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Infestation of Aulacaspis tubercularis (Homoptera: Diaspididae) on Mango Fruits at Different Stages of Fruit Development, in Western Ethiopia

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Abstract
The occurrence of white mango scale, *Aulacaspis tubercularis* in Ethiopia was reported for the first time from a mango orchard in western Ethiopia by 2010. It spread and has become a threat to mango production. This study was aimed at investigating the levels of infestations of *Aulacaspis tubercularis* on mango fruits at different stages of fruit development. Level of infestation was found to be the highest at yellow stage with significant difference from green and pre-yellow ($p< 0.01$). However, there was no statistical difference in levels of infestations between green and pre-yellow stages. The fruit was infested more by the female pest with significant difference from the male ($p< 0.01$). The level of infestation by female *Aulacaspis tubercularis* among the three stages of fruit development was also found to be statistically different ($p< 0.01$). Infestation by the male pest was significantly the highest at the yellow stage compared to pre-yellow and green stages. The current research concluded that white mango scale infested mango fruit starting mainly when the fruit began to have matured, and reached its peak when it was ripe. Moreover, it was confirmed that mango fruit was infested more by the female pest in the study area. It was recommended that the measures to be designed to control white mango scale should pay due attention mainly to the female white mango scale.
Keywords: Fruit, mango, infestation, *Aulacaspis tubercularis*

1. Introduction

Mango is a member of the family Anacardiaceae within the genus *Mangifera* which consists of over 25 species, of which *Mangifera indica L* is the only species grown commercially on large scale (Ramcharan, 1997; Griesbach, 2003). Various literatures underline that mango was originated in tropical Asia and has been distributed, naturalized and adapted to tropical and subtropical regions throughout the world (Kansci *et al.,* 2003; Dirou, 2004; Bally, 2006; Crane *et al*, 2013; Okoth *et al*., 2013).

Mango is attacked by a variety of insect pests such as stone weevil (*Sternochetus* spp.), mealy bugs, fruit flies, scales, and mites, and various diseases of which fungal diseases are the common (Balock and Kozuma, 1963; Halteren, 1970; Griesbach, 2003; FAO, 2010). Among insect pests of mango, white mango scale is the most important of hard scale insects which is reported to have damaged mango in various parts of the world (Cunningham, 1996; SRA, 2006; Germain *et al*., 2010; Abo-Shanab, 2012). The population density of white mango scale was formerly recorded on mangoes in few parts of the world. However, it has been spread by the transport of infested plant materials and widened its scope and has become an important mango pest in many mango growing countries such as West Africa, Egypt, South Africa, North and South America and the Caribbean Islands (El-Metwally *et al.,* 2011; Nabil *et al.,* 2012).

In white mango scale fertilization takes place and the tiny crawlers hatch out and move about until they glue themselves to the part of the plant where they develop and remain sucking the juice of the plant under their armours (Louw *et al*., 2008; Goble *et al.,* 2012). It injures mango by feeding on the plant sap through leaves, twigs and mainly through fruits, causing defoliation, drying up of young twigs, dieback, poor blossoming, and results in decreased fruit bearing, and fruits may mature with insufficient juice, and total death of the plant can become evident if infestation occurs as of nursery stage (Bakr *et al.,* 2009; Abo-Shanab, 2012). A recent study on leaf penetration pattern of *A. tubercularis* revealed that it can penetrate not only cell wall but also the lignified xylem materials leaving behind a reddish mass which was believed to have been phenolic acid (Juárez-Hernández, 2014). Attacks of the pest on mango fruits causes development of conspicuous pink blemishes around its feeding sites, and as a result export potential of the fruits and their commercial value are greatly affected (Abo-Shanab, 2012).

In Ethiopia white mango scale was recorded for the first time in 2010 in a place called Anger Gutin (25 Kilometres away from Nekempte, the capital of East Wollega Administrative Zone) where an Indian agro industry called Green Focus Ethiopia grew mango plantation (Temesgen, 2011). According to this survey, the pest moved from these foci in different directions and has already travelled a distance of over 100km in the west, the direction in which the most mango growing regions such as Assosa and Mendi are located.It has been known that mango production in western Ethiopia is highly constrained by white mango scale at the moment (Plate 1.1 and 1.2 below).

