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Full Length Research

Ants (Hymenoptera: Formicidae) associated with scale insects (Hemiptera: Coccomorpha) on citrus trees in Coastal and Lower Eastern Counties, Kenya

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ABSTRACT: A survey of citrus orchards was conducted in Kilifi, Kwale, Machakos and Makueni counties, Kenya to collect and identify ants (Hymenoptera: Formicidae) and natural enemies associated with scale insects (Hemiptera: Coccomorpha) feeding on citrus trees (Sapindales: Rutaceae). Nine ant species were found associated with nine scale insect species feeding on three citrus species (*Citrus limon, C. reticulata* and *C. sinensis*) for their honeydew. The ants associated with the scales in the study areas were: *Cataulacus brevisetosus* (Forel), *Camponotus rufiglaucus* (Jerdon), *Crematogaster castanea* (Smith), *Cr. sjostedti* (Mayr), *Monomorium afrum* (Andre), *Myrmicaria opaciventris* (Emery), *Oecophylla longinoda* (Latreille), *Pheidole megacephalla* (Fabricius), and *Technomyrmex albipes* (Fr. Smith). The ant *Myrmicaria opaciventris* was recorded attending four scale insects' species: *Coccus hesperidum, Co. viridis, Pulvinaria polygonata* (Hemiptera: Coccidae) and *Pseudococcus cryptus* (Hemiptera: Pseudococcidae) in Kilifi County. Host-plant identities and localities surveyed are also presented. These new data for citrus-growing areas in Kenya will contribute to the development of integrated pest management programs on citrus.

Keywords: Hemipteran-ant association, honeydew, Kenya, mealybugs, soft scales.

INTRODUCTION

Ants (Hymenoptera: Formicidae) are one of the most diverse insect groups, and interact with other species at every trophic level. In agriculture, these interactions are influenced by both biotic and abiotic factors. Many sternorrhynchans like scale insects, aphids and whiteflies produce a liquid sugary waste (honeydew) and are visited by hymenopterans such as ants, wasps and bees, to feed on this rich source of carbohydrates (Ülgentürk, 2001). The mutual associations between ants and myrmecophilous coccids are well-documented phenomena (Ülgentürk, 2001; Schneider et al., 2013; Peeters et al., 2017; Fanani et al., 2020). These interactions provide mutual benefits to both the scale insects and the ants. The ants benefit from scales as they obtain carbohydrates from the honeydew produced by the scale insects (Ülgentürk, 2001; Kenne et al., 2008; Mansour et al., 2011). The scales benefit from the removal of honeydew, which saves them from drowning in it or being suffocated by sooty molds that develop on it; they may also be protected from predators and parasites by the attendant ants. In addition, scales, which are mostly sessile except for the first-instar crawler stage, are sometimes transported to more favorable

feeding sites by attendant ants (Ülgentürk, 2001).

There is no substantial evidence that ants can fully protect coccids from predation and parasitism (Ülgentürk, 2001), but in the presence of ants, the scale insect mortality rate is decreased (Ülgentürk, 2001; Fanani et al., 2020). This in turn facilitates coccid multiplication, resulting in increased plant damage (Mansour et al., 2011). There is some evidence that presence of ant colonies has no effect on predation and parasitism levels of scale insects; the amount of protection provided by different ant species to scale insects depends on the aggression level of the ant species (Fanani et al., 2020).

Some ants construct tents (also called carton shelters) over colonies of scale insects (Peeters et al., 2017). The shelters provide protection from predation, parasitism, strong sunlight and harsh weather. Close proximity with the ants in the shelters may also reduce coccid disease due to antibiotic secretions produced by the ants; this kind of protection is most beneficial to coccids found in tropical climates (Ülgentürk, 2001; Shiran et al., 2013). Some predatory ants that are dependent on sugary honeydew, like species of *Anoplolepis*, *Oecophylla*, *Dolichoderus*, *Solenospis* and *Azteca*, may be used for biological control of a wide range of non-scale pests. Association of such ants with some plants like citrus have been proven to reduce pest attack levels, increasing the fruit yield (Ülgentürk, 2001; Mele et al., 2007).

Ants associated with scale insects recorded by other authors worldwide include species of: *Anonychorma, Anoplolepis, Azteca, Cardiocondyla, Cladomyrma, Iridomyrmex, Linepithema, Nylanderia, Papyrius, Myrmex, Podomyrma, Pseudomyrmex, Solenopsis, Tetraponera* and Zacryptocerus (Bodenheimer, 1951; Way, 1963; Rosen, 1967; Buckley and Gullan, 1991; Way and Khoo, 1992; Ülgentürk, 2001). Ant-scale insect associations have not been extensively studied in Kenya, however, where there have been only two such studies by Young et al. (1996) and Palmer et al. (2000). Therefore, the objective of the survey was to document the ant fauna associated with scale insects feeding on citrus trees in Kilifi, Kwale, Machakos and Makueni counties, and the host-plants where these insect associations were found.

