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Original Research Article

Some scale insects and fungi infesting mango trees in Ismailia, Egypt

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Abstract

The aim of the present work was to largely identify the scale insects and fungi living on mango leaves in order to find out from their biology whether there is a possible relationship between the two groups of organisms so that specific recommendations for their control can be made. A white hard scale insect *Aulacaspis tubercularis* Newstead (Diaspididae) and a green soft scale insect *Kilifia acuminata* Signoret (Coccidae) as well as four saprotrophic fungi belonging to the genera *Alternaria* Nees: Fr., *Cladosporium* Link., *Helminthosporium* Link ex Fr. and *Stemphylium* Wallr., were detected based on their morphological features in accordance with the identification keys and descriptions of scale insects and fungi. The infestation of mango leaves with the saprotrophic fungi was interpreted as a secondary infection due to the primary infection with the scale insects as honeydew producers on which the fungal spores develop and reproduce. Therefore, it is recommended to control the scale insects at an infection rate of 10% or more by means of which the application of fungicides could be dispensed. Furthermore, it cannot be ruled out that the climatic changes (e. g. fluctuating temperatures, increased relative humidities and greenhouse gases) as well as the increasing use of pesticides with their associated changes in the build-up of resistance, entomological and fungal biodiversities and in the balance sheets to the natural enemies are of greater importance as to provide a possible explanation for the seasonal fluctuations in the qualitative and quantitative mango crop failures.

Keywords: *Alternaria* sp.; *Aulacaspis tubercularis*; *Cladosporium* sp.; *Helminthosporium* sp.; *Kilifia acuminata*; *Mangifera indica*; *Stemphylium* sp.

INTRODUCTION

For decades, mango cultivation is one of the most important sources of economic income in Egypt and is mainly concentrated in eight governorates in the Nile delta. Mango leaves, buds and fruits are infected with various phytopathogenic and saprotrophic fungal species that belong to the ascomycetes, basidiomycetes and their imperfect forms (May et al., 2019). Such fungal diseases as *Alternaria* leaf spots caused by *Alternaria alternata* (Fr.: Fr.) Keissl. and *A. tenuissima* (Kunze: Fr.) Wiltshire, *Stemphylium* – rot caused by *Stemphylium vesicarium* (Wallr.) E. Immons, and others were collected by Pernezny and Simone (2000).

In addition to the fungal diseases, mango leaves, buds, flowers and fruits serve as a food source for many insect species such as aphids, fruitflies, mites, scale insects and wasps or as places for reproduction, coexistence or parasitism.

Scale insects are the most invasive parasitic group of insects. They are polyphagous, transmit many plant pathogens, feed mostly on phloem juice (Jiang et al., 2019) and belong to the suborder Coccina that includes the superfamily Coccoidea with its approximately 8.000 species in 32 families (Gullan and Cook, 2007). The families Diaspididae, Pseudococcidae and Coccidae have the mostly described species of about 2.500, 2.000

and 1.150, respectively (Garcia Morales et al., 2016). In contrast to the short-lived (few days) and usually winged males (if they are present), the sedentary adult females live longer and cause economic damages on host plants around the world (Pellizzari and Germain, 2010).

Bakr et al. (2009), Abo-Shanab (2012), Abd-Rabou et al. (2012; 2014), Sayed (2012), Nabil (2013), Mokhtar et al. (2015) and Salem et al. (2015) studied scale insects from different ecological, biological and occurrence aspects, as well as their economic role and control, whereas many mango fungal diseases have been only listed by Pernezny and Simone (2000) or partially investigated as by Tam (2017), which means only entomological or mycological studies have been performed without considering their possible relationships to one another.

In the recent years a rampant infestation with scale insects and sooty moulds was found in all mango orchards in Ismailia governorate, Egypt, so that the surfaces of the leaves still hanging on the trees and the plant materials lying on the ground around the tree trunk in a radius of about two meters were covered with a black powdery-like sticky plaque (fungal spores), while scale insects live en masse on the undersides of the leaves as well as on small branches. This mass of infestation impaired the vitality of the trees by reducing chlorophyll formation and photosynthesis (Nabil, 2013) so that their susceptibility to subsequent diseases caused by sooty moulds and other pathogens would be increased. Additionally, many farmers have reported that despite the intensive and uncontrolled use of plant protection products, the harvest varied from year to year so that yields were offset by up to 50% losses. These losses can be mainly attributed to the increasing infestation with scale insects and fungal diseases that are favoured by optimal temperature and relative humidity in Egypt. Furthermore, the confused use of many mineral oils, fungicides and insecticides in all of the visited mango orchards in Ismailia did not achieve the desired effect so that many farmers had torn down the trees that were up to 30 years old.

The previously mentioned critical and complicated disease state of the mango trees was the decisive consideration in the present work with the aim of finding out and clarifying the reasons for this epidemic infection and how to control it. The present study comprised therefore three steps built on each other and made to identify firstly the scale insects and sooty moulds living in a community on mango leaves and then to find out based on their biology whether there is a possible relationship between the two groups of organisms and finally to derive specific recommendations for combating pests and saprotrophic fungi.

