Research Note

INSECT VISITORS ON THE FLOWERS OF FOUR CULTIVARS OF MANGIFERA INDICA *AT THE AGRICULTURAL EXPERIMENT SUBSTATION OF JUANA DIAZ, PUERTO RICO*[1]

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Pollinator biodiversity is an important research area for agricultural production in the world (Winfree et al., 2018). Pollinators are essential for horticultural, forage and seed production (FAO, 2019). There is a broad diversity of pollinating insects that includes most of the approximately 20,000 species of bees (Hymenoptera: Apidae) as effective pollinators, and together with moths, flies, wasps, beetles and butterflies, they make up the majority of pollinating species (FAO, 2008). Tropical areas of the world are not only more dependent on pollinating animals for agricultural crops but may also be more susceptible to pollinator loss (FAO, 2008). Sampling of flower-visiting insects in any crop is an essential component to determine the effectiveness of pollinators and their effects on the reproductive system (Howlett et al., 2018). Therefore, the first step to start any study with pollinators is to be able to identify the floral visitors to the selected crop, which in our study was mango (*Mangifera indica* L.).

Mangifera indica L. (Anacardiaceae) is distributed in the tropical and subtropical regions (Galán-Saúco, 2009; Jiron and Hedström, 1985) and represents a tropical fruit of great economic importance (Galán-Saúco, 2009). Flowers of this crop are visited by a high diversity of insect species, although the composition and quantity of species vary among the different geographical areas where species diversity has been studied. For instance, in studies conducted in India to identify insect visitors to mango cultivar Dashehari, Singh (1988, 1997) documented at least 27 genera of flower visitors, while a second study in the state of Himachal Pradesh documented 13 insect species different from those in the initial study, including some unidentified specimens of the Stratiomyiidae, Sarcophagidae, Calliphoridae and Tachinidae families (Bathia et al., 1995). Only two insect species, *Apis indica* and *Episyrphus balteatus*, were shared between the two localities in India (Singh, 1988, 1997; Bathia et al., 1995). In another work, also in India, six species of visiting insects were reported (*Apis dorsata*, *A. florea*, *Camponotus compressus*, *Chrysomya megacephala*, *Musca domestica* and *Ropalidia marginata*), where only *A. dorsata*, *A. florea*, *Chrysomya megacephala* and *Musca domestica* were also observed in the studies reported by Singh (1988, 1997) and Kumar et al. (2012). In other Asian countries, such as Taiwan and the Philippines, 39 species of mango-visiting insects and several unidentified specimens of the families Braconidae, Chalcididae, Culicidae, Lonchaeidae, Sarcophagidae, Sphecidae, Tachinidae and Tenthredinidae were collected

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(Sung et al., 2006). In the Philippines, Fajardo et al. (2008) reported 21 species of visiting insects to the cultivar Carabao and some unidentified specimens from the Anthophoridae, Chrysomelidae, Curculionidae, Meloidae, Noctuidae and Vespidae Families. At the localities of Taiwan and the Philippines, there were only four species in common, these were *Apis cerana*, *A. mellifera*, *Idioscopus clypealis* and *Menochilus sexmaculatus.*

In Israel, 46 species of visiting insects were collected in 14 regions where mango is grown (Dag and Gazit, 2000). While in northern Australia, 26 species and some unidentified specimens of the Sarcophagidae, Sepsidae, Syrphidae, Tachinidae and Typhiidae Families were reported for two mango cultivars, Kensington Pride and Common (Anderson et al., 1982). None of the insect species listed in these two studies were shared with previous studies conducted in Asia.

