outbreaks (Raupp et al. 2004, Szczepaniec and Raupp 2012a, 2012b; Szczepaniec et al. 2013).

Contact insecticides registered for soft scale management in the United States include carbamates, organophosphates, pyrethroids, neonicotinoids, juvenile hormone mimics, fenoxycarb, pyriproxyfen, flonicamid, buprofezin, tolylpyren, spirotetramat, diamides, azadirachtin, horticultural oils, and insecticidal soaps. A layer of wax, which is impermeable to aqueous insecticide solution, covers the body of older nymphs and adults. Targeting crawlers and settled first instars, which lack or have only a thin protective wax layer, can achieve the greatest efficacy (Kosztarab and Kozár 1988, Kabashima and Dreistadt 2014). Repeated applications (sometimes biweekly depending on insecticide residual longevity) may be needed because crawlers emerge over several weeks or months. IPM practitioners can use short residual or compatible insecticides (such as horticultural oil and insect growth regulators) to minimize impact on pollinators, natural enemies, and other nontarget organisms (Kosztarab and Kozár 1988, Kabashima and Dreistadt 2014).

Voltinism affects the frequency of contact insecticide application. When timed and applied properly, insecticides can reduce the population of univoltine species within one season (Chong, unpublished data). Suppressing the population of a multivoltine species may require multiple applications targeting crawlers of different generations (Bethke 2010, Chong, unpublished data).

Acknowledgments

We thank four anonymous reviewers for their constructive comments. This project was supported by United States Department of Agriculture, National Institute of Food and Agriculture (USDA-NIFA) under project number SC-1700473 and grant number 2010-34103-21144. This is Technical Contribution No. 6286 of the Clemson University Experiment Station.

References Cited

Abd-Elalim Moharum, F. 2011. Ecological studies on the citrus wax scale insect, Ceroplastes floridensis Comstock (Hemiptera: Cocidae) on banana plants. Ann. Agric. Sci. Mohshohor 49: 469–472.

Abd-Rabou, S., N. Ali, and M. M. El-Fatih. 2009. Life table of the hemispherical scale, Saissetia oleae (Walker) (Hemiptera: Cocidae). Egypt. Acad. J. Biol. Sci. 2: 165–171.

Abd-Rabou, S., N. Aly, and H. Badary. 2012. Biological studies of the cotylyd camelia scale, Pulvinaria florivora (Hemiptera: Cocidae) with updating lists of host plants and natural enemies in Egypt. Egypt. Acad. J. Biol. Sci. 5: 107–112.

Alford, D. V. 2007. Pests of fruit crops: a color handbook. Plant Protection Handbook Series. Academic Press, Elsevier, Burlington, MA.

Amarasekare, K. G., and C. M. Mannion. 2011. Life history of an exotic soft scale insect Phalacrocorax howertoni (Hemiptera: Cocidae) found in Florida. Fla. Entomol. 94: 588–593.

Angel, R. A., and S. G. Radwan. 2013. On the scale insects infesting mango trees and their parasites at Qaloubia governorate, Egypt. Egypt. J. Biol. Pest Control 23: 131–135.

Ammerman, D. P. 1969. Biological studies on the immature stages of soft brown scale, Coccus hesperidum Linnaeus (Hemiptera: Cocidae). South Afr. J. Agric. Sci. 9: 205–227.

(AQSIQ) General Administration of Quality Supervision, Inspection and Quarantine of the People’s Republic of China. 2007. Reply on supplementary information on pests in table grapes exported from China to Australia received on 19 March 2007. In Biosecurity Australia (2011), China’s Commercial Production Practices for Table Grapes 15. Department of Agriculture, Fisheries and Forestry, Canberra, Australia.

Argyriou, L. C. 1963. Studies on the morphology and biology of the black scale [Saissetia oleae (Bernard)] in Greece. Annales de l’ Institut Phytopathologique Benaki 5: 353–377.