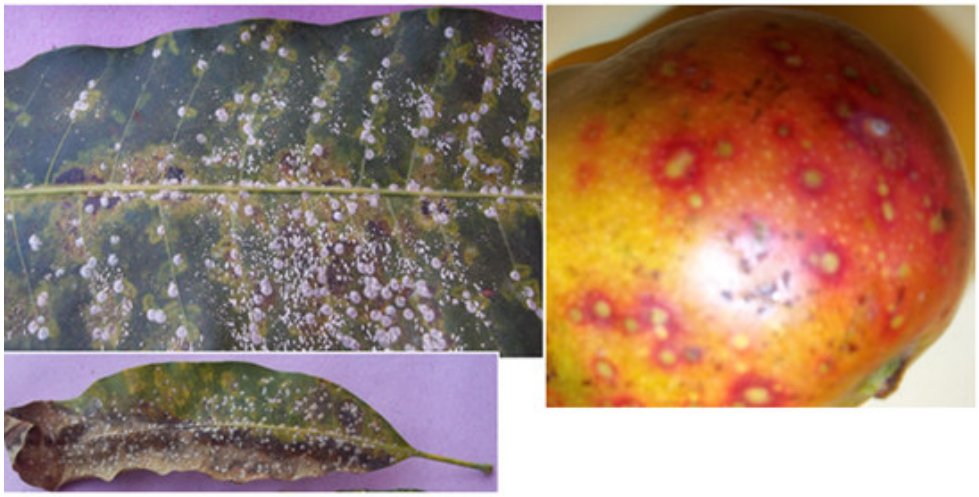

Plate 1.1. Heavy infestations by *A. tubercularis* on mango and consequent drying of its leaf and pink blemish on ripe mango fruit (Photo: Ofgaa from Bako Orchard)

Plate1. 2. A mango tree infested by *A.tubercularis* (Photo: Ofgaa from Arjo Orchard)

2. Materials and methods

The current study was conducted in two mango orchards in western Ethiopia from December 2013 to May 2014, the period of time in which mango began to bear small green fruits and attained maturity and eventually ripening stages in the area. Bako orchard was found at the coordinates of 09^0 07.410′ N and 037^0 03.130′E. The second was Arjo orchard which was located at the coordinates of 09^0 03.168′N and 036^0 16.696′ E.

Randomized Complete Block Design was used in such a way that both orchards were categorized into five quadrats which were located at the four corners and the centre. During each visit a total of 10 fruits i.e., 4 fruits from the lower canopy, 3 fruits from the middle canopy and another 3 fruits from the upper canopy were picked from one tree within every quadrat monthly for six successive months. The presence and absence of live male and female white mango scales were investigated by the use of hand lens. When present, they were counted and recorded. In all the quadrats, the mango trees from which samples were taken were marked with permanent marker.

The data were analysed by the use of GenStat software (Release 10.3 DE). One way and two way analyses of variance (ANOVA) were run to determine the levels of infestation of mango fruit by the pest at different levels of fruit development. In the meantime mean separation was done with Fisher's Protected Significant Difference (LSD) at 5% level of error. T-test was used to compare the levels of infestation caused by different sexes of the pest to the fruit, and the infestation levels between the two sites.

During the study, mango fruit development was categorized in to three stages for the convenience of investigation. Green stage covered the course of fruit development starting from shedding of the flowers and appearance of new mango fruit as small as bean size up to the time before attainment of full size. During this period, all of the fruits were green in colour and were not stiff in texture. The second stage was pre-yellow, in which the mango fruits were developing to the attainment of full size and stiff texture, and change of colours began to have appeared on few trees. The last stage was referred to as yellow stage, which comprised the course of time in which the fruits were matured and entered in to ripe stage. During this period, most of the fruits were yellow in colour and were aromatic. Bender *et al*. (2000) classified these last two stages as Mature-Green and Tree-ripe, respectively in a study conducted on Tommy Atkins mangoes. Kader (1999) used colour as an index

of maturity in some fruits.

3. Results

3.1. Levels of infestations of white mango scale of mango fruit

In the study area, fruit at yellow stage was infested at the highest level with significant difference compared to green and pre-yellow (P<0.01). But there was no significant difference between green and pre-yellow in this regard (Table 3.1).

Table 1.1. Mean number of white mango scale on mango fruits at different stages of fruit development in the study area

Stages of development	Mean± SE
Green	0.53±0.12a
Pre-yellow	1.77±0.46a
Yellow	13.54±5.95c

Means with the same letter are not significantly different at P = 0.05(LSD)

When levels of infestations among the three stages of fruit development were considered separately in each of the two orchards, the resulted also indicated the occurrence of the highest level of infestation at yellow stage with still significant difference from both green and pre-yellow (P<0.01) whereas there was no significant difference between green and pre-yellow stages (Table 3.2). There was no significant difference in the levels of infestations between Arjo and Bako orchards (P=0.40) (Table 3.3).

