MANAGEMENT OF SCALE INSECTS IN ACEROLA ORCHARDS IN THE BRAZILIAN ACEROLA BELT

MANEJO DE COCHONILHAS DA ACEROLEIRA NO CINTURÃO ACEROLEIRO BRASILEIRO

MANEJO DE COCHINILLAS DE LA ACEROLA EN EL CINTURÓN ACEROLERO BRASILEÑO

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ABSTRACT

The Brazilian acerola belt, composed of production hubs in the Northeast, forms the main global acerola production region. In Northeast Brazil, acerola trees have adapted better to edaphoclimatic conditions; farms operate production systems with higher technological levels and maturity, and there is infrastructure for agro-industrial processing. One of the factors that compromise acerola production is infestation by scale insects (Hemiptera: Sternorrhyncha: Coccomorpha). Nymphs and adult females cause injury and damage through stylet insertion, continuous sap sucking, and injection of toxic saliva during feeding. The management of scale insects represents a critical factor, as these pests can cause financial losses by reducing productivity and increasing production costs. In this context, this chapter aims to synthesize current scientific information on scale insects associated with acerola, with particular emphasis on their management in acerola cultivation within the Brazilian acerola belt.

Keywords: Fruit Growing. Pests. Hemiptera.

RESUMO

O cinturão aceroleiro brasileiro, constituído pelos polos de produção do Nordeste, formam o principal cinturão de produção mundial. No Nordeste do Brasil a aceroleira se adaptou melhor às condições edafoclimáticas, as propriedades possuem sistema de produção com maior nível e maturidade tecnológica e encontra-se infraestrutura para o processamento agroindustrial. Um dos fatores que comprometem a produção da aceroleira é a infestação por cochonilhas (Hemiptera: Sternorryncha: Coccomorpha). As ninfas e fêmeas adultas ocasionam injúria e dano a partir da introdução do estilete, sucção contínua de seiva e injeção de saliva tóxica durante a alimentação. O manejo de cochonilhas representa um fator crítico, as cochonilhas podem ocasionar prejuízo financeiro com a redução da produtividade e aumento do custo de produção. Nesse contexto, com o presente capítulo buscou-se sintetizar as informações científicas atuais sobre as cochonilhas associadas à aceroleira,

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discutindo particularmente sobre o manejo de cochonilhas no cultivo da aceroleira no cinturão aceroleiro brasileiro.

Palavras-chave: Fruticultura. Pragas. Hemiptera.

RESUMEN
El cinturón aceroleiro brasileño, constituido por los polos de producción del Nordeste, conforma la principal región productora de acerola a nivel mundial. En el Nordeste de Brasil, la acerola se ha adaptado mejor a las condiciones edafoclimáticas; las propiedades cuentan con sistemas de producción con mayor nivel y madurez tecnológica, y existe infraestructura para el procesamiento agroindustrial. Uno de los factores que comprometen la producción de la acerola es la infestación por cochinillas (Hemiptera: Sternorrhyncha: Coccomorpha). Las ninfas y las hembras adultas ocasionan lesiones y daños mediante la introducción del estilete, la succión continua de savia y la inyección de saliva tóxica durante la alimentación. El manejo de cochinillas representa un factor crítico, ya que estas plagas pueden ocasionar pérdidas económicas debido a la reducción de la productividad y al aumento de los costos de producción. En este contexto, el presente capítulo tuvo como objetivo sintetizar la información científica actual sobre las cochinillas asociadas a la acerola, abordando particularmente su manejo en el cultivo de la acerola en el cinturón aceroleiro brasileño.

Keywords: Fruticultura. Plagas. Hemiptera.

1 INTRODUCTION

Acerola is the common name of *Malpighia emarginata* DC (Magnoliopsida: Malpighiaceae), a fruit tree found naturally in tropical and subtropical America, whose temperature demand varies between 15 and 32 °C (Assis et al., 2008; Calgaro; Braga, 2012). This name also applies to *Malpighia glabra* L. (= *Malpighia punicifolia* L.), a fruit tree with small, tasteless fruits and low juice production (Ritzinger, Ritzinger, 2011). The widely cultivated species (i.e., *M. emarginata*) is a shrub up to 3 m tall, with dense and scattered branches, opposite leaves, inflorescence with 3 to 5 perfect flowers and rounded, oval or conical fruits of red, purple, yellow or white color when ripe (Calgaro; Braga, 2012).

