White Mango Scale

Subjects: Entomology

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The white mango scale (WMS) insect, *Aulacaspis tubercularis* (Hemiptera: Diaspididae), is a polyphagous, multivoltine pest which is a serious threat to qualitative mango production and export. The WMS insect sucks sap from leaves, branches and fruits. The heavy infestation of this pest may cause the falling of young leaves, drying up of twigs, poor flowering, and, finally, reduce the quality of fruits by producing pink spots on fruits' surface.

Aulacaspis tubercularis | environmental variables | damage | cultural control

1. Introduction

Mango (*Mangifera indica* Linn. Family: Anacardiace), the so-called "King of fruits", is an important fruit crop throughout the world, including Pakistan. Mango fruits are popular because they are delicious and rich in vitamins A and C. Good flavor and taste add further value to this fruit. In recent years, mango production has been decreased by multiple factors, viz., nutrients deficiency, flood, drought, thermal regimes, improper management practices (ploughing and intercropping) [1][2], and biotic factors (insect pests and diseases) [3][4]. The most prevalent insect pests in Pakistan are scales (*Aulacaspis tubercularis* (Newstead)), mango hopper (*Idioscopus clypealis* (Lethierry)), midges (*Dasineura amaramanjarae* (Grover)), mealybug (*Droschia mangiferae*), fruit fly (*Bacrtrocera dorsalis* (Hendel) and *Bactrocera zonata* (Saunders)), thrips (*Scirtothrips dorsalis* (Hood)), and bark beetle (*Hypocryphalus mangiferae* (Stebbing)) [5][6].

In recent years, white mango scale (*Aulacaspis tubercularis* Newstead; Diaspididae; Hemiptera) has increased to the extent that it is now regarded as an important economically destructive and potential export risk in different parts of the world [7][8] including south-east Asia. This pest was first reported on the island of Formosa on *Mangifera indica* in 1929, and later on in the Caribbean Islands (2012), India and Brazil (2021) [9]. *A. tubercularis* originated from Asia [9] and later on it was observed in South Africa [10][11], Australia, East and West Africa, North and South America and the Caribbean Islands [12]. Now it is found in almost 69 mango-producing countries of the world, and being polyphagous in nature, this pest attacks several crops. The damage of the pest is always variable depending upon the climate and mango variety. This sucking insect pest can be observed on different parts of mango plants, including shoots, twigs, leaves, branches and fruits (**Figure 1**).

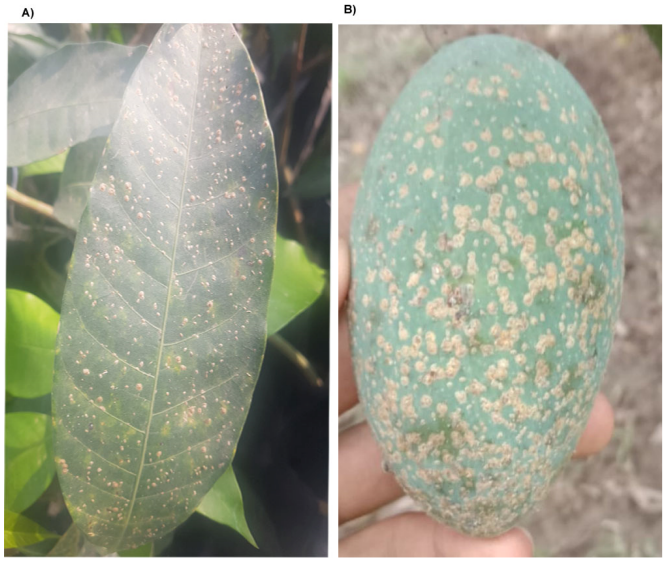

Figure 1. White mango scale insect on leaves and fruit in farmer orchards in Pakistan. (**A**) WMS population on leaves. (**B**) WMS population on fruit.

2. Occurrence

WMS (*A. tubercularis*) had been considered a native to the Asian continent; however, later on, it was distributed in other mango-producing countries through infested plant material [13]. WMS infestation has been reported in more than 60 mango-growing countries, including Africa, Asia, Oceania, South and Central America, parts of Europe and the 80 Caribbean islands [14].