Argyriou, L. C., and A. G. Ioannides. 1975. Coccus aegaeus (Homoptera, Cocicidae, Cocidae) De Lotto: Nouvelle espèce de lecanine des citrus en Grèce. Fruits 30: 161–162.

Argyriou, L. C., and S. S. Paloukis. 1976. Some data on biology and parasitization of Sphaerolecanium paranistris Fonscolomb (Homoptera Cocicidae) in Greece. Annales de l’Institut Phytopathologique Benaki 11: 230–240.

Argyriou, L. C., and A. L. Kournadagas. 1980. Ceroplastes floridensis Comstock an important pest of citrus trees in Aegean islands. Fruits 35: 705–708.

Argyriou, L. C., and A. P. Santorinio. 1980. On the phenology of Ceroplastes ruscii L. (Hom.: Cocidae) on fig-trees in Greece. Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversite Gent. 45: 593–601.

Asquith, D. 1949. Two generations of European fruit lecanium in southern California. J. Econ. Entomol. 42: 853.

Avido, Z., and A. Zaiziev. 1960. On the biology of the mango shield scale Coccus mangiferarum (Green) in Israel. Kvavin 10: 125–137.

Avido, Z., and I. Harzap. 1969. Plant pests of Israel. Israel Universities Press, Jerusalem, Israel.

Babayan, G. A. 1973. The soft scale Dideaecoccus unifasciatus (Arch.) (Homoptera, Cocicidae) in Armenia and the characteristics of its morphology. Entomol. Rev. 52: 97–101.

Babayan, G. A. 1976. Morphological and biological characteristics of Eucalenium tiliae L. (Homoptera, Cocicidae, Cocicidae) in Armenia. Entomol. Rev. 55: 34–38.

Babayan, G. A. 1986. Scale insects of stone fruit crops and control measures against them. Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri 43: 133–138.

Bach, C. E. 1991. Direct and indirect interactions between ants (Pheidole megacephala), scales (Coccus viridis) and plants (Pluchea indica). Oecologia 87: 223–239.

Baker R.F.A., S. F. Mousa, L. S. Hamouda, R. M. Badawy, and S. A. Atteia. 2012. Scale insects infesting guava trees and control measure of Pulvinaria psidi (Hemiptera: Cocicidae) by using the alternative insecticides. Egypt. Acad. J. Biol. Sci. 5: 89–106.

Bakr, R. F., R. M. Badawy, S. H. Laila, E. Helmy, and S. A. Attia. 2010. Taxonomic and ecological studies on the new record, Ceroplastes cripipiformis Comstock, 1881, (Cocicidae: Homoptera) at Qalubiya governorate. Egypt. Acad. J. Biol. Sci. 3: 119–132.

Barbitallo, S. 1974. Notizie sulla presenza in Sicilia di una nuova coccinglia degli agumi: Coccus pseudomagnoliarum (Kuwana) (Homoptera, Cocicidae). Osservazioni Biologiche Preliminarie. Entomologia 10: 121–139.

Bartlett, B. R. 1961. The influence of ants upon parasites, predators, and scale insects. Ann. Entomol. Soc. Am. 54: 543–545.

Bartlett, B. R. 1978. Cocicidae, pp. 57–74. In C. P. Clausen (ed.), Introduced parasites and predators of arthropod pests and weeds: A world review. Agriculture Handbook, United States Department of Agriculture, Agricultural Research Service, Washington, DC.

Bayer CropScience Chile. 2014. Problems: Conchuelas. Bayer S.A., Santiago, Chile. (http://www.bayercropsience.cl/soluciones/problemas.aspx)

Beatrice, G.A.C., and J. C. Kaldor. 1990. Comparison of high-volume oscillating boom and low-volume fan-assisted rotary atomiser sprayers for the control of Chinese wax scale, Ceroplastes sinensis del Guercio (Hemiptera: Cocicidae), on Valencia orange, Citrus sinensis (L.) Osbeck. Gen. Appl. Entomol. 22: 49–53.