Figure 1. Infected mango leaves with saprophytic fungi.

Figure 2. Infected mango leaves with hard white scale insects; male (m), female (f) (above) and soft scale insects females (f) (below).

MATERIAL AND METHODS

Sampling

Twenty five infected mango leaves of two varieties (Ewees & Balady) were diagonally taken on April 29, 2019 from a private garden (150 × 44 m) inside Ismailia City in Egypt at a temperature of 27 °C and relative humidity of ± 55%, transferred in sealed plastic bags and stored at 8 °C until transportation to Germany. From April 30, 2019 the leaves were kept in the cold room at 4 °C of the Institute of Phytopathology, CAU-University, Kiel, Germany.

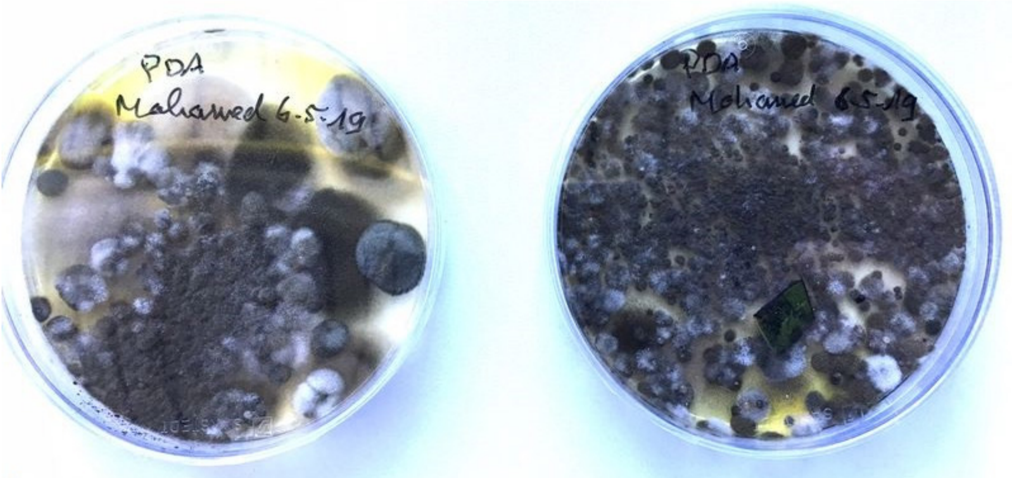

Figure 3. Fungal cultures on PDA agar.

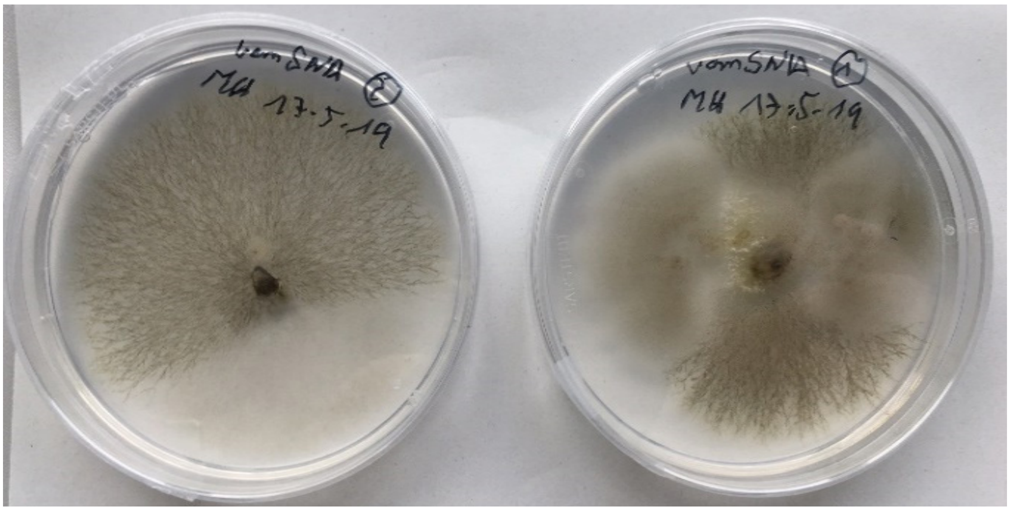

Figure 4. Fungal cultures on SNA agar.

Provision, observation and propagation of fungal cultures

At a sterile workbench, smears with a sterile vaccination needle were directly taken from infected mango leaves, transferred onto PDA (potato dextrose agar) and SNA (small nutrient agar) Petri dishes of nine cm diameter, and then stored at 25 °C. At different intervals of three to seven days, the plates were examined under the light microscope. Up to four different types of conidia were found per plate. To identify the fungi, it was necessary to reinoculate and isolate the overlapped fungal mycelia from each other onto new PDA (Fig. 3) and SNA (Fig. 4) plates to obtain possibly only one fungal culture.