In the Americas, insects visiting mango flowers were reported by Simao and Maranhao (1959) in Sao Paulo, Brazil, where species of the insect Orders Coleoptera, Hymenoptera, Thysanoptera and unidentified specimens from the Families Blattidae, Calendridae, Capsidae, Chrysomelidae, Crysopidae, Entomobrydae, Formicidae, Frenatae, Lathridiidae, Megalopodinae, Meliponidae, Nitidulidae, Phoridae, Polystinae and Vespidae were identified as visitors. In the town of Sao Francisco, Brazil, De Siqueira et al. (2008) reported that cultivar Tommy Atkins was visited by insects from the Diptera and Hymenoptera Orders and unidentified specimens of Lepidoptera. Interestingly, the species reported in both locations of Brazil are not shared between sites. In Costa Rica, Jiron and Hedstrom (1985) reported 24 insect species and two unidentified species: *Chauliognathus* sp., *Chrysomya rufifascies*, *Cochliomyia macellaria*, *Dryax julia*, *Hermetia illucens*, *Marpesia petreus*, *Megaleura peleus*, *Meromaerus* new sp., *Ornidia obesa*, *Palpada* spp., *Paratucilia wheeleri*, *Phaenicia purpurescens*, *Rhynchosciara* spp., *Strigoderma rutclina*, *Synocca septentrionalis*, *Syrphidae* spp., *Tabanus* sp., *Tachinidae* spp., *Techla damo*, *Tipulidae* spp., *Trigona fulvinentris*, *Trigona* spp., and two unidentified species of the Ithomidae and Lycaenidae Families at The Garita in Alajuela, Costa Rica. Also, two species of thrips (*Frankliniella cephalica* and *Frankliniella gardeniae*) were reported as mango flower visitors at Valverde in Alajuela, Costa Rica (Retana-Salazar and Rodríguez, 2015). In the town of Magdalena, Colombia, Corredor and García (2011) reported six insect species from the Orders Coleoptera, Diptera, Hemiptera, Hymenoptera and Lepidoptera visiting mango flowers in the Hilacha and Tommy Atkins cultivars. The authors did not identify the visiting individuals to the species level; therefore, it is not possible to compare the species that visit the mango flowers in Colombia with those of other South American countries. Only one species of dipteran is shared between Costa Rica and Brazil (*Ornidia obesa*). In Miami, Florida (USA), in mango flowers of unidentified cultivars, Popenoe (1917) reported 24 insect species belonging to the Families Calliphoridae, Tabanidae, Syrphidae, Bombillidae, and one unidentified Sarcophagidae, in addition to 12 insect species of the Order Hymenoptera.

In Puerto Rico, although mango is a major crop of economic importance that represents $26 million in annual revenue (Department of Agriculture, 2014-2015) few studies have been done on the diversity of insects that visit mango flowers and how these visitors can vary among different cultivars of *M. indica.* There is only one study, dating from 1955, carried out in the cultivar Cambodiana in Mayagüez, that reported insects of the Orders Coleoptera, Collembolla, Diptera, Hemiptera, Hymenoptera, Isoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonaptera, Thysanoptera, and Trichoptera visiting mango flowers (Spencer and Kennard, 1955). Unfortunately, they did not identify the insects at the species level within the reported families. This study demonstrated that mango flowers are visited by insects of various orders. It is important to identify the communities of pollinators during flowering season of all crops, so that we can know

which insects visit and be able to develop studies on the efficiency and effectiveness of these visitors on a crop. In this way, management and protection programs for these pollinators can be developed (Kevan, 1975; Allen et al., 1998).

To investigate the diversity of insect visitors to flowers of four mango cultivars, a study was conducted at the Juana Díaz Agricultural Experiment Substation during the months of January to April in three different years, 2017, 2018 and 2019. The study site is located on the southern coast of the island (180 01›N, 660 31›W). The principal germplasm collection in the Juana Díaz Agricultural Experiment Substation is an orchard of various cultivars of *M. indica*. The mango cultivars evaluated in this study were Julie, Keitt, Kent, and Tommy Atkins. Keitt is the cultivar most sown in the southern part of the island, while Kent is a favorite cultivar in Latin America (Campbell, 1992). Tommy Atkins is preferred for the color of the fruit (Campbell, 1992) and Julie is the favorite cultivar throughout the Caribbean (Morton, 1987).

Fifty inflorescences per cultivar were examined. For every inflorescence examined, each insect visitor was legitimated when the corolla was open and the insect visitor was collecting a resource (nectar or pollen) from it. Insect visitors were collected for five weeks. For each sampling week, we collected individuals every other day, for a total of three days. The observation period ran from 09:00 until 14:00 for each sampling day. Once collected, each specimen was identified as to family, genus, and species level. We used different taxonomic keys for species identification and some specimens were confirmed with the help of experts [Diptera group: Floyd W. Shockley of the Smithsonian National Museum of Natural History (NMNH); Eliana Buenaventura, NMNH; Christian Thompson, NMNH; Silvio Shigueo Nihei, Department of Zoology University of Sao Paulo; Allen Norrbom, NMNH; and Valery A. Korneyev, I.I. Schmalhausen Institute of Zoology, National Academy of Sciences, Ukraine. Hymenoptera group: Julio Genaro, Caribbean Natural History Group]. An ANOSIM test was used to determine significant differences in the composition of flower visitors by year. A SIMPER test was used to identify which species contributed to the observed similarity (or dissimilarity) between cultivars by year; a Bray Curtis dissimilarity matrix was used for both tests. All collected individuals were used in the analysis; however, Table 1 shows only the species with the greatest contributions to the community.