Cattell, G.A.C., A. D. Clift, W. J. Allender, L. Jiang, and Y. A. Wang. 1991. Efficacies of low- to high-volume (960–10 700 litre ha–1) citrus sprayers for applying petroleum spray oil to control Chinese wax scale. Pest. Sci. 32: 47–59.

Beigieola, G. O. 1969. Notas sobre la biologia de Saissetia oleae Bernh. (Hom.: Cocicidae) “querea negra del olivo”en laboratorio y en el campo. Revista Peruana de Entomologia 12: 130–136.

Benassy, C., and E. Franco. 1974. On the ecology of Ceroplastes ruscii L. (Homoptera, Lecanoidae) in the Alpes-Maritimes. Ann. Zool. Ecol. Anim. 6: 11–39.

Ben-Dov, Y. 1968. Occurrence of Sphaerolecanium paranistris (Fonscolombe) in Israel and description of its hitherto unknown third larval instar. Annales des Epiphyties 19: 615–621.
**Kosztarab, M.** 1957a. *Coniferous forest trees*, pp. 343–346. 

**Kosztarab, M.** 1959. *Studies on the genus Ceroplastes: their biology, natural enemies and control, vol. 7A*. Elsevier Science B.V., Amsterdam, The Netherlands.

**Kosztarab, M.** 1966. *The consequence of ant-attendance to the biological control of the red wax scale insect Ceroplastes rubens by Anecetus beneficialis*. J. Appl. Ecol. 33: 609–618.

**Jarraya, A.** 1974. *Observations biologiques sur une cochenille citricole dans la region de Tunis, Saissetia oleae* (Bernard) (Homoptera, Cococcidae). Bulletin-Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique 3: 135–157.

**Johnson, W. T., and H. H. Lyon.** 1991. *Ceroplastes rubens: biological control of the red wax scale insect*. J. Econ. Entomol. 84: 126–130.

**Kapranas, A., and A. Tena.** 2015. Enzyme parasitoids of soft scale insects: Biology, behavior, and their use in biological control. Annu. Rev. Entomol. 60: 195–211.

**Katsyvanyos, P.** 1996. *Integrated insect pest management for citrus in northern Mediterranean countries*. Benaki Phytopathological Institute, Kiphissia, Athens, Greece, p. 110.

**Kattoulas, M. E., and C. S. Koehler.** 1965. *Studies on the biology of the irregular pine scale*. J. Econ. Entomol. 58: 727–730.

**Kawecki, Z.** 1987. *Studies on the genus Lecanium Burm*. Part IV. Materials to a monograph of the brown scale, *Lecanium corni* Bouché, Marchal (Hemiptera: Coccidae). Annales Zoologici Warszawa 17: 135–245.

**Kehr, A. E.** 1972. Research – what’s new in ‘72. Presentation given at 1972 Pests in the spotlight: Top tips. 

**Kehn, C. E.** 1988. Results of exploration for parasitoids of citricola scale, *Coccus pseudomagnoliarum* (Homoptera: Cococcidae), in Japan and their introduction to California. Kontyu, Tokyo 56: 445–457.

**Kerr, C. E., K. S. Hagen, and K. M. Daane.** 1995. *Citricola scale, pp. 148–149*. In *J. R. Nechols, L. A. Andres, J. W. Beardsley, R. D. Goeden, and C. G. Jackson (eds.), Biological control in the western United States: Accomplishments and benefits of regional research project W-84, 1964–1989*. University of California, Division of Agricultural and Natural Resources, Oakland, CA.

**Klingeman, B., P. Lambdin, and F. Hale.** 2002. *Bionomics of Ceroplastes floridensis (Homoptera: Coccidae)*. University of Florida, Gainesville.

**Kosztarab, M., and F. Koza´r.** 1988. *Scale insects of central Europe*. Budapest: Akadémiai Kiadó 41: 1–456.

**Kozor, F.** 1972. *Susceptibility of peach varieties to infection by scale, with special regard to San José scale*. Acta Phytopathol. Acad. Sci. Hungaricae 7: 409–414.