Identification of saprotrophic fungi and scale insects

The identification of the saprotrophic fungi, sometimes referred to as sooty moulds, was based on the morphological properties of the conidia and conidiophores such as colour, shape origin, structure, and measurements. It was carried out under the light microscope using the identification keys and description of Barnett and Hunter (1998) and Petrini and Petrini (2002). The Nomenlature is based on the International Code for algae, fungi and plants as mentioned in chapter F by May et al. (2019). The closed Petri dishes were directly examined and partially the lidless ones for better observations of conidiophores and conidia outstanding from the agar. The growing mycelia, conidiophores and conidia were sketched, measured and then photographed, also from prepared slides.

The infected mango leaves with scale insects were also examined directly under the light microscope, identified according to the identification keys and descriptions of Miller and Davidson (2005), Schmutterer

(2008), Bakr et al. (2009) and Pellizzari and Germain (2010), measured, and then photographed.

RESULTS

Proven saprotrophic fungi

The following saprotrophic fungi at genus level have been identified:

Alternaria Nees: Fr.
(teleomorph: *Clathrospora, Leptosphaeria; Pleospora*).
The morphological features of the genus *Alternaria* are summarised as follows according to:

1. Barnett and Hunter (1998, pages: 51, 132; 133): Conidia (porospores), long-beaked, obclavate to elliptical or ovoid, chain-like, dark, typically with both cross and longitudinal septa; borne acropetally in apical simple or branched appendage. Conidiophores dark, mostly simple, determinate or sympodial; rather short or elongate. Parasitic or saprophytic on plant material.
2. Petrini and Petrini (2002, pages: 52, 53, 59, 65; 66): Conidia (porospores) brown, one- or several-celled, growing in acropetally chains at conidiophores, often branched, borne clearly through sprouting (holoblastic), club-like, often drawn into a point (rostrum) at the top, with transverse and mostly longitudinal and oblique septa (wall-shaped septate), conidiogenic loci melanised and arranged sympodial; conidia can grow into conidiophores.

The results of the microscopic examinations (Fig. 5, 6, 7, 8) comply with the description of conidiophores and conidia of the genus *Alternaria* Nees: Fr., according to the mentioned identification keys.

Cladosporium Link.
(teleomorph: *Mycosphaerella* Johanson*; Venturia* de Not.).
The morphology of the genus *Cladosporium* is described as follows after:

1. Barnett and Hunter (1998, pages: 49, 50, 106; 107): Conidia (blastospores) dark, one- or two-celled, variable in shape and size, ovoid to cylindrical and irregular, some typically lemon-shaped; often in simple or branched acropetalous chain. Conidiophores tall, dark, upright, branched variously near the apex; clustered or single. Parasitic on higher plants or saprophytic on fresh dead plant materials.
2. Petrinia and Petrini (2002, page: 53, 59; 72): Conidia one-to-four-cells, without or only with cross septa, in arcopetally chains, conidiogenic loci sympodial arranged; often olive-brown. Conidiophores clearly formed, branched, dark; cellular. Species of *Cladosporium* are everywhere (soil,

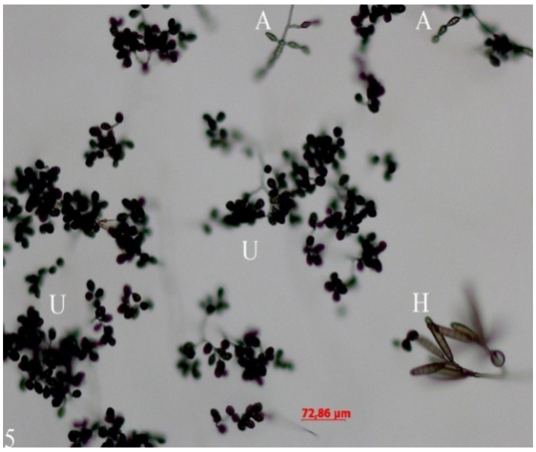

Figure 5. A mixed culture of three different fungi: *Alternaria* sp. (A), *Helminthosporium* sp. (H) and unknown (U).

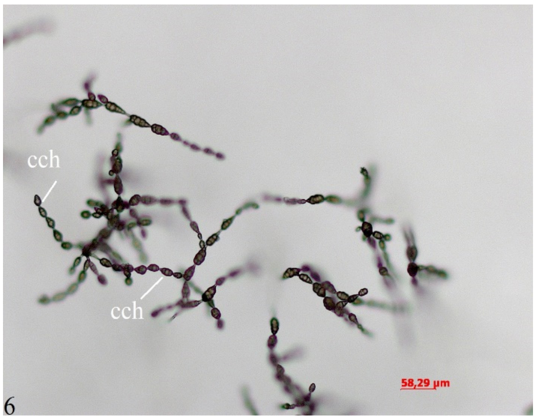

Figure 6. *Alternaria* sp., typical conidial chain (cch). Conidia with longitudinal and cross septa; elliptical, club- or ovoid-shaped.