In Mexico, this pest was first detected in 1999 on 300 acres, and later on, due to extensive damage caused by the pest, it has been regarded as the second most important mango pest after fruit flies (*Anastrepha* sp.; Diptera: Tephritidae) [15]. Morsi et al. [16] observed WMS in Minia (Egypt); later on, the pest was observed in all mango-growing areas of Egypt. In Ethiopia, WMS infestation was first reported in 2010 [17]. Late on, it became a serious threat to mango productivity in western Ethiopia [18][19]. In Spain and Andalusia, WMS caused extensive damage to mango production during 2010 (Málaga and Granada provinces) [20].

In 1947, WMS was observed in South Africa on a few mango cultivars; later on, the pest was also observed feeding on avocados in South Africa [21]. WMS moved from South Asia to Ethiopia through the import of mango seedlings in 2010 [17] and further dispersed 100 km west of the original site within a year in the same way [18]. Global dispersal of this devastating insect pest was observed through the movement of infested material.

North Atlantic Plant Protection Organization (NAPPO) [22] considered this as an important pest and put it on the alert list, but European countries, EPPO, although considering it as an important pest, did not place it on the threat list [20]. WMS is considered an important pest in the Mediterranean basin, and strict quarantine measures are implemented to restrict its dispersal.

3. Epidemiological Requirement

Climatic factors, viz., temperature, relative humidity, hurricane, and wind, affect the abundance of WMS [23]. The population of WMS, insect physiology and insect behavior were also affected by environmental factors [24][25], host plants, competitors and natural enemies [26][27]. Temperature can even affect the male-female ratio. Females were most abundant between 18–22 °C and 73–78% RH while males were abundant at temperatures between 25–28 °C and 66–71% RH [28]. At times of peak abundance, 1:20 female to male was observed [28].

WMS (*A. tubercularis*) males cluster in the lower canopy of trees [28]. Although females are homogeneously distributed in trees, when the temperature increases, they migrate to lower plant canopy [28]. After emergence, males cluster around new virgin females and copulate. Males survive 1–2 days after emergence and do not feed. First, instar nymphs can travel and disperse through winds to the new tree. After reaching there, they establish a colony. However, infested plant material movement from one place to another place for export, movement through birds carrying food in claws, wind and irrigation water can spread the pest in the whole orchard or distant orchards as well.

4. Damage

WMS is a cosmopolitan, highly fecundate and polyphagous pest (feeding on crops belonging to more than 30 different genera and over 18 families [14][29][30]. The pest was abundant on host plants belonging to four families, i.e., Anacardiaceae, Lauraceae, Palmae, and Rutaceae, particularly mangoes and cinnamon [31][32].

WMS is a serious pest of mangoes [33] in Argentina [34], Australia [35], Brazil [36], China [37], Colombia [38], Ecuador [39], Egypt [40], Ethiopia [41], India [37], Kenya [42], Mexico [43], Pakistan [37], South Africa [44], Spain [20] and many other countries [14].

The losses caused by this pest on mangoes varied based on the prevailing climate, variety and pest population. For example, in Kenya, it was not considered an important pest by the mango community as its impact was less serious [42], while in other countries such as Ethiopia [19], Egypt [45] and South Africa [46], the pest threatened production.

WMS feeds on plant parts, including fruits, through sucking cell sap. The infestation of WMS results in deformations which ultimately affect plant yield. WMS, during feeding, releases toxic saliva that affects the commercial value of fruits and their export. Greater damage was noticed in late mango cultivars [47][48] due to the abundance of scales on fruits and quantitative and qualitative damage produced [49][50].

The less mobile nature of the pest, the presence of chlorotic spots on the leaves and twigs, and less conspicuous blemishes on fruit skin might have been overlooked by farming communities in some countries (for example, in Kenya) [51][52]. Leaf loss and death of twigs were common in young trees, especially during hot and dry weather [40]. Small mango plants in nurseries could die because of heavy infestation of pests at the juvenile stage [51][53]. Mild infestation of WMS in the nursery may delay

mango growth in the nursery, particularly during hot, dry seasons [54]. Due to the infestation of WMS, the plant photosynthesis process is affected; hence the leaves change color from green to pale yellow [55] (**Figure 2**).