MATERIALS AND METHODS

Surveys were undertaken in the main citrus-producing areas in Kenya, two coastal counties (Kilifi and Kwale) and two lower eastern counties (Machakos and Makueni), in July-August (dry season) and November-December (wet season), 2019. A total of 328 orchards situated 1-5 km from the main roads were sampled. On each farm, five citrus trees were selected randomly and all parts of the plants were inspected thoroughly for scale insect infestations. Any arthropods found in association with the scale insects were collected. Ants were collected using a fine camel-hair brush and were placed in a killing jar. After immobilization, the specimens were preserved in labelled vials containing 70% ethanol. Samples of the scale insects were also collected from the same plants by cutting off infested plant parts with secateurs and placing them in paper bags. The bag tops were folded and stapled to prevent sample loss, and bags were labelled with the date, county name, locality, GPS coordinates, collector's name and host plant. The specimens were then kept in a cool box and transported to the National Museums of Kenya laboratory in Nairobi for sorting and identification. The scale insects were preserved in 70% alcohol and subsequently mounted on slides using the method described by Sirisena et al. (2013). The scale insect slide mounts were examined using a Zeiss compound microscope with phase contrast illumination at a magnification of ×25 to ×800. Species were identified using unpublished keys (Watson and Ouvrard, (In prep)). Ants were identified by Josiah Achieng (technician, National Museums of Kenya) using the key by Bolton (1994) and by comparison with reference specimens at the national repository, National Museums of Kenya in Nairobi, Kenya.

RESULTS

At the study sites, citrus plants attacked by scale insects were found to be frequently attended by ants. The attendant ants were nine species belonging to eight genera in three subfamilies (Tables 1 and 2). Several ant species were found on the branches, leaves, fruits and bark of scale-infested citrus trees. At several localities during the wet season, *Myrmicaria opaciventris* (Emery) and *Oecophylla longinoda* (Latreille) were found together attending three coccid species; *Coccus hesperidum*, *Pulvinaria polygonata* and *Pseudococcus cryptus*. Two ant species were found to attend the same scale insect species on *Citrus sinensis* during both the wet and dry seasons: *Technomyrmex albipes* (Fr. Smith) tended *Icerya seychellarum* and *Pseudococcus cryptus*, and *Camponotus castanea* (Smith) tended *Coccus hesperidum*. *Monomorium afrum* (André) was the only attendant ant species found during the dry season, on *Citrus sinensis* in the lower eastern region of Kenya attending *Coccus viridis. Crematogaster sjostedti*, *Camponotus rufiglaucus* and *Cataulacus brevisetosus* were only found attending scale insects during the wet season, on citrus in the coastal region of Kenya. The ant species *Camponotus rufiglaucus*, *Cataulacus brevisetosous*, *Crematogaster castanea*, *Myrmicaria opaciventris*, *Pheidole megacephalla* (Fabricius) and *Monomorium afrum* were also found on colonies of armored scales (Diaspididae) but it was not possible to

Table 1. Ant species attending scale insects on citrus trees in coastal and lower eastern counties of Kenya during the wet season (November/December 2019).

Ants	Coccids	Host-plants of the scales	Localities
Camponotus rufiglaucus	*Coccus hesperidum*	*Citrus limon*	Malindi
	Pulvinaria polygonata	*Citrus sinensis*	Malindi
	Coccus viridis	*Citrus sinensis*	Malindi
Cataulacus brevisetosous	*Coccus hesperidum*	*Citrus sinensis*	Lunga Lunga
	Icerya seychellarum	*Citrus sinensis*	Lunga Lunga
Crematogaster castanea	*Icerya seychellarum*	*Citrus sinensis*	Matuga
	Coccus hesperidum	*Citrus sinensis*	Lunga Lunga
	Crisicoccus longipilosus	*Citrus sinensis*	Matuga
Crematogaster sjostedti	*Icerya seychellarum*	*Citrus sinensis*	Lunga Lunga
	Icerya purchasi	*Citrus sinensis*	Lunga Lunga
	Pseudococcus cryptus	*Citrus sinensis*	Lunga Lunga
Myrmicaria opaciventris	*Coccus hesperidum*	*Citrus sinensis*	Kilifi North
	Pseudococcus cryptus	*Citrus sinensis*	Kilifi North
	Pulvinaria polygonata	*Citrus sinensis*	Kilifi North
Oecophylla longinoda	*Coccus hesperidum*	*Citrus sinensis*	Lunga Lunga
	Coccus viridis	*Citrus sinensis*	Lunga Lunga
	Icerya seychellarum	*Citrus sinensis*	Lunga Lunga
	Pseudococcus cryptus	*Citrus reticulata*	Kilifi North
	Pulvinaria polygonata	*Citrus sinensis*	Lunga Lunga
	Saissetia zanzibarensis	*Citrus sinensis*	Lunga Lunga
	Undinia farquharsoni	*Citrus sinensis*	Lunga Lunga
Pheidole megacephala	*Coccus viridis*	*Citrus sinensis*	Kaiti
Technomyrmex albipes	*Icerya seychellarum*	*Citrus sinensis*	Kilifi North
	Pseudococcus cryptus	*Citrus sinensis*	Kilifi North