During the three-year period of our study, 1,088 individuals were collected in cultivar Julie, 891 individuals in cultivar Keitt, 701 individuals in cultivar Kent, and 1,124 individuals in cultivar Tommy Atkins. The collected individuals represent 50 insect species, grouped as follows: 25 species belonging to nine families of Diptera; 11 species belonging to six families of Hymenoptera; seven species belonging to three families of Coleoptera and six species belonging to five families of Lepidoptera. The ANOSIM test showed that the community of insect visitors varied significantly by year (p=0.0003, R=0.79).

When we observed which insect species contributed the most to the differences between all flower visitors per cultivar during the three years of this study, the SIMPER tests indicate that six species tended to offer the greatest variation to the community of visitors (Table 1). These species were *Palpada vinetorum*, *Palpada albifrons*, *Cochliomyia minima*, *Apis mellifera*, *Chrysomya megacephala* and *Allograpta radiata* (Table 1). However, their abundance as expressed as their percentage of contribution, differs by cultivar and by year. For example, in cultivar Julie, *Palpada vinetorum* contributed 32% to the dissimilarity between 2017 and 2018, 39% between 2017 and 2019, and 52% between 2018 and 2019. In cultivar Keitt, *Cochliomyia minima* varied its contribution to dissimilarity with 38% between 2017 and 2018, and 37% between 2018 and 2019. Comparing 2017 with 2019, we observed *Palpada vinetorum* contributed the most to dissimilarity with 38% in that cultivar. Regarding cultivar Kent, the greater contributor to dissimilarity between 2017 and 2018 was *Cochliomyia minima* with 34%, while

TABLE 1.—*SIMPER analysis shows the species that contribute most to the dissimilarity between the flower visiting insect's assemblage of the sampling for cultivars / three years.*

Cultivar/ *Species*	2017-2018 Contribution %	**Cultivar** /*Species*	2017-2019 Contribution %	**Cutivar**/*Species*	2018-2019 Contribution %
Julie		**Julie**		**Julie**	
Palpada vinetorum	31.91	*Palpada vinetorum*	39.42	*Palpada vinetorum*	51.50
Cochliomyia minima	28.41	*Cochliomyia minima*	30.19	*Apis mellifera*	16.30
Apis mellifera	10.88	*Apis mellifera*	8.821		
Palpada albifrons	6.721				
Keitt		**Keitt**		**Keitt**	
Cochliomyia minima	38.49	*Palpada vinetorum*	38.15	*Cochliomyia minima*	36.76
Palpada vinetorum	16.71	*Apis mellifera*	25.91	*Palpada vinetorum*	28.08
Apis mellifera	15.20	*Palpada albifrons*	6.219	*Apis mellifera*	11.81
Allograpta radiata	7.632				
Kent		**Kent**		**Kent**	
Cochliomyia minima	33.51	*Palpada vinetorum*	49.19	*Palpada vinetorum*	48.75
Apis mellifera	18.14	*Apis mellifera*	16.82	*Cochliomyia minima*	25.74
Palpada vinetorum	14.23	*Cochliomyia minima*	6.264		
Allograpta radiata	7.157				
Tommy Atkins		**Tommy Atkins**		**Tommy Atkins**	
Cochliomyia minima	49.50	*Apis mellifera*	21.22	*Cochliomyia minima*	42.71
Apis mellifera	12.11	*Palpada vinetorum*	17.21	*Chrysomya megacephala*	16.00
Palpada vinatorum	8.966	*Chrysomya megacephala*	16.95	*Apis mellifera*	10.76
		Cochliomyia minima	16.80		

TABLE 2.—*Species visitors in four mango cultivars (Julie, Keitt, Kent, Tommy Atkins) in three years in Puerto Rico with entomological: Family, Order, new record, new report, new species, other countries, references.*