Acerola was disseminated after the discovery of the high content of ascorbic acid in fruits (Calgaro; Braga, 2012), which also have phenolic compounds, carotenoids, anthocyanins and antioxidant power (Mariano-Nasser et al., 2017; Prakash; Baskaran, 2018). Fruits and by-products are relevant in human and animal food and pharmacology (Almeida et al., 2014; Corrêa et al., 2017; Reis et al., 2017; Milindro et al., 2019). The fruit is climacteric, develops and matures in about 21 days, providing several harvests and short time for commercialization (Ritzinger et al., 2018). The fruit is harvested green for the vitamin supplement industry or ripe (beginning of ripeness) when destined for fresh consumption or juice and pulp industry.

The acerola tree has been cultivated in Brazil, Mexico, India, and Southeast Asia (Duke; Ducellier, 1993; Rezende et al., 2017). It was introduced in Brazil by multiple incursions throughout the nineteenth and twentieth centuries (Soares Filho; Oliveira, 2003; Calgaro; Braga, 2012). Initially it was introduced without commercial appeal, later the cultivation prospered due to its nutritional relevance. The first commercial orchards were established in the State of Pernambuco in 1955, marking the establishment of the species as cultivated in Brazil (Ritzinger; Ritzinger, 2011), recognized as an introduced cultivated species by ordinance No. 221 of September 12, 2018 (MAPA, 2018). Brazil has become the largest producer, consumer and exporter of acerola (IBGE, 2017).

The productive poles of the Northeast named here as Baixo Parnaíba (Parnaíba, Tianguá and Ubajara), Norte Cearense (Maranguape and Baturité), Submédio valley of the São Francisco River (Petrolina, Casa Nova, Juazeiro and Sobradinho), Baixo valley of the São Francisco River and adjacent municipalities (Coruripe, Lagarto, Poço Redondo and Penedo) and Zona da Mata (Alhandra, Pitimbu, Moreno, Pombos, Conde and Vitória de Santo Antão) form the main world production belt (i.e., the Brazilian acerologer belt) covering the states of Piauí, Ceará, Rio Grande Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia. Where the acerola tree has adapted better to the edaphoclimatic conditions, the properties have a production system with a higher level and technological maturity and there is infrastructure for agro-industrial processing.

Several species of insects have been associated with acerola, which can cause a relevant reduction in fruit quality and productivity. Acerola insects are phytophagous, entomophagous (predators and parasitoids), pollinators, trophobions, and pillages. The phytophagous insect guild is composed of hemiptera, coleoptera, diptera and hymenoptera, with particular relevance as a pest for hemiptera (Albuquerque et al., 2002; Ritzinger et al., 2018).

The order Hemiptera is the most diverse among hemimetabolous insects, about 106 thousand species belonging to the suborders Heteroptera (about 45 thousand), Auchenorrhyncha (about 43 thousand), Sternorryncha (about 18 thousand) and Coleorrhyncha (37 species) are known (Grazia et al., 2024). The mealybug complex (Hemiptera: Sternorryncha: Coccomorpha) brings together the main pests of acerola, particularly in the Northeast production belt.

Mealybugs are the morphologically most specialized members of the order Hemiptera, forming a monophyletic group within the suborder Sternorrhyncha, with tarsal monomers and a single claw, the remaining sternorrhynchus have two tarsal claws (Hodgson et al., 2021; Wolff et al., 2024). Within the Infraorder Coccomorpha, 56 families are currently recognized (36 current and 20 extinct) (Wolff et al., 2024).

Currently, about 559 species are known distributed in 20 families in Brazil (Grazia et al., 2024). Mealybugs are insects that infest a wide range of economically exploited hosts, including acerola (Ramos et al., 2018). Here, we synthesize the current scientific information on mealybugs associated with acerola, particularly discussing the management of mealybugs in the cultivation of acerola in the Brazilian acerola belt.

2 CATALOGED RECORD OF MEALYBUGS ASSOCIATED WITH ACEROLA.

In the "*ScaleNet*" *database* there are about 27 species of mealybugs associated with plants of the genus *Malpighia* L., several species are associated with *M. glabra* (García Morales et al., 2016). Currently there are 18 species belonging to six zoological families associated with the M acerola tree. *emarginata*, mainly in countries or territories of the American continent (Table 1). In Brazil, 12 species from five zoological families (i.e., Coccidae, Diaspididae, Monophlebidae, Ortheziidae and Pseudococcidae) were found to be associated with acerola (Table 1).