Source: Survey data, 2019.

document whether they were attending to the diaspidids (which do not produce honeydew). Only a few ant-diaspidids interactions are known worldwide. They could have been attending other honeydew-producers like immature whiteflies (Hemiptera: Aleyrodomorpha) in the canopy.

The study identified eight ant-attended scale insect species belonging to six genera in three families: Coccidae: *Coccus hesperidum* Linnaeus, *Co. viridis* (Green), *Pulvinaria polygonata* Cockerell, *Saissetia zanzibarensis* Williams and *Udinia farquharsoni* (Newstead); Monophlebidae: *Icerya purchasi* Maskell, *I. seychellarum* (Westwood); and Pseudococcidae: *Pseudococcus cryptus* Hempel. The ants involved in scale insect attendance during the wet and dry seasons are listed in Tables 1 and 2, respectively.

DISCUSSION

According to the literature, *Camponotus rufiglaucus, Cataulacus brevisetosus*, *Monomorium afrum* and *Technomyrmex albipes* have not been found attending scale insects before; here they are recorded attending soft scales (Coccidae) and mealybugs (Pseudococcidae) for the first time.

Crematogaster sjostedti has been recorded attending *Ceroplastes* sp. (Coccomorpha: Coccidae) on an *Acacia*

Table 2. Ant species attending scale insects on citrus trees in coastal and lower eastern counties of Kenya during the dry season (July/August 2019).

Ants	Coccids	Host-plants of the scales	Localities
Crematogaster castanea	*Coccus hesperidum*	*Citrus sinensis*	Yatta
	Icerya purchasi	*Citrus sinensis*	Yatta
Myrmicaria opaciventris	*Coccus viridis*	*Citrus limon*	Malindi
Monomorium afrum	*Coccus viridis*	*Citrus sinensis*	Yatta
Oecophylla longinoda	*Icerya seychellarum*	*Citrus sinensis*	Lunga Lunga
	Saissetia zanzibarensis	*Citrus sinensis*	Lunga Lunga
Pheidole spp	*Coccus viridis*	*Citrus reticulata*	Wote
	Icerya seychellarum	*Citrus reticulata*	Wote
Technomyrmex albipes	*Pseudococcus cryptus*	*Citrus sinensis*	Malindi
	Saissetia zanzibarensis	*Citrus sinensis*	Malindi

Source: Survey data, 2019.

tree in Kenya before (Young et al., 1996; Palmer and Young, 2017); *Crematogaster castanea* and *Camponotus rufiglaucus* were also reported as being present but showed no ant-coccid association (Young et al., 1996). *Citrus sinensis* is a new plant association for *Crematogaster sjostedti* attending *Icerya seychellarum* in Kwale County.

Oecophylla longinoda was found attending seven scale insect species during the wet season and only two species during the dry season. In Zanzibar, *O. longinoda* was reported attending *Saissetia zanzibarensis* (Way, 1954), as was observed in this study. The ant has also been found in close association with other mealybugs and scale insects (Dwomoh et al., 2008; Olotu et al., 2013); it is used as a biological control agent against other, non-scale pests' elsewhere (Way, 1954; Mele et al., 2007; Olotu et al., 2013; Carrillo et al., 2017; Rwegasira et al., 2020).

Pheidole megacephala was found in close association with two coccid species on both *Citrus sinensis* and *C. reticulata* during the wet and dry seasons. The ant has been recorded attending *Coccus viridis,* Bach (1991), but its association here with *Icerya seychellarum* is a new observation. *Pheidole megacephala* is also associated with honeydew-producing psyllids (Hemiptera: Psyllomorpha) (Aléné et al., 2011).

Myrmicaria opaciventris was found attending four different coccids in this study. The literature records this ant as a good attendant to leaf hoppers, psyllids and few scale insects (Kenne et al., 2008; Aléné et al., 2011). The association of *Myrmicaria opaciventris* with *Coccus hesperidum, Co. viridis, Pseudococcus cryptus* and *Pulvinaria polygonata* are new mutualistic association records found in this study.

This work did not determine whether there was any mutual relationship in the ant-diaspidids interaction observed, but it seems unlikely because armored scale insects do not produce honeydew. The information obtained will be used to develop integrated pest management strategy for scale insects affecting citrus to improve citrus production in the country.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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