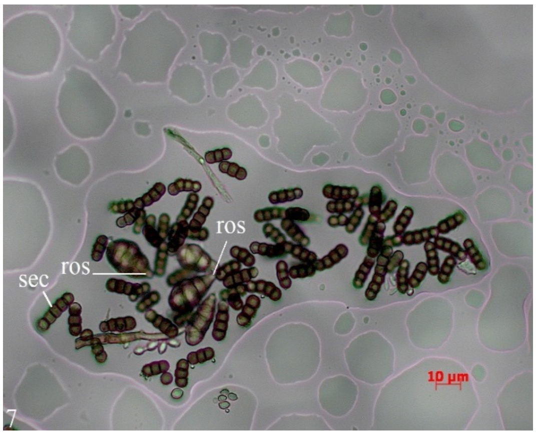

Figure 7. *Alternaria* sp., conidia with cross and longitudinal septa (septed conidia = sec) and a beak at the distal end (rostrum = ros); club- or ovoid-shaped.

air, food; cereal crops), grow at higher water activity and cause a black plaque. Parasitic or saprophytic.

The identified characteristics of the genus *Cladosporium* (Fig. 8; 9) are also consistent with those in the morphological description of conidiophores and conidia given by the authors mentioned above.

Helminthosporium **Link ex Fr.**

The morphological features of the genus *Helminthosporium* are summarised below after Barnett and Hanter (1998, pages: 51, 124; 125) since this genus is not present in the book of Petrini and Petrini (2002):

Conidia (porospores) several-celled, cylindrical to obclavate, develop straight, sideways throughout pores below the septa, while the apex of the conidiophore is still growing, often appearing in whorls, single, subhyaline to brown, obclavate, phragmosporous, pseudoseptate, with prominent basal scar. Mycelium dark, often in substrate; stromata often present. Conidiophores single or clustered, tall, erect, brown; simple. Parasitic or saprophytic.

The description of conidiophores, conidia and their origins according to the authors quoted above agree with the obtained results of the identified genus *Helminthosporium* (Fig. 5; 10).

Stemphylium **Wallr.**

The morphology of the genus *Stemphylium* is represented as follows according to:

1. Barnett and Hunter (1998, pages: 51, 132; 133):

   Conidia (porospores) dark, with cross and longitudinal septa, variable in shape, frequently globose, broadly ellipsoid or ovoid; often constricted at major septum. Conidiophores elongating percurrently, dark, mostly simple with dark terminal swelling, short to long, bearing a single, terminal conidium or successive conidia on new growing tips; often proliferating through old conidial scar. Parasitic or saprophytic.

2. Petrini and Petrini (2002, pages: 55, 56; 96):

   Conidia (porospores) several celled, cross and longitudinal septa (wall-shaped septate), develop throughout pores connected with conidiogenic cells. Conidiophores holistically at the top and continue to grow. The genus contains about six species. Saprobic or weak parasitic on different plants.

There is a match in the structure, colour and origin of the photographed conidiophores and conidia of the genus *Stemphylium* (Fig. 11; 12) with the description of the same genus given by the previous authors.

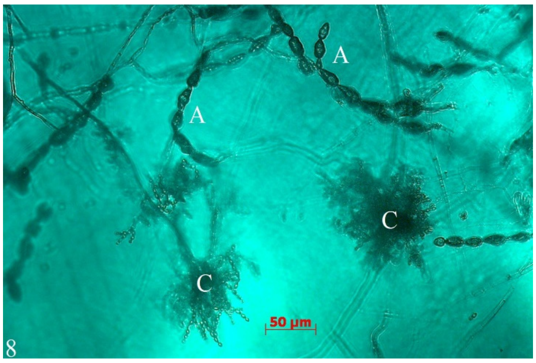

Figure 8. Two fungal cultures of *Alternaria* sp. (A) and *Cladosporium* sp. (C).

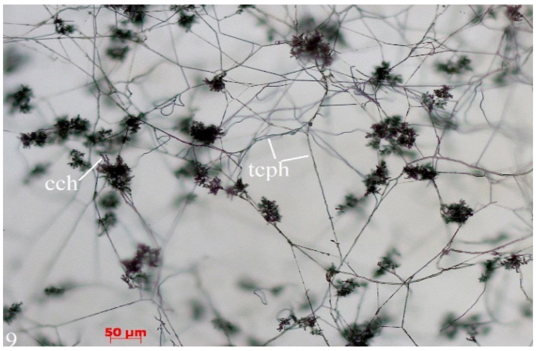

Figure 9. *Cladosporium* sp., tall conidiophores (tcph), dark; bearing 1- or 2-celled dark conidia, simple or in acropetal chains (conidial chain = cch).