**Krischik, V., and J. Davidson.** 2003. *IPM of Midwest landscapes: tactics and tools for IPM*. University of Minnesota, Minnesota Agriculture Experiment Station, St. Paul, MN.

**Kulhanek, A.** 2009. User-friendly methods for timing integrated pest management strategies: An analysis of degree-day models and biological calendars. M.S. thesis, Ohio State University, Columbus, OH.

**Kunkel, H.** 1997. Factors affecting the built-up of scale insect populations, pp. 297–298. In *Y. Ben-Dov and C. J. Hodgson (eds.), Soft scale insects: Their biology, natural enemies and control*, vol. 7A. Elsevier Science B.V., Amsterdam, The Netherlands.

**Kwana, S. I.** 1923. *Descriptions and biology of new or little-known coccids from Japan*. Bull. Agric. Commer. Imp. Plant Quarantine Stn. Yokohama 3: 1–67.

**Lai, C. B.** 1993. *Study on the bionomics of Ceroplastes ceriferus Anderson in tea gardens and its control*. Entomol. Knowl. 30: 337–338.

**Landis, D. A., S. D. Wratten, and G. M. Gurr.** 2000. *Habitat management to conserve natural enemies of arthropod pests in agriculture*. Ann. Rev. Entomol. 45: 175–201.

**LeBude, A. V., A. S. White, A. F. Fulcher, S. Frank, J.-H. Chong, M. R. Chappell, A. Windham, S. K. Braman, W. E. Klingenman III, K. Ivors, et al.** 2012. Assessing the integrated pest management practices of southeastern U.S. nursery operations. Pest Manag. Sci. 68: 1278–1288. (doi:10.1002/ps.3295).

**Li, C.-Y., and T. H. Su.** 2002. *Effects of temperature on development of the hemispherical scale, Saissetia coffeae* (Walker) (Homoptera: Cococcidae), and its occurrence on cacao (*Cycas taiwanian Carr.*). Formosan Entomol. 22: 65–74.

**Li, Z. X.** 2004. *Control of pests and diseases of table grape*. In *Biosecurity Australia (2011), China’s commercial production practices for table grapes*. 15. Department of Agriculture, Fisheries and Forestry, Canberra, Australia.

**Lloréns, J. M.** 1990. *Homoptera 1 - Cochinillas de los citricos y su control biológico, 3rd ed. Pisa Ediciones, Valencia, Spain.

**Lloréns-Climent, J. M.** 1984. *Las Cochinillas de los Agrios. Conselleria de Agricultura, Pesca y Alimentacion, Servicio de Proteccion de los Vegetales, Valencia, Spain*

**Lo, P. L., and R. B. Chapman.** 1998. The role of parasitoids and entomopathogenic fungi in mortality of third-instar and adult *Ceroplastes destructor* and *C. sinensis* (Hemiptera: Cocccidae: Ceroplasticinae) on citrus in New Zealand. Biocontrol Sci. Technol. 8: 573–582.

**Lo, P. L., R. H. Blank, and D. R. Penman.** 1996. *Phenology and relative abundance of Ceroplastes destructor and C. sinensis* (Hemiptera: Cocccidae) on citrus in Northland, New Zealand. N Z. J. Crop Horticult. Sci. 24: 315–321.

**Loch, A. D., and M. P. Zalucki.** 1997. *Variation in length, fecundity and survival of pink wax scale, Ceroplastes rubens* (Hemiptera: Cocccidae), on umbrella trees. Aust. J. Zool. 45: 399–407.

**Longo, S., and D. Benfatto.** 1982. *Note biologiche su Coccus hesperidum L. (Rhyphocota, Cococcidae) e risultati di prove di lotta. Giornale Fitopatologico 3: 139–146.