Species visitors	Family	Order	New record of flowers visitors in mango[1,2]	Cultivars[3]	Flower visitors in mango in other countries	References
Chrysomya megacephala	Calliphoridae	Diptera	X	J, Kei, Ken, TA[3]	India; Taiwan	Sung et al., 2006
Chrysomya rufifacies	Calliphoridae	Diptera	X	J, Kei, Ken, TA	Costa Rica	Jiron & Hedström, 1985
Cochliomyia minima	Calliphoridae	Diptera	X	J, Kei, Ken, TA		
Lucilla eximia	Calliphoridae	Diptera	X	Kei, Kent, TA		
Chloropidae sp	Chloropidae	Diptera	X	Kei		
Villa lateralis	Bombyllidae	Diptera	X	J, Kei, Ken, TA		
Musca domesticae	Muscidae	Diptera		J, Kei, TA	Australia; Brazil; India, Israel; Taiwan	Anderson et al., 1982; Sung et al., 2006
Lepidodexia pacta	Sarcophagidae	Diptera	X	J, Kei, TA		
Peckia sp.	Sarcophagidae	Diptera	X	J, TA		
Hermetia illucens	Stratiomyiidae	Diptera	X	Kent	Costa Rica	Jiron & Hedström, 1985
Architas marmoratus	Tachinidae	Diptera	X	Kent		
Gonia crassicornis	Tachinidae	Diptera	X	J, Kei, TA		
Linnaemya fulvicauda	Tachinidae	Diptera	X	Kei		
Phtilodexia rufianilis	Tachinidae	Diptera	X	Ken		
Euxesta stigmatias	Ulidiidae	Diptera	X	J, Kei, Ken, TA		
Physiphora clausa	Ulidiidae	Diptera	X [1]	J, Kei, Ken, TA		
Allograpta radiata	Syrphidae	Diptera	X	J, Kei, Ken, TA		
Capestylum pallens	Syrphidae	Diptera	X	Kei, Ken, TA		

[1]New report species for Puerto Rico
[2]New species
[3]Cultivars: J=Julie, Kei=Keitt, Ken=Kent, TA=Tommy Atkins

TABLE 2.—*(Continued) Species visitors in four mango cultivars (Julie, Keitt, Kent, Tommy Atkins) in three years in Puerto Rico with entomological: Family, Order, new record, new report, new species, other countries, references.*

Species visitors	Family	Order	New record of flowers visitors in mango[1,2]	Cultivars[3]	Flower visitors in mango in other countries	References
Copestylum vacuum	Syrphidae	Diptera	X	J, Kei		
Lepidomya calopus	Syrphidae	Diptera	X	J, Kei, Ken, TA		
Monoceromyia wolcotti	Syrphidae	Diptera	X [1]	Kei, Ken, TA		
Ornidia obesa	Syrphidae	Diptera	X	Kei, Ken, TA	Costa Rica	Jiron & Hedström, 1985
Palpada albifrons	Syrphidae	Diptera	X	J, Kei, Ken, TA		
Palpada furgata	Syrphidae	Diptera	X	Kei		
Palpada vinetorum	Syrphidae	Diptera	X	J, Kei, Ken, TA	Brazil	De Siqueira et al., 2008
Psedodorus clavatus	Syrphidae	Diptera	X	J, Kei, Ken, TA		
Apis mellifera	Apidae	Hymenoptera		J, Kei, Ken, TA	Africa; Brazil; India; Israel; South Africa; Taiwan; Japan Philippines; USA (Fla)	Bhatia et al., 1995; Dag & Gazit, 2000; Carvalheiro et al., 2010; Fajardo et al., 2008; Kumar et al., 2012; Popenoe, 1917; Sasaki et al., 1988; De Siqueira et al., 2008; Sung et al., 2006; Reddy et al., 2017
Exomalopsis similis	Apidae	Hymenoptera	X	J, TA		
Hopliosoides niger	Crabronidae	Hymenoptera	X	Kei, TA		
Liris fulginosus	Crabronidae	Hymenoptera	X	J, Kei, Ken, TA		
Liris labiatus	Crabronidae	Hymenoptera	X	TA		

[1]New report species for Puerto Rico
[2]New species
[3]Cultivars: J=Julie, Kei=Keitt, Ken=Kent, TA=Tommy Atkins

TABLE 2.—*(Continued) Species visitors in four mango cultivars (Julie, Keitt, Kent, Tommy Atkins) in three years in Puerto Rico with entomological: Family, Order, new record, new report, new species, other countries, references.*