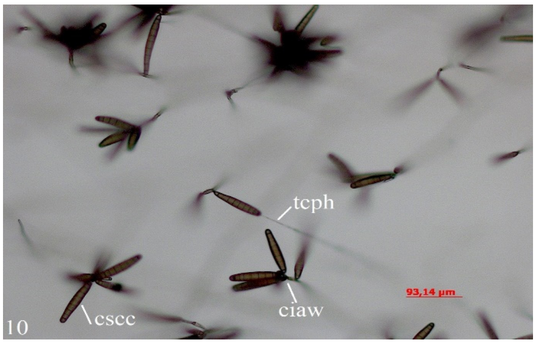

Figure 10. *Helminthosporium* sp., cylindrical, several celled conidia (cscc), brown; arising laterally from pores under the septa in a whorl (conidia in a whorl = ciaw). Tall conidiophores (tcph), single or clustered; brown.

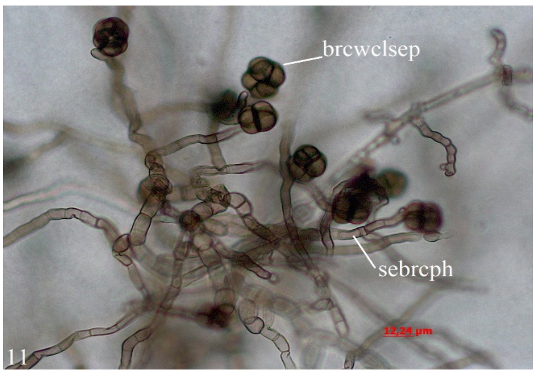

Figure 11. *Stemphylium* sp., septed, brown conidiophores (sebrcph), short or tall, branched; bearing often a single conidium. Brown conidia with cross and longitudinal septa (brcwclsep), globose or ovoid; constricted at the major septum.

Identified scale insects

The identification of scale insects is based on the morphological criteria of the females, since the short-lived males are in the minority and present no economic importance in agriculture.

A white hard scale insect *Aulacaspis tubercularis* Newstead (Diaspididae) and a soft scale insect *Kilifia acuminata* Signoret (Coccidae) were mainly identified according to the identification keys of Schmutterer (2008, pages: 30–40)[(1)] and Bakr et al. (2009, pages: 77–78)[(2)] as follows:

Class: Insecta, **Order:** Hemiptera; **Suborder:** Coccina

1. Abdominal pairs of stigmas are absent[(1)]......................2
2. Further developed scale insects[(1)] 3
3. Superfamily: Coccoidea[(1)]..4
4. Mango scale insects (females)[(2)]

4.1. Pink (eggs, immature and adults); covered with short filamentous white waxy secretion; female oval, microscopically with 9-segmented antennae and numerous dorsal oral rim ducts; male with one pair of wings; vestigial mouth-parts; long antennae and two long caudal filaments. ....Family: Pseudococcidae
– Not pink colour; without filamentous white waxy secretion; male and female are not as above................ 4.2

4.2. Yellowish white; adult female enclosed in a tough spherical cyst composed of very thin layers, adult female looks like a hairy ball with purplish body contents microscopically; antennae short and stout; eyes well developed........................Family: Margarodidae
– Not enclosed in spherical cyst; female not like a hairy ball 4.3

4.3. Hard scale covered with armoured scale; microscopically without abdominal spiracles; the anus without a rigid anal ring and anal plates; legs not well developed; male head fused with prothorax..Family: Diaspididae
– Female circular, whitish, flat, thin; antennae without setae or ducts, with dark oval spots; microscopically the body widens above the anterior spiracle; macroducts absent from thorax and head; female with elongate pygidium .... *Aulacaspis tubercularis*

Family: Diaspididae[(1)] – Hard scale insects

Female under removable shield consisting of secretions of the skin glands, excrements and exuvia; shield shape rounded, oval or mussel-like, colour white, yellowish, grey, black or brown; body shape round, oval, pear-shaped or elliptical, mostly white, yellow, orange or reddish; body size mostly 1–3 mm; antennae very small and stubby; mouth parts well developed; eyes mostly small; reduced pigmented spots or completely absent;

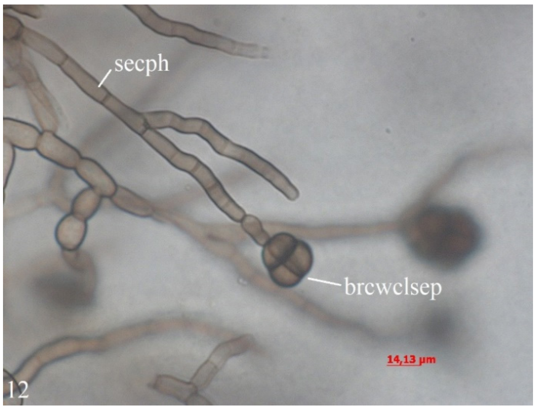

Figure 12. Enlarged view of typical conidiophores (septed conidiophores = secph) and conidia (brown conidia with cross and longitudinal septa = brcwclsep) of *Stemphylium* sp.