The Coccidae family includes the soft mealybugs, currently 1,223 species are known distributed in 177 genera (Garcia Morales et al., 2016). In Brazil, 156 species are known in 43 genera (Grazia et al., 2024). In the acerola tree, species belonging to the subfamily Pulvinariscinae and to the genera *Saissetia* Deplanche and *Coccus* Linnaeus have already been recorded. The genus *Saissetia* has 46 valid species (García Morales et al. 2016), among which *Saissetia coffeae* (Walker) and *Saissetia oleae* (Olivier) have already been recorded in acerola in the municipality of Angulo – PR (Albuquerque et al., 2002). The genus *Coccus* has 114 valid species, among which *Coccus viridis* (Green) has already been recorded in acerola in the municipality of Angulo – PR (Albuquerque et al., 2002) and *Coccus hesperidium* (Linnaeus) has already been recorded in acerola in Paço do Lumiar – MA (Ramos et al., 2018). In the chapter "Pests of acerola tree", published in the book "Pests of tropical fruit trees of agro-industrial importance", in 1998, the authors refer to *the species C. viridis* and *C. hesperidum* as a pest of acerola and mention its occurrence in Brazil (Sobrinho et al., 1998).

Table 1

Records of infestation by mealybugs in the acerola tree

Taxonomic identification	Geographic region		Source
Species2	Country	State1	
Cerococcus deklei	Cuba	-	Fernández et al., 2021
Ceroplastes cirripediformis	France	French Antilles	Matile-Ferrero and Étienne, 2006
Pulvinaria urbicola	Japan	Ryukyu Islands	Tanaka and Kamitani, 2020
Saissetia coffeae	Brazil	Paraná	Albuquerque et al., 2002
Saissetia oleae	Brazil	Paraná	Albuquerque et al., 2002
Coccus viridis	Brazil	Paraná	Albuquerque et al., 2002

Coccus hesperidum hesperidum	Brazil	Maranhão	Ramos et al., 2018
Chrysomphalus aonidum	Brazil	Paraná	Albuquerque et al., 2002
Selenaspidus articulatus	Brazil	Paraná	Albuquerque et al., 2002
Icerya purchase	Brazil	-	Sobrinho et al., 1998
	USA	Hawaii	Hale et al 1970
Crypticerya zeteki	Brazil	Maranhão	Ramos et al., 2018
Insignorthezia insignis	Brazil	Ceará	Ponte et al., 2004
Praelongorthezia praelonga	Brazil	Paraná	Albuquerque et al., 2002
		Pernambuco	Barbosa et al., 2007
		Bahia	Nascimento; Habibe, 2009
Spilococcus mamillariae	France	French Antilles	Matile-Ferrero and Étienne, 2006
Paracoccus marginatus	India	Tamil Nadu	Sakthivel et al 2012
Maconellicoccus hirsutus	Brazil	Maranhão	Ramos et al., 2018
	Brazil	Alagoas	Broglio et al., 2015
Planococcus lilacinus	-	-	García Morales et al., 2016
Dysmicoccus brevipes	Brazil	Pernambuco	Sá e Oliveira, 2021

[1]State, province or territory. 2Scientific names according to García Morales et al., 2016.
Source: compiled and prepared by the authors.

Diaspididae is the largest family of coccids, with 2,696 species distributed in 417 genera (García Morales et al., 2016). They are known as shielded or carapace mealybugs because their body is covered by a detachable waxy secretion (Grazia et al., 2024). Only the species *Chrysomphalus aonidum* (L.) and *Selenaspidus articulatus* (Morgan) were recorded in the acerola tree in the municipality of Angulo, PR (Albuquerque et al., 2002). Both are polyphagous and cosmopolitan, registered in all continents and several states of Brazil

(García Morales et al., 2016). *Chrysomphalus aonidum* has been associated with plants of 181 genera in 74 botanical families in 87 countries and *S*. *articulatus* has been associated with 105 genera in 53 botanical families in 62 countries (García Morales et al., 2016).

The Monophlebidae family has 265 species distributed in 48 genera (García Morales et al., 2016), in Brazil there are 17 species distributed in nine genera (Grazia et al., 2024). They are known as giant mealybugs, 35 mm long, usually oval (Grazia et al., 2024). The species *Icerya purchasi* Maskell and *Crypticerya zeteki* Cockerell have already been recorded in acerola in Brazil (Sobrinho et al., 1998; Ramos et al., 2018).