**Longo, S., and A. Russo.** 1986. Distribution and density of scale insects (Homoptera, Cocccidae) on citrus-groves in Eastern Sicily and Calabria, pp. 41–50. In *Integrated pest control in citrus-groves*, Proceedings of the Experts’ Meeting, 26–29 March 1985. Acricale. Commission of the European Communities. Rotterdam, The Netherlands.

**Madsen, H. F., and M. M. Barnes.** 1959. *Pests of pear in California*. Calif. Agric. Exp. Stn. Circular 478: 1–10.

**Malumphy, C. P.** 1992. *A morphological and experimental investigation of the Pulvinaria vitis complex in Europe*. Ph.D. thesis, Imperial College, University of London, United Kingdom.

**Malumphy, C. P.** 1997. *Morphology and anatomy of honeydew eliminating organs, pp. 269–274*. In *Y. Ben-Dov and C. J. Hodgson (eds.), Soft scale insects: their biology, natural enemies and control*, vol. 7A. Elsevier Science B.V., Amsterdam, The Netherlands.

**Malumphy, C., D. Eyre, and R. Cannon.** 2011. *Plant pest factsheet: fletcher scale Panomera lecanium fletcheri*. The Food and Environmental Research Agency, Crown Publishers, Sand Hutton, York, United Kingdom. (http://www.fera.defra.gov.uk/plants/publications/documents/factsheets/fletcherScale2011.pdf)
Soria, S., P. Del Estal, and E. Vinuela. 1996. Direct and indirect effects of imidacloprid on spider mites on elm trees in urban landscapes PLoS ONE 6: e20018.

Tassan, R. L., and K. S. Hagen. 1995. Iceplant scales, pp. 150–154. In J. R. Nechols (ed.), Biological control in the western United States: accomplishments and benefits of regional research project W-84, 1964-1989. University of California, Division of Agriculture and Natural Resources, publication 3361, Oakland, CA.

Tena, A., A. Soto, R. Vercher, and F. Garcia-Mari. 2007. Density and structure of Saissetia oleae (Hemiptera: Coccidae) populations on citrus and olives: relative importance of the two annual generations. Environ. Entomol. 36: 700–706.

Tena, A. and F. Garcia-Mari. 2008. Suitability of citrula scale Coccus pseudomona- lulorum (Hemiptera: Coccidae) as host of Metaphycus helvolus (Hymenoptera: Encyrtidae): Influence of host size and encapsulation. Biol. Control. 46: 341–347.

Teras, A. L. and N. H. Gayot. 1969. La cochinilla del delta. Lecanium delticum (Lizer) (Hom., Coccidae), en Tucumán. Acta Zoologica Lilloana 24: 135–149.

Tereznikova, E. M. 1981. Scale insects: Eriococcidae, Kermeidae and Coccidae. Fauna Ukraine. Akademiya Nauki Ukrainskoi SSR. Institut Zooloogii. Kiev 2: 1–215.

Thiem, H. 1933a. Beitrag zur parthenogenenese und Phanologie der Geschlechter von Eulecanium cori (Bouch) (Coccidae). Zeitschrift fur Morphologie und Oekologie der Tiere 27: 294–324.

Thiem, H. 1933b. Sexual biologische studien an der zwetschen schildaune (Eulecanium cori), Forchungen und Forschritte 9: 492–493.

Thomson, M. 1929. Sex determination in Lecanium, pp. 18–24. In K. Jordan and N. W. Horn (eds.), Proceedings of the 4th International Congress of Entomology, August 1928, Ibaca, NY. G. Patz, Naumburg, Germany.

Trumble, J. T., E. J. Graenf-Cardwell, and M. J. Brewer. 1995. Spatial disper- sion and binomial sequential sampling for citricia scale (Homoptera: Coccidae) on citrus. J. Econ. Entomol. 88: 897–902.

Tulashvili, N. 1930. Observations on pests of tea and citrus on the Batum coast during 1927–28, pp. 189–190. In Mitt. PilSbAbt. Volkslom. Landw. SSR Georgien, Tiflis, GA.