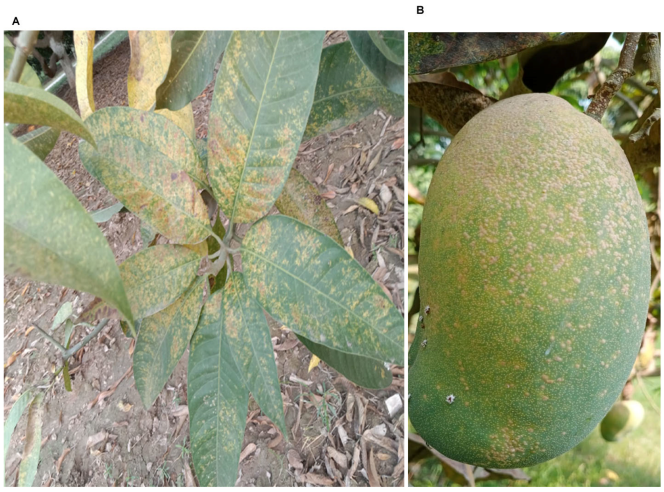

Figure 2. White mango scale damage on leaves and fruit in farmer orchards in Pakistan. (**A**) Chlorosis on leaves due to WMS infestation (**B**) Chlorotic spots on fruits due to WMS infestation in Pakistan.

The conspicuous blemishes on mango fruit skin not only reduce the export of mango fruits but also enhance the economic losses to farmers as well as to exporters [56]. The volatiles and odors emitted from ripening fruits might have attracted WMS because the fruits are filled with sugars on which insects feed [57]. More than 50% of losses in exports of mango fruits have been recorded due to the presence of chlorotic spots on the epidermis [37][43][46].

When the pest is abundant in mango crops, it is observed on all plant parts, including leaves, twigs, and fruits [58]. The odors released by ripening fruits attract the female WMS; hence they are highly abundant on the fruit at the ripening stage [19][58]. However, less acidic, viscous and sweet ripened mangoes may be more attractive compared to the immature ones due to their biochemical composition [59][60][61].

The management costs and economic losses caused by soft-scale infestations throughout the world have reached greater than one billion US dollars annually [62]. In Kenya, farmers spend about 13% of the mango orchard income on the management of WMS [42]. In Germany, 97% and 67% of mango fruits were rejected due to scales insect infestation on cultivar Sensation and Fascell, respectively [35].

About four–five *A. tubercularis* per fruit had caused up to 50% loss in commercial orchards in Spain due to the downgrading of mango fruits' cosmetic value. However, the susceptibility of mango cultivars to WMS infestation varies based on different characteristics. In this regard, a study was conducted in Puerto Rico, where it was concluded that the Haden, Edward and David Haden cultivars were most susceptible to scale insects infestation, while the Irwin and Keitt cultivars were less susceptible and Palmer was the most resistant [63]. Mango scale insect infestation in mango orchards of small farmers resulted in less production and reduced quality as well [18].

Due to severe infestation of WMS on citrus and fern, chlorotic spots were produced [64]. WMS was reported on citrus in Egypt [65]. An increase in one WMS per mango leaf decreased fruit yields by up to 4.28 kg per tree per year [54].

5. Life Cycle

White mango scale (WMS) tiny-shelled insects have more than 300 species [23][66]. For mass rearing of this pest, optimum growth conditions were 25 °C and 70% relative humidity, respectively [67]. However, 24–35 °C and relative humidity of 70–95% have been regarded as ideal environmental conditions for an increase in the population of WMS in field conditions [68]. Both types of reproduction, sexual and asexual, were observed in WMS [69].

5.1. Adult

The adult female is similar to nymphs without legs and wings [70]; a circular scale made up of wax 2 mm in diameter, having three longitudinal ridges and an exuviae terminal covering the body [37][71][72]. The exposed body of the gravid female is 1.5–2.0 mm long and brownish in color. Both forms of reproduction, ovipary and vivipary, were observed in scale insects [73].

The adult male WMS is usually small, slender, and winged [74]. Males bear vestigial mouthparts, hence are short-lived. Adult males were yellow to orange colored, about 0.53 mm long, and were unable to feed due to vestigial mouthparts. Adult males soon after emergence mate and die within 1–2 days [35]. Adult females excrete sex pheromones to attract male-scale insects [75]. Adult WMS vary in size (1.5–25 mm), shape and color [72][76]. Males usually cluster around females, while females usually occur singly [62].

5.2. Eggs

A female lays 80–200 eggs [77]. The eggs are 0.17 mm long, oval, and initially reddish brown in color, which later on become purple-colored depending upon maturity [76]. However, egg-laying fecundity is dependent upon the weather conditions as well, as in Australia, 50 eggs per female *A. tubercularis* were recorded. In South Africa, during summer, spring and winter conditions, about 203, 261 and 82 eggs per female were recorded, respectively. However, under semi-field conditions (27.5 °C and 81% R.H, 65), Gutierrez [70] observed 98.55 eggs per female [35]. At 27 °C and 81% RH, the incubation period was 8 days [70].