The Ortheziidae family has 214 species distributed in 24 genera (García Morales et al., 2016), in Brazil 13 species have already been recorded in seven genera (Silva et al., 1968; Bem-Dov et al., 2011). They are covered by wax arranged in the form of plates, on the dorsum and marginally (Grazia et al., 2024). In the Ortheziidae family, the species *Insignorthezia insignis* Browne and *Praelongorthezia praelonga* (Douglas) (Hemiptera: Ortheziidae) have already been recorded in acerola in Brazil (Albuquerque et al., 2002; Ponte et al., 2004; Barbosa et al., 2007; Nascimento; Habibe, 2009).

The Pseudococcidae family has 2,042 species distributed in 259 genera (García Morales et al., 2016), in Brazil more than 96 species have been recorded in about 22 genera (Grazia et al., 2024). They are called "mealybugs" because adult females have their bodies covered with whitish powdery wax (Grazia et al., 2024). The species *Spilococcus mamillariae* (Bouche*), Paracoccus marginatus* Williams & Willink's granara, *Maconellicoccus hirsutus* **(**Green), *Planococcus lilacinus* (Cockerell) and *Dysmicoccus brevipes* (Cockerell) have already been recorded in acerola (Table 1). In Brazil, the species *M*. *hirsutus* and *D*. *brevipes* were found infesting acerola in the Northeast region (Broglio et al., 2015; Ramos et al., 2018; Sá and Oliveira, 2021).

3 RECOGNITION OF THE KEY PEST(S)

The mealybugs associated with acerola on planet earth (18), Brazil (12) and Northeast (six) were summarized in Table 1. Only three species were associated with acerola in the Brazilian semi-arid region: *P*. *praelonga* (Barbosa et al., 2007; Nascimento; Habibe, 2009), *I. insignis* (Ponte et al., 2004) and *D. brevipes* (Sá; Oliveira, 2021). The productive poles of the acerola belt are predominantly located in the semi-arid region, however, the scarce scientific records do not translate the importance of mealybugs as an agricultural pest in the acerola belt, it only identifies the need for scientific research.

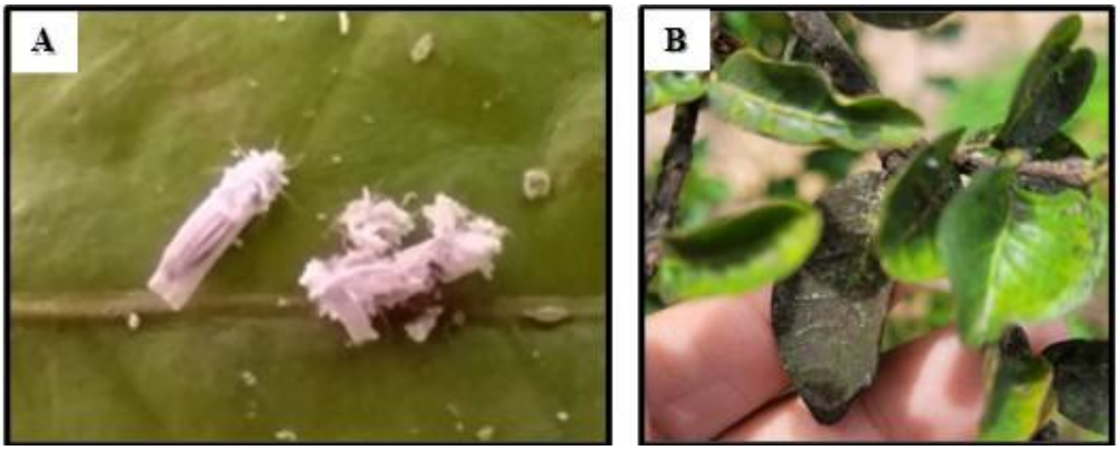
The ortézia is the main species found in the acerola tree, and it also represents the cochineal with the largest number of scientific records (Table 1). To date, the ortézia is the only one that can be considered a key pest. Secondary pests are found to be the brown mealybug, *C. hesperidium*, green mealybug, *C. viridis* the white aphid, *I. purchasi*, and the Hibiscus Pink Mealybug, *M. hirsutus*. The latter has been an emerging problem, it is a polyphagous cochineal that feeds on plants of 259 genera and 84 botanical families and registered in 110 countries (Garcia Morales et al., 2016). The first record in Brazil occurred in 2010 in the State of Roraima (Marsaro Júnior et al., 2013), shortly thereafter it was detected in Espírito Santo (Culik et al., 2013), Mato Grosso (Morais et al., 2015), Alagoas (Broglio et al., 2015), Bahia (CEPLAC/CEPEC, 2014) and Santa Catarina (Alexandre et al., 2014). For the other species cataloged, there are no widely known records of outbreaks and losses in acerola orchards.