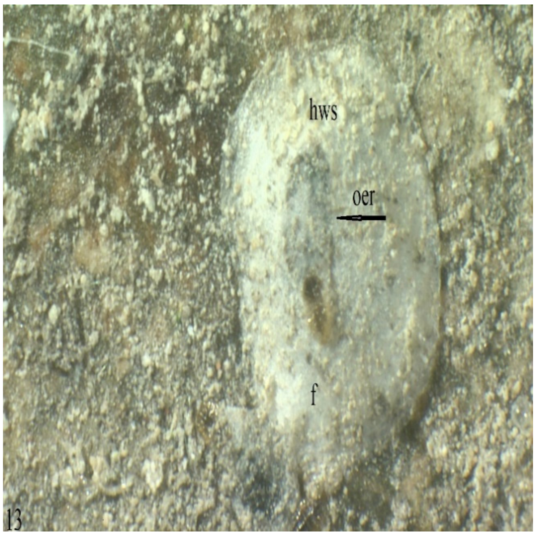

Figure 13. Adult female (f) of *Aulacaspis tubercularis* covered with a waxy hard white scale (hws); oval-shaped exuvial rings (oer) of L_1 and L_2 larval stages (instar nymphs), dorsal view.

Figure 14. *Aulacaspis tubercularis*, a longitudinal-shaped male (m) covered with a waxy hard white scale; removed hard white scale (rhws) from a brown adult female (f), that may be parasitised throughout a hole (p).

legs not well developed; ventral thoracic stigma (two pairs) funnel-shaped; rear abdominal segments fused into sclerotic plate (pygidium), rear edge of the pygidium with rags, plates and glandular spines; dorsal side with tubular skin glands of different sizes; ventral side with disc-shaped skin glands, five-pored, usually arranged in groups around the vulva.

4.4. Soft scale without armoured scale; microscopically with abdominal spiracles; anus with anal rings and plates; legs usually well developed; male head with fairly distinct neck....................................Family: Coccidae
– Triangular in shape, with blunt pointed front tip; yellowish green; mesothoracic and metathoracic coxae different in shape than prothoracic coxae; ventral duct absent...*Kilifia acuminata*

Family: Coccidae(1)– Soft scale insect

Female round, oval or elongated oval; usually relatively flat or only slightly curved before laying eggs, later often to be hemispherical and bowl-to berry-shaped; the rear third of the dorsal side with two triangular, strongly sclerotised anal plates and anal subsequent cleavage; anal ring well developed and with six strong bristles and some pores; edge of the body with one or more rows of bristles; at the height of the stigmas are three strong bristles differing in size and shape from the normal bristles; numerous disc-shaped, multi-pored skin glands on abdominal segments around the genital opening; tubular skin glands on the ventral and dorsal sides.

White scale insect: *Aulacaspis tubercularis* Newstead

Numerous rounded to oval-shaped brown adult females were found on the underside of the mango leaves, the body of which is protected under an appropriate white-grey, removable and granulated shield, on its dorsal side, oval-shaped exuvial rings of the first and second instar nymphs were recognised, as well as a shimmering dark brown circular hole (Fig. 13). This hole may be an indicator of a possibly parasitised female (Fig. 14; 15).

By folding over the shield, the dark brown female with its eggs became visible (Fig. 15). The eggs are usually protected in a shell behind the abdomen. In contrast to the almost rounded body of the female with up to 2.3 mm, the elongated body of the male measures about 3.0 mm and is also covered with a corresponding white shield, to which many threads-like hardened waxes adhere (Fig. 14). The mouthparts are well developed by the sedentary females and regressed by the rarely, winged, short-lived and movable males. On the ventral side of the female's body there are disc-shaped skin glands around the vulva.

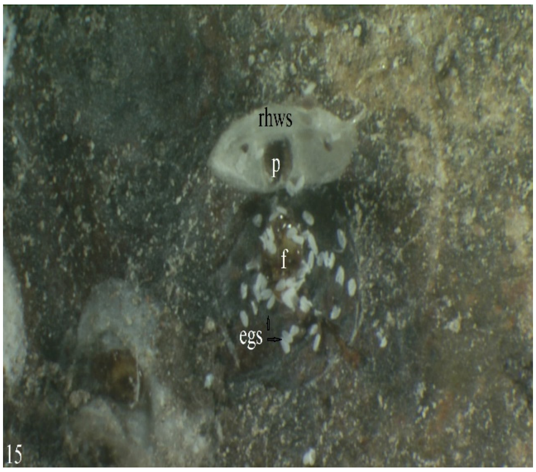

Figure 15. Ventral view of another female (f) of *Aulacaspis tubercularis,* that may be parasitised throughout a hole (p); removed hard white scale (rhws) and white young eggs (egs).

Figure 16. A green pear-shaped adult female of *Kilifia acuminata* covered with a transparent soft shield (dorsal view).

Figure 17. Another adult female of *Kilifia acuminata* (dorsal view).