5.3. Hatching

After fertilization, the eggs hatch in 8 days [28]. Oviparous and viviparous reproduction was observed in scale insects population [58]. In sexual dimorphism, the female lays eggs. From these eggs, nymphs develop. Four stages (nymph stage 1, nymph stage 2, pre-pupa and pupa) were observed in the male population, while there are two female instars (nymph stage 1 and nymph stage 2) [35][71] in the female WMS population.

5.4. 1st Instar

The first instar nymphs emerge from eggs, settle down onto the tender part of the plant and suck the plant nutrients. Newly emerged first instar nymphs settle down within 24 h after hatching. Magsig-Castillo et al. [78] described that to find a good place for a feeding site, the first instar nymph can travel a distance of less than one meter. Once occupying some specific place, they insert their stylets, which ultimately form a food canal within the plant parts; hence they suck the sap from areas of colonization, either leaves, fruits or developing tissues [79]. After that, filaments of thread made up of wax were produced, which ultimately covered the upper epidermis [72]. Female crawlers often uniformly distribute within plant parts, while male crawlers settle near female crawlers in the form of groups. Although instar nymphs settle in groups, their population can be dispersed by various factors [33][80]. First, the instar male WMS colonizes near the adult female [70][72]. A study showed that about 10–80 males group near emerging adult female insects.

Nymphal instars and the male adults can move [35], but the movement of female crawlers through wings, bird claws or any other means is very important to initiate the infestation in a new tree or orchard [81]. In winter (7 and 23 °C), spring (13 and 26 °C), and summer (18 and 29 °C), the female first instar stage may last from 11.1–17.1 days [35] while at 27 °C and 81% R.H, the first female and male instar last 10 and 9 days, respectively [70]. In further development, about 80% of crawlers become males [77].

5.5. 2nd Instar

The second instar female WMS varies in size. In female WMS, the scale developed on the epidermis of the WMS was 3–4 mm, rectangular and developed from waxy filaments. The second instar female antennae were ovoid, translucent yellow colored and bear very small antennae [71]. The second instar male develops under the scale protective sheath bearing three longitudinal ridges [71]. In winter, spring and summer simulated conditions, the duration of the second female instar ranges from 11.1–25.3 days [35], while at 27 °C and 81% relative humidity, the second female and male instars may last for 5–8 days, respectively [70].

5.6. Pre-Pupa to Pupa

No change takes place in the size of WMS males from pre-pupae to pupae [71]. The pre-pupa and pupa stages may last for 3–5 days, respectively [70]. The pupal stage is found only in the case of males.

Life cycle period:

Environmental conditions and climate affect the life cycle of WMS [19]. In Australia, during summer, the WMS life cycle is completed in 35–40 days. In Winter, the life cycle is completed in 70–85 days [52][82]. A Female's WMS completes life in 52 days, while a male's only lasts 36 days [52]. The life cycle of WMS was completed in 68.9 in winter, 52.5 in spring and 42.7 days in summer [35].

This pest has 3–4 overlapping generations in a year [31][83]. There may be 5–6 generations per year, at 26 °C daytime temperature and 13 °C nocturnal temperature [55]. WMS has three generations in Mexico [23][51] and Egypt [31][40][53]. This is an important pest of mangoes in Egypt [84].

In Spain, it has three–four overlapping generations in a year [19][71][85], and in Southern Spain, it has two generations (spring and autumn) [71]. The ecological studies on pest resting behavior revealed that pest colonizes on the south sides of the tree in two locations (Kaapmuiden and Nelspruit, South Africa) [86].

5.7. Feeding Mechanism

In the WMS population, the adult male insects have vestigial mouthparts and hence live for only a few hours. A female WMS normally feeds and lives longer [87]. A male, after emergence, mates and dies within 1–2 days. WMS has piercing and sucking mouthparts. This chitinous tube is composed of four stylets, two maxillae and two mandibles [79]. During feeding, the female WMS obtains nutrients by pushing mouthparts into the parenchymatous tissues [88][89][90][91].

Histological studies show that the WMS scratches the interior of leaf tissue, including vascular bundles [92]. WMS, during feeding, not only punctures the parenchymatous tissues, but the lignified materials of the xylem are also punctured to obtain food. The pest secretes phenolic acid, which leaves a reddish scar [79].

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