As general characteristics, mealybugs have a body with variable shape and color and length between 0.5 and 35 mm, with a waxy coating or covered by lacquer with a characteristic composition and structure that determine the separation of many families (Cruz, 2018). Adult females are always apterous and neotenic, reaching the adult stage after two or three instars and have a completely fused head, thorax and abdomen; with developed appendices, or they may still be apodated and have reduced numbers of antennal segments in some families (Cruz, 2018). Unlike females, adult males are winged, have a division of the body into head, thorax and abdomen, in addition to having their mouthparts atrophied and passing through two or three mobile nymphal instars and one or two pupals (prepupae and pupa) (Cruz, 2018).

The key pest Orthozia is easily recognized in the field, males and females have characteristic sexual dimorphism. Females are apterous, neotenic (with morphological characteristics of nymphs), white (their bodies are covered by waxy white plaques), devoid of chitinous carapace, and have a completely fused head, thorax, and abdomen. In the posterior part of the females' body, the ovisack (elongated tail covered by waxy plaques) develops, where the eggs are deposited. The ovisack protects the eggs and ensures the hatching and protection of the nymphs until the first ecdysis, favoring the gradual displacement of the nymphs to the plant structures (Figure 1A).

Figure 1

Ortézia in acerola. (A) Female; (B) Sooty mold on the leaf surface



Source: prepared by the authors.

The nymphs of males and females are the same, however, in the second instar the males move to the trunk where they group and transform into pseudopupa until they reach the adult stage. Males are winged, bluish and have tails with elongated white bristles.

4 BIOECOLOGY, DAMAGE AND LOSS.

Bioecological and behavioral aspects determine the spatial distribution, fluctuation and infestation of mealybugs in the field. Mealybugs have a fast biological cycle and a high capacity to generate offspring (Cruz, 2018). In the acerola orchard, initially the mealybugs have a heterogeneous and localized distribution (i.e., in a reboleira), mainly because the females are apterous. Some plants may present infestation while in others the pest is not detected, with the advance of the infestation the mealybugs can spread throughout the plot or orchard. The infestation initially occurs in the internal shoots and basal branches, making early diagnosis difficult. Detection is facilitated with the multiplication of mealybugs and the development of sooty mold (Benvenga et al., 2001).

The mealybugs disperse using the wind as a vehicle for natural dissemination between plants, plots, orchards and between orchards, providing primary and secondary infestation. Dispersion can also occur by walking itself, through infested seedlings and mechanically when provided by man, machinery and equipment in the various operations (i.e., harvesting, cultural treatments, irrigation, fertilization and phytosanitary management). There are also species of ants (Hymenoptera: Formicidae) that provide protection and dispersion of ants to maximize the production of *honeydew*, secretion of mealybugs used for food by ants.

The cochineal ortézia *P. Praelonga* easily dispersed in the acerola production environment, the absence of chitinous carapace provides high mobility in the plant in the nymph and adult stages, facilitating its natural dissemination by the wind. The waxy coating of the body favors mechanical dissemination over short and long distances due to the insect's adherence to humans (e.g., clothing), machinery and equipment. Orcezia polyphagia also favors dispersal in the orchard environment, since other host plants can act as green bridges providing shelter, feeding, multiplication and consequent dispersion and reinfestation of the orchard by the orthezia.

Mealybugs can be found during all months of the year, however, they are favored by high temperatures and low relative humidity. The greatest infestations occur in the dry season, a period with rainfall lower than evapotranspiration and lower relative humidity of the air. As a hypothesis, it is suggested that in the dry period there is a higher concentration of nutrients in the sap of acerola trees, favoring the development and reproduction of sucking insects. In addition, the dry period usually restricts the development of entomopathogens, reducing the natural mortality of mealybugs.