Table 1.2 .Mean number of pests on mango fruits at different stages of fruit development in Arjo and Bako orchards

Study site	Mean±SE		
	Green	Pre-yellow	Yellow
Arjo	0.50±.01a	1.66±0.44a	13.03±0.36b
Bako	0.56±0.01a	1.88±0.03a	14.14±6.91b

Means with the same letter in a row are not significantly different at P = 0.05(LSD)

Table 1.3. Mean number of white mango scale on mango fruits in Arjo and Bako orchards

Study sites	Mean± SE
Arjo	3.50±0.06a
Bako	4.23±0.07a

Means with the same letter are not significantly different at P = 0.05(LSD)

3.2. Infestation levels on mango fruits by female and male white mango scale

This study depicted that the level of infestation by the female white mango scale was higher than that by the male with significant difference (P<0.01), in the study area in general (Table 3.4) and within each study site or orchard in particular (Table.3.5). Likewise, the pest count on mango fruit revealed that female to male ratio in the study area was found to have been 7 to 1, indicating a highly female bias sex ratio.

Table 1.4. Mean number of female and male white mango scale on mango fruit in the study area

Pest sex	Mean±SE
Female	7.67±0.09a
Male	1.12±0.01b

Means with the same letter in a row are not significantly different at P = 0.05(LSD)

Table 1.5 Mean number of female and male white mango scale on mango fruit within Arjo and Bako orchards

Study sites	Mean±SE	
	Female	Male
Arjo	7.24±0.17a	1.08±0.02b
Bako	8.06±0.21a	1.16±0.02b

Means with the same letter in a row are not significantly different at P = 0.05(LSD)

Investigation of the relationships between levels of infestation at different stages of mango fruit development and the pest sexes revealed that infestation levels by the female were significantly different at all the three stages (P<0.01). But in the male pest, infestation of the fruits showed that yellow stage was infested the most with significant difference from green and pre-yellow, but no significant difference between green and pre-yellow stages (p=0.15) (Figure 1).

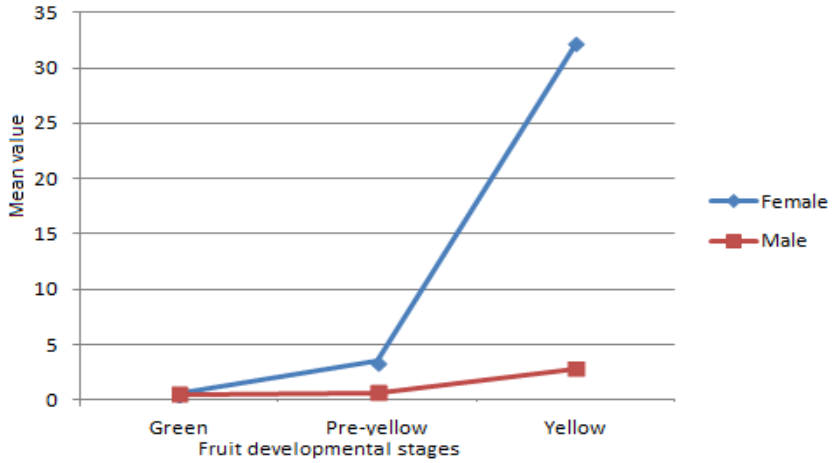

Figure 1.Trends in the levels of infestation at different stages of fruit development by female and male white mango scale in the study area

4. Discussion

The result of the present study revealed that white mango scale has become a devastating pest to mango fruit in western Ethiopia. It attacked the fruit leaving pinkish blemish on skin of matured and ripe fruits. That the level of infestation was the highest at ripening stage and also considerably high at maturity stage may be because matured and ripe mango fruits are more aromatic than the green mango fruits due to the presence of a lot of volatile chemical substances in the former (Appiah *et al*., 2011) which could be used as lures for capturing white mango scales. Bender *et al*. (2000) also states that levels of most aromatic volatile substances are greater in tree-ripe mango fruits than in the mature-green ones. It is more likely that white mango scale, as a sucking insect, adapted to feed on plant materials at the stage when the substances are more sugary and with readily flowing fluids. It is indicated in various studies that ripe mangoes contain more soluble sugars, are less acidic and less viscous compared to the immature ones (Kansci *et al*., 2003; Lebrun *et al*., 2008; Lechaudel and Joas 2007; Appiah *et al*., 2011). It is obvious that female white mango scales need much energy to produce eggs which were observed in mass under their scales.

The current investigation on differential level of infestation on the fruit between the two sexes underlined that infestation by the female was considerably higher than that by the male in the study area and also within each orchard. This could help to infer that most of the damages caused by white mango scale to mango fruit by leaving blemishes on their skins may account for infestation by the female. A study performed on the responses of oriental fruit flies, *Bactrocera dorsalis* Hendel, to the odors of different stages and types of fruits confirmed that females were most attracted to odors of soft and ripe fruits (Cornelius *et al*., 2000). Moreover, a related investigation on behavioural responses of