Soft scale insect: *Kilifia acuminata* Signoret

Despite the well-developed three pairs of legs (the rearly one is the longest), the adult females of *Kilifia acuminata* are immobile, sit on the underside of the leaves and suck out the phloem juice. Each female is covered with a soft transparent scale upon its slightly dorsal-vaulted, pear-to-oval-shaped and olive-brown body (Figs 16–18). The cover originates from the secretions of the skin glands. The body of a female is approximately 3.0 mm long and 2.5 mm wide at the widest part of the body. On the back of the dorsal side of the body there are two triangular anal plates and a subsequent anal cleft. The anal ring is provided with six strong bristles, whereas one or more rows of bristles are attached along the body edge. The freshly laid eggs are white, turn later to brown, are protected between elevations of the ventral side of the body (Fig. 18). Most species of coccids reproduce parthenogenetically, rarely bisexually.

Figure 18. *Kilifia acuminata*, a ventral view of the same female from Fig. 17 to show the different ages of eggs (egs).

Figure 19. Reduced quality and quantity of mango fruits caused by scale insects and fungal infections.

DISCUSSION

Fungi are ubiquitous, they feed on organic substrates and include two groups of saprobionts and parasites depending on their ecological and biological requirements. Their spores reach mango leaves through the wind, rain, insects and friction between infected and healthy leaves. The detected saprotrophic fungi of the genera: *Alternaria, Cladosporium, Helminthosporium* and *Stemphylium* were identified and characterised using the identification keys and descriptions of Barnett and Hunter (1998) and Petrini and Petrini (2002). Besides the saprotrophic species of the recorded genera, there are many pathogenic species belonging to the same genera *Alternaria* and *Stemphylium* such as *Alternaria alternata* (Fr.: Fr.) Keissl., and *A. tenuissima* (Kunze: Fr.) Wiltshire, that cause leaf spots and fruit rot as well as *Stemphylium vesicarium* (Wallr.) E. Immons, which cause *Stemphylium* rot. These species are listed as pathogens in the database of the American Phytopathological Society (APS) by Pernezny and Simone (2000), whereas the detected other two genera *Cladosporium* and *Helminthosporium* are not included, which would be considered besides the two genera *Alternaria* and *Stemphylium* as the first record of saprotrophic genera with pathogenic species on mango. Furthermore, in contrast to the genera *Alternaria* and *Cladosporium*, whose sexual forms (teleomorphs: *Clathrospora, Leptosphaeria; Pleospora* and *Mycosphaerella* Johanson*; Venturia* de Not., respectively) and asexual forms (anamorphs) are known, the sexual forms (teleomorphs) of the genera *Helminthosporium* and *Stemphylium* are still unknown. Therefore, it was necessary, despite of the advanced phylogenetic systematics, to keep the group of fungi imperfecti (Deuteromycetes/Anamorphs) besides the Ascomycetes and Basidiomycetes in the fungal morphological systematics. This has been confirmed by examples of Nomenclature of some ascomycotal fungi based on the typical type of each genus including the ana- and teleomorph (if known) forms in the last updated chapter F in the International Code of Nomenclature for algae, fungi and plants, Chenzhen, 2018, as submitted to the XI International Mycological Congress in San Juan, Puerto Rico, July, 2018 and published by May et al. (2019).

Scale insects prefer sunny and dry places with dense plant populations (Schmutterer, 2008). The Egyptian mango plantations offer such climate from spring to late summer/autumn so that the scale insects can rapidly reproduce. They live mainly on the underside of the leaves, feed on the carbohydrate-rich juice from the sieve tubes and then excrete the honeydew that drips on the topside of the underlying leaves, sticks and serves as a food for many other insects and saprotrophic fungi that rapidly develop and reproduce.

Some scale insects of the family Diaspididae such as the recorded species *Aulacaspis tubercularis* (Newstead) feed on the juices of the parenchymal tissues/cells (Kondo et al., 2008), whereas those of the Coccidae as the detected species *Kilifia acuminata* (Signoret) and Pseudococcidae on the phloem (Ross et al., 2010) so that the last two groups produce more honeydew than the diaspidids.

According to Petrini and Petrini (2002), scale insects would be described here as species adaptable to their environment. This is because they begin from the first larval stages (crawlers) to build hard wax shields as by *Aulacaspis tubercularis* (Newstead) or soft clear ones as by *Kilifia acuminata* (Signoret) to protect themselves from unfavourable environmental conditions, predators, parasitoids (Abd-Rabou et al., 2012, 2014; El-Husseini et al., 2018) and partially against pesticides.

The first instar nymphs (L1) are movable and responsible for the spread of scale insects, where their low weight plays a crucial role in their dispersal. In addition, scale insects have an enormous propagation potential so that they can colonise the trees within few years at about four generations a year, which leads to the gradual death of the trees. This is due to the reduction of photosynthesis and the associated increase of fungal infection so that the leaves turn yellow, dry and then fall off. For example, Nabil (2013) recorded a loss in the formation of photosynthesis pigments (chlorphyll a and b) and the associated photosynthesis due to the infection of mango leaves, variety Shmama, with *Kilifia acuminata* (Signoret). Finally, the trees became weak and sensitive to more infections with other pests and pathogens.