Tuncurey, M., and C. Oncuer. 1974. Studies on aphisiparous scale insects and their hosts, citrus deasipar scale insects, in citrus orchards in the Aegean region. WPRS Bull. 3: 95–108.

Tzalev, M. 1968. Beitrag uber die erforschung der schildaufenauna (Homoptera, Coccidae) der park und zierpflanzen in Bulgarien. Bulletin de l’Institut de Zoologie et Musee 28: 265–286.

Ulgenturk, S., and H. Canakcioglu. 2004. Scale insect pests on ornamental plants in urban habitats in Turkey. J. Pest Sci. 77: 79–84.

Ulgenturk, S., H. Canakcioglu, and A. Topper Kaygın. 2004. Scale insects of the conifer trees in Turkey and their zoogeographical distribution. J. Pest Sci. 77: 99–104.

Vance, S., D. A. Potter. 2010. Ant-exclusion to promote biological control of soft scales (Homoptera: Coccidae) on woody landscape plants. Environ. Entomol. 39: 1829–1837.

Vesev-Fitzgerald D. 1940. The control of coccidiae on coconut in the Seychelles. Bull. Entomol. Res. 31: 253–256.

Viggiani, G. 1997. Eulophiidae, Pteromalidae, Eupelmidae and Signiphoridae, pp. 147–160. In Y. Ben-Dov and C. J. Hogson (eds.), Soft scale insects: their biology, natural enemies and control, vol. 7b. Elsevier Science B.V., Amsterdam, The Netherlands.

Viggiani, G., P. Finimand, and M. Bianco. 1973. Ricerca di un metodo di lotta integrata per il controllo della Saissetia oleae (Oliv.). Atti Giornate Fitopatologiche, Bologna: 251–259.

Vranjic, J. A. 1997. Effects on Host Plant, p.p. 323–336. In Y. Ben-Dov and C. J. Hodgson (eds.), Soft scale insects: their biology, natural enemies and control, vol. 7A. Elsevier Science B.V., Amsterdam, The Netherlands.

Vu, N. T., R. Eastwood, C. T. Nguyen, and L. V. Pham. 2006. The fig wax scale Ceroplastes rusci (Linnaeus)(Homoptera: Coccidae) in south-east Vietnam: pest status, life history and biocontrol trials with Eublemma amabi- lis Moore (Lepidoptera: Noctuidae). Entomol. Res. 36: 196–201.

Wakgari, W. M., and J. H. Giliomee. 2000. Fecundity, fertility and phenology of white wax scale, Ceroplastes destructor Neuwedt (Homoptera: Coccidae), on citrus and Syzygium in South Africa. Afr. Entomol. 8: 233–242.

Wakgari, W. M., and J. H. Giliomee. 2001. Effects of some conventional insecticides and insect growth regulators on different phenological stages of the white wax scale, Ceroplastes destructor Neuwedt (Homoptera: Coccidae), and its primary parasitoid, Aprostocetus seroplastae (Girault) (Hymenoptera: Eulophidae). Int. J. Pest Manag. 47: 179–184.

Wallner, W. E. 1969. Insects affecting woody ornamentals, shrubs and trees. Michigan State University Cooperative Extension Service, Farm Science.
Washburn, J. O., and G. W. Frankie. 1981. Dispersal of a scale insect, *Pulvinaria mesembranthemi* (Homoptera: Coccoidea) on iceplant in California. Environ. Entomol. 10: 724–727.

Washburn, J. O., and L. Washburn. 1984. Active aerial dispersal of minute wingless arthropods: Exploitation of boundary-layer velocity gradients. Science 223: 1088–1089.

Washburn, J. O., G. W., Frankie, and J. K. Grace. 1985. Effects of density on survival, development and fecundity of the soft scale, *Pulvinaria mesembranthemi* (Homoptera: Coccidae) and its host plant. Environ. Entomol. 14: 755–761.