The dry season in the Brazilian acerola belt lasts for up to eight months, which favors the multiplication of mealybugs. The semi-arid Northeast presents marked interannual variability of precipitation with some rainy or dry years, and even drier years may occur. Dry years result in greater damage caused by mealybugs in acerola trees, resulting in crop failure. In addition, the mealybug population can increase exponentially in the rainy season due to the occurrence of veranicos (consecutive days with no precipitation).

Mealybugs can be found in practically all plant structures, including leaves, shoots, branches, trunks, flowers and fruits (Sobrinho et al., 1998; Broglio et al., 2015; Ramos et al., 2018; Cruz, 2018). In the acerola tree, mealybugs form colonies with numerous specimens, in addition, they have overlapping generations with all stages of development.

The damage is caused by nymphs and adult females, adult males do not cause damage to the plant since they have an exclusive function of reproduction. The nymphs and females cause injury and damage from the introduction of the stylet, continuous suction of sap and injection of toxic saliva during feeding, culminating in malformation of shoots, leaves, branches, stems, flowers and fruits.

Mealybugs occur from the molting stage, the earlier the infestation, the greater the effect on the development and formation of the acerola tree. The damage caused depends on the population density of the pest and the stage of development, vigor, nutrition and water supply of the acerola tree. Mealybugs can cause growth retardation, decline and death of seedlings and newly transplanted plants in the first two years. The infested adult plant withers, with drying of the branches and premature fall of leaves and fruits (Barbosa et al., 2007). The infestation reduces the productivity of the current crop and eventually of the future ones.

Mealybugs have low feed conversion and excrete approximately 90% of the ingested food (i.e., *honeydew*). The fungus (*Canopodium* spp.), precursor of sooty mold *, uses honeydew* for its nutrition and develops superficially in the vegetative shoot (i.e., leaves, branches and eventually fruits), and can propagate throughout the crown of the acerola. The fungus does not infest the plant's tissues, it only covers them with sooty mold, a coating of thick sticky black crust formed by the fungus' black and sooty mycelia (Figure 1B). Sooty mold decreases the photosynthesis, respiration and transpiration of the plant, in addition, it stains the fruit reducing its commercial value (Ramos et al., 2018).

5 INTEGRATED MANAGEMENT OF MEALYBUGS IN ACEROLA ORCHARD.

For phytosanitary management, the rural entrepreneur must consult an Agronomist, a qualified professional for guidance and consulting. The rural entrepreneur must choose to plant certified, healthy and pest-free seedlings, mitigating infestations in the field in the most critical period (i.e., establishment of the crop). Control must be strict to prevent seedlings from constituting an initial source of infestation in the field. In the seedling production phase, the relevant pests are sucking insects (i.e., mealybugs and aphids).

The seedling nursery (i.e., greenhouse or greenhouse) should contain an antechamber and insect screen to mitigate the entry of mealybugs and aphids. In infestations in the nursery, it is possible to adopt simple curative measures depending on the number of seedlings. Insect vacuums are practical for collecting and removing nymphs and adult females from mealybugs, in addition, it is possible to carry out manual scavenging and crushing, mealybugs in these biological phases are apterous and easy to see and collect. It is also possible to clean the infested parts with water jets, brushes or other equipment, the application of water with the addition of detergent/soap can increase the effectiveness of control causing removal, anoxia and/or dehydration due to the removal of the wax layer from the cuticle of the integument by lauric acid.

Oils (mineral and vegetable) and phytoprotective mixtures (i.e., soap, lime sulfo, and Bordeaux) can be sprayed on seedlings for curative control of mealybugs in the nursery. Details about the mixtures can be found in the agroecological files of the Ministry of

Agriculture, Livestock and Supply - MAPA. As a last resort, pesticides registered in MAPA should be applied for acerola. The active ingredient flupyradifurone of the chemical group butenolide is the only active ingredient with a commercial formulation registered in Brazil for the acerola crop for the curative control of the key pest *P. praelonga* and the secondary pests of the genus *Saissetia* and *Icerya*. The pesticide can be used in the seedling nursery and in the field as discussed below (Table 2).

Table 2

Mealybug management techniques in the production of acerola seedlings

Control	Management technique
Preventive	Protected cultivation adopting a greenhouse with antechamber and protective screen against mealybugs.
Dressing	Aspiration of mealybugs.
	Manual picking and crushing.
	Mechanical control with application of soapy water flow.
	Application of mixtures (calcium and Bordeaux sulfo).
	Spraying mineral or vegetable oils.
	Spraying of insecticide with active ingredient flupyradifurone.