Species visitors	Family	Order	New record of flowers visitors in mango[1,2]	Cultivars[3]	Flower visitors in mango in other countries	References
Ophionellus sp.	Ichneumonidae	Hymenoptera	X [1,2]	J		
Monomorium floricola	Formicidae	Hymenoptera	X	Ken		
Pepsis marginata	Pompilidae	Hymenoptera	X	J, Kei, Ken, TA		
Pepsis rubra	Pompilidae	Hymenoptera	X	Kei		
Pepsis ruficornis	Pompilidae	Hymenoptera	X	J, Ken		
Pachodynerus guadulpenis	Vespidae	Hymenoptera	X	TA		
Chilocorus nigritus	Coccinellidae	Coleoptera	X	J, Ken, TA		
Coelophora inequalis	Coccinellidae	Coleoptera	X	Kei, Ken		
Cycloneda sanguinea	Coccinellidae	Coleoptera	X	J, Kei, Ken		
Hippodamia convergens	Coccinellidae	Coleoptera	X	J		
Olla v-nigrum	Coccinellidae	Coleoptera	X	Ken, TA		
Cryptocephalus irroratus	Chrysomelidae	Coleoptera	X	Kei		
Thonalmus chevrolati	Lycidae	Coleoptera	X	Ken		
Panoquina lucas woodruffi	Hesperiidae	Lepidoptera	X	J, Kei		
Electrostrymon angelica	Lycaenidae	Lepidoptera	X	J, Kei, Ken, TA		
Junonia genoveva neildi	Nymphalidae	Lepidoptera	X	J, Ken		
Ascia monueste eubotea	Pieridae	Lepidoptera	X	Ken		
Phidotricha erigens	Pyralidae	Lepidoptera	X	J, Kei, Ken		
Synchlora herbaria	Geometridae	Lepidoptera	X	J		

[1]New report species for Puerto Rico
[2]New species
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for the years 2017-2019 and 2018-2019, *Palpada vinetorum* contributed the most to dissimilarity with a 49% contribution for both periods. In the case of cultivar Tommy Atkins, *Cochliomyia minima* contributed 49% and 43% between the years 2017-2018 and 2018-2019, respectively, and *Apis mellifera* contributed 21% between 2017 and 2019 (Table 1).

The insect species reported for these four mango cultivars are new records (Table 2). They include three species that are new reports to Puerto Rico, namely *Physiphora clausa*, *Monoceromyia wolcotti* and *Ophionellus* sp., the latter being a new species within the Family Anomalonidae (Table 2). When compared to species that have been reported in mango elsewhere, only seven species in this study are reported elsewhere. These are: *Chrysomya megacephala*, reported in India and Taiwan (Singh, 1988; Sung, 2006); *Chrysomya rufifacies*, *Hermetia illucens* and *Ornidia obesa*, reported in Costa Rica (Jiron and Hedström, 1985); *Musca domesticae* being reported in Australia, Brazil, India, Israel, and Taiwan (Anderson et al., 1982; Sung et al., 2006); *Palpada vinetorum,* reported in Brazil (De Siqueira et al., 2008), and *Apis mellifera*, reported in Africa, Brazil, India, South Africa, Israel, Taiwan, Philippines, Japan and the United States of America (Bathia et al., 1995; Dag and Gazit, 2000; Carvalheiro et al., 2010; Fajardo et al., 2008; Kumar et al., 2012; Popenoe, 1917; Sasaki et al., 1998; De Siqueira et al., 2008; Sung et al., 2006; Reddy et al., 2017).

On the other hand, *Exomalopsis similis*, *Cycloneda sanguinea* and *Olla v-nigrum* were present in the cultivars studied during 2017. That year Puerto Rico was impacted by two intense atmospheric events. These species were not observed again in 2018 or 2019. Therefore, atmospheric disturbances could also generate changes in the abundance of local pollinators; moreover, it has been suggested that in areas where hurricanes are common (as in the Caribbean), these drastic changes in pollinator abundance represent an important evolutionary factor in the reproductive systems of native plants (Rivera-Marchand and Ackerman, 2006).

Knowing the diversity of floral visitors in any crop allows us to understand what is occurring with the possible pollinators of this crop, whether these species vary among cultivars and what could occur with their populations over time. Moreover, food security may be at risk with recent global changes, as the climate and the availability of pollinators could modify the production of agricultural crops (Wheeler and Von Braun, 2013; Ladányi and Horváth, 2010). This study recognizes the diversity of floral visitors in four cultivars of *Mangifera indica* allowing us to develop strategies to mitigate the impacts on these populations and help sustain the food security of important agricultural crops.

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