Bakr et al. (2009) investigated the occurrence and ecology of scale insects in four mango plantations in Al-Qaliobiya governorate, Egypt. They recorded 14 species belonging to four families: Diaspididae, Coccidae, Pseudococcidae and Margarodidae, among which were the two species *Aulacaspis tubercularis* and *Kilifia acumulata* identified in the present work. They also found that the population densities of the 14 species were largely depending on temperature of about 25 °C and relative humidity of 55%. Furthermore, they reported that the mango variety Alphonso had a resistance of about 79% against the 14 detected species because the leaves possess thicker epidermis layers and contain some repellent and toxic substances as well as fewer carbohydrates compared with the other two investigated varieties Hendi and Langra. These last results may explain the high infection rate of the two in this study examined varieties Ewees and Balady because of their probably opposite nature of the leaves which would be necessary to investigate in the future. Under these conditions, the scale insects will reproduce and produce more honeydew, thus leading to more fungal and other insect infections. As a result of the complicated infection situation, the quality and quantity of the harvest were negatively affected (Fig. 19).

The climatic influence on the population densities of scale insects was also studied by Abo-Shanab (2012), Mokhtar et al. (2015) and Salem et al. (2015). They registered high population densities of *Aulacaspis tubercularis* on mango leaves at 20 °C and 60% relative humidity in the three Egyptian governorates El-Beheira, Ismailia and Kalubyia, whereas the population density of the soft scale insect: *Kilifia acuminata* was lower than that of *A. tubercularis* despite of higher temperatures of 27.5 °C – 31.7 °C and relative humidities of 59.5 % – 62.3 % in the Ismailia orchard (Mokhtar et al., 2015). At the ime of sampling on April 29, 2019 in Ismailia in bright sunshine and temperature of 27 °C and relative humidity of ± 55%, the infestation with the two recorded scale insects and four sooty moulds was rampant. This means that the ecological and biological requirements of various species are different.

To the best of our knowledge, the identified saprotrophic fungi and their relationship to the scale insects on mango leaves in Ismailia are described here for the first time in Egypt and may occur worldwide.

CONCLUSION AND RECOMMENDATIONS

Two species of scale insects: *Aulacaspis tubercularis* Newstead (Diaspididae) and *Kilifia acuminata* Signoret (Coccidae) as well as four genera of saprotophic fungi: *Alternaria* Nees: Fr., *Cladosporium* Link., *Helminthosporium* Link ex Fr. and *Stemphylium* Wallr., were identifed from infected mango leaves based on their morphological features. The infection with the sooty moulds is considered to be a secondary infection due to the primary infection with the scale insects as honeydew producers on which the sooty moulds feed, reproduce, eliminate the phytosynthesis, make the trees even more susceptible for additional infestations and subsequently reduced the quality and quantity of the harvest. It is therefore recommended to control the scale insects at an infection of 10% and thus to reduce the use of insecticides and fungicides worldwide which make a contribution to our environmental protection.

The following recommendations are based on the introduction, results and discussion of the present work with references to some supporting literatures:

1. From an infection frequency of about 10% (personal estimate) of the leaves with scale insects, the chemical control with different active

ingredients must be followed to save the crops and prevent the build-up of resistance to insecticides. To increase the efficiency of insecticides, the application should be intensified during the movable developmental phase of the first instar nymphs (approximately 2 weeks) because the control of the adult sedentary females that envelop under hard waxy or transparent soft shells in the Diaspididae and Coccidae, respectively, is more expensive and difficult. Generally, the use of mineral oils, insecticides, acaricides and eventually fungicides must be managed.

2. Fungal diseases such as: *Alternaria* leaf spots, antracnose, powdery mildew, *Stemphylium* rot and *Fusarium* crown rot must also be controlled with fungicides upto an infection rate of 10% (personal estimate).
3. Where it is possible, natural enemies of scale insects should be promoted (Abd-Rabou et al., 2012, 2014; Mansour et al., 2017; El-Husseini et al., 2018) as well as antimicrobial sprays (Jiang et al., 2019).
4. At the end of the harvest time in August/September, the prophylactic plant protection measures should be started. They include: tree cutting to ventilate the trees, removing the weeds between the trees, reducing nitrate fertilisation, irrigation by dropping or sprinkling especially at higher temperatures, burning infested leaves, avoiding monocultures and resistance formation by using resistant varieties.
5. Scale insects hibernate in one or more stages of development like eggs, first and second stage or imago stage in some diaspidids and coccids species. The lifespan of females is about 3–4 or 6–8 months with hibernation and a few days for males since they die after fertilisation (Schmutterer, 2008). Therefore, it would be useful to flood the fields in order to kill the hibernating stages. With rising temperature in Egypt from February/March onwards, the newly hatched first larval stages (crawlers) become very active, search for food, and develop to complete their life cycles. The ants wandering on mango trees can give an indication for the occurrence of scale insects (Schmutterer, 2008).

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CONFLICT OF INTEREST

The author declared that there are no conflicts of interest with respect to research, authorship and publication of this article.

ETHICAL COMPLIANCE

The authors have followed the ethical standards in conducting the research and preparing the manuscript.

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