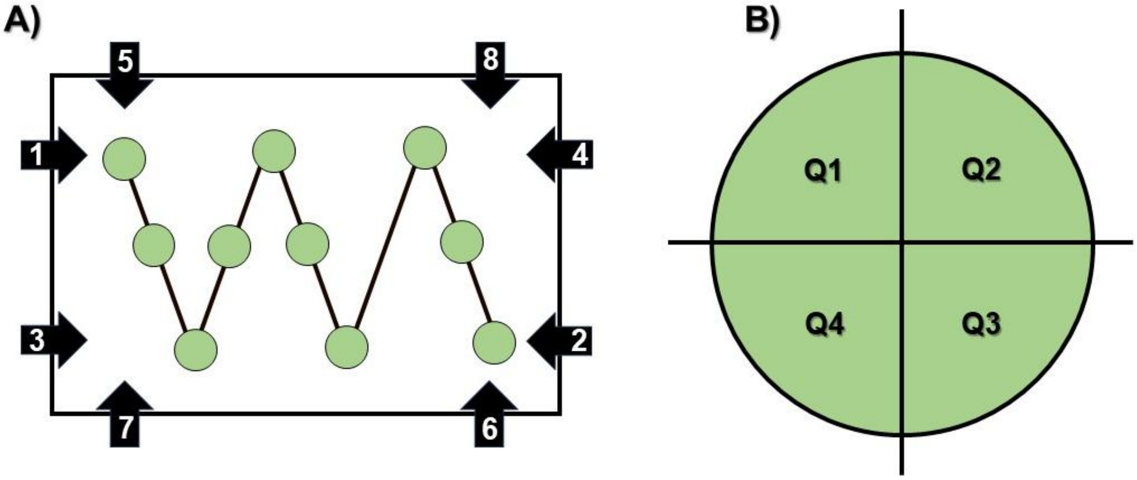
Source: prepared by the authors.

Field monitoring aims to detect the presence and establish the history of occurrence of mealybugs on the property, reducing costs and losses. The diagnosis of mealybugs should be carried out during the day, weekly and systematically through active inspection of the occurrence of nymphs and adult females. In the monitoring, at least one percent of the plants in the cultivated area (plot) must be inspected in a randomized manner in a zigzag path (Figure 2A). In an area of one hectare with 1,000 plants, it is recommended to examine at least 10 plants. At each sampling point, the plant should be divided into quadrants and one branch per quadrant should be examined, totaling four branches per plant (Figure 2B). The inspector should observe the underside of the leaves and branches to check for the presence of mealybugs and sooty mold, in addition, the trunks of the plants should also be inspected. The plant should be considered infested when the presence of at least one nymph or adult female is found. The presence of mealybugs associated with sooty mold indicates a higher population density of the pest in the acerola plant and/or orchard.

If mealybugs are detected during monitoring (routine inspection), then a plant-by-plant sweep inspection in the orchard becomes necessary. In this operation, the infested plants will be demarcated and the spatial distribution of the mealybugs will be defined. The ideal time to use curative control is when the initial focus is detected in the field, i.e., when they still have localized (aggregated) distribution. Curative control can be used only in the foci of the infestation, individually in infested plants or in shrubs. Success depends on the early and accurate diagnosis of infested plants and the immediate adoption of curative control, since mealybugs have a high reproduction capacity. In plants with low infestation, visualization can be difficult due to the presence of mealybugs on basal branches, internal leaves and absence of sooty mold. On the other hand, the uniform distribution of mealybugs indicates a high population density of the pest and requires curative treatment in the total area.

Figure 2

Monitoring of mealybugs in the acerola orchard. A) Zigzag walking. B) Quadrants



Source: prepared by the authors.

In the field, planting at the beginning of the rainy season is recommended, since the population of mealybugs is usually lower at this time. Precipitation can remove mealybugs and wash sooty mold from the canopy of the plant, particularly from the leaf surface. Planting in the rainy season linked to proper irrigation management avoids water stress and favors the establishment and rapid development of the acerola tree, minimizing the losses generated by any infestations. It is also necessary to manage nutrition (chemical and/or organic fertilization) according to soil or foliar analysis and crop requirements, avoiding nutrient deficiency and/or excess (Table 3).