Waterhouse, D. F., and D.P.A. Sands. 2001. Classical biological control of arthropods in Australia. ACIAR Monograph 67, ACIAR (Australian Center for International Agricultural Research), Canberra, Australia.

Waterworth, R. A., and J. G. Millar. 2012. Reproductive biology of *Pseudococcus maritimus* (Hemiptera: Pseudococcidae). J. Econ. Entomol. 105: 949–956.

Wen H. C. and H. S. Lee. 1986. Seasonal abundance of the ceriferus wax scale *Ceroplastes pseudoceriferus* in southern Taiwan and its control. J. Agric. Res. Chin. 35: 216–221.

Westcott, C. 1973. The gardener’s bug book, 4th ed. Doubleday, Garden City, NY.

Williams, M. L. 1997. The immature stages, pp. 31–48. In Y. Ben-Dov and C. J. Hodgson (eds.), Soft scale insects: their biology, natural enemies and control, vol. 7A. Elsevier Science B.V., Amsterdam, The Netherlands.

Williams, M. L. and M. Kosztarab. 1972. Morphology and systematics of the coccidae of Virginia with notes on their biology (Homoptera: Coccoidea). Res. Div. Bull. Virginia Polytechnic Inst. State Univ. 74: 1–215.

Williams, J. R., and D. J. Williams 1980. Excretory behavior in soft scales (Hemiptera: Coccidae). Bull. Entomol. Res. 70: 253–257.

Wu, S., and W. Yu. 2000. A study on *Physokermes shaxiensis* Tang (Homoptera: Coccoidea: Coccidae). Scient. Silvae Sin. 36: 98–102.

Xia, C. Y., W. Zhang, X. Q. Sun, H. P. Li, and G. H. Dai. 2005. Observations on biological habits of *Ceroplastes rubens* Maskell in Shanghai. J. Shanghai Jiaotong University (Agricultural Science) 4: 022.

Xie, Y., X. Liu, J. Li, and M. Tang. 1995. The effect of urban air pollution on populations of *Eulecanium giganteum* (Shinji) (Coccidae) in Taiyuan City, China. Israel J. Entomol. 29: 165–168.

Yardeni, A. 1987. Evaluation of wind dispersed soft scale crawlers (homoptera: Coccidae), in the infestation of a citrus grove in Israel. Israel J. Entomol. 21: 25–31.

Yardeni, A., and D. Rosen. 1995. Crawler phenology and generation development of the Florida wax scale, *Ceroplastes floridensis*, on citrus planted in two soil types. Phytoparasitica 23: 307–313.

Yasumatsu, K. 1951. Further investigations on the hymenopterous parasites of *Ceroplastes rubens* in Japan. J. Faculty Agric. Kyushu Univ. 10: 1–27.

Yasumatsu K. 1953. Preliminary investigations on the activity of a Kyushu race of *Anicetus ceroplustis* Ishii which has been liberated against *Ceroplastes rubens* Maskell in various districts of Japan. Sci. Bull. Faculty Agric. Kyusuh Univ. 14: 17–26.

Yasumatsu, K. 1958. An interesting case of biological control of *Ceroplastes rubens* Maskell in Japan, pp. 771–775. In Proceedings of the 10th International Congress of Entomology, 1956, Montreal, Canada.

Yasumatsu, K. 1969. Biological control of citrus pests in Japan. Proc. 1st Int. Citrus Symp. Riverside 2: 773–780.

Yongxiang, W. 2008. Occurrence regularity and damage of *Ceroplastes japonicus* in poplars [J]. Forest Pest and Dis. 4: 5.

Yun, L. 1994. A preliminary study on *Ceroplastes floridensis* Comstock. J. Yunnan Agric. Univ. 9: 137–140.

Zhao, C., M. Feng, M. He, and X. Song. 1998. Preliminary studies on biological characteristics of *Ericerus pela* Chavannes. J. Anhui Agric. College 25: 367.

Received 12 March 2015; accepted 30 September 2015.