To reduce the infestation resulting from the natural spread by the wind, it is recommended to implement live fences (barriers) in the surroundings and crop strips with non-host crops and upright size inside the acerola orchard. To reduce the infestation resulting from mechanical dissemination, it is recommended to restrict the traffic of vehicles and people, as well as the preventive inspection of vehicles, machinery, equipment and people. Protection must be exercised from the external to the internal environment (that is, from the outside to the inside of the property/orchard) and from infested plots to plots free of mealybugs. In the latter case, the movement of people, machinery and equipment in the infested plot should be restricted and the infested plants should be harvested after the end of the other plots free of mealybugs (Table 3).

The plant should be conducted adopting proper pruning management to allow greater luminosity and internal aeration of the canopy. The stages of plant formation consist of the establishment of the seedling, single-stem conduction, definition of the structural branches and budding (for details see Calgaro; Brandão, 2012). The acerola tree produces continuous shoots, making it necessary to carry out periodic cleaning pruning, eliminating thieving and poorly located branches (i.e., branches directed downwards and/or facing the interior of the crown), dry branches and those most infested by mealybugs, which must be burned or buried. Such a measure reduces the proliferation of sooty mold, since the fungus precursor of sooty mold develops better where air circulation is poor and humidity is high. In addition, under these circumstances, mealybugs have a higher energy cost for locating feeding points and shelter in the canopy of the plant, which may increase natural mortality due to the higher rate of encounter with entomophages (predators and parasitoids) and eventual exposure to solar radiation (dehydration). With pruning, the mealybugs also start to be more exposed to possible curative treatments, such as mixtures (soap, calcium sulfur and Bordeaux), oils (mineral and vegetable) and pesticides (Table 3).

To reduce multiplication and secondary dissemination in the orchard, it is recommended to control the host weeds of mealybugs. Weed control should be carried out mainly in the area close to the foci of occurrence of mealybugs, clearing the area at least within a radius of 10 m from the infestation foci (Table 3). The weeds *Emilia sonchifolia (L.) DC.*, *Momordica charantia L.*, *Cyperus rotundus L.* and *Cenchrus echinatus L.* are commonly found in acerola orchards in the semi-arid region (Sousa et al., 2020) and have already been found with *P. praelonga* (Nascimento et al., 1993; Skorupa; Cesnik, 1999), *M. hirsutus* (Lopes et al., 2019) and *D. brevipes* (Lopes et al., 2019).

Table 3

Techniques for managing mealybugs in acerola production in the field

Control	Objective	Management technique
Preventive	Disruption of the synchrony between mealybugs and acerola tree in the field deployment.	Planting in the rainy season.
		Adequate management of irrigation and nutrition aiming at the rapid establishment of the seedling.
	Reduction of the natural spread of mealybugs	Implementation of hedges in the surroundings and crop strips inside the orchard.
		Control of host weeds of mealybugs.
	Reduction of the mechanical spread of mealybugs	Traffic restriction, inspection and cleaning of vehicles, machinery, equipment and people.
		Harvesting in the infested plots last.
	Reduction of favorable microclimate for mealybugs and sooty mold	Execution of pruning providing greater luminosity and aeration of the acerola tree's crown.
Dressing	Population reduction	Application of mixtures (soap, lime sulfo)
		Spraying mineral or vegetable oils.
		Spraying of insecticide with active ingredient flupyradifurone.

Source: prepared by the authors.

As a last resort, the active ingredient flupyradifurone, the only active ingredient with a commercial formulation registered in MAPA for the control of mealybugs in acerola, should be sprayed. The commercial formulation based on flupyradifurone can be applied in the crown of the tree or via "*drench*", the active ingredient can circulate systemically in the acerola tree. The mealybugs are exposed and absorb the insecticidal molecule through contact and/or ingestion, depending on the form of application. Mealybugs are led to death through neuromuscular action in which the active ingredient acts as a competitive modulator of nicotinic acetylcholine receptors (Table 3).

Systemic insecticides are more recommended for the control of sucking insects, in particular for the *P species*. *Praelonga*. Contact insecticides are less effective in controlling the orthezia due to the reduced penetration into the waxy layer that covers the body of this species, in addition, the effect in the initial phases is less due to the females protecting the eggs and nymphs from the first instar in the opossace. The barrier of the waxy layer can be minimized with the use of surfactants in the spray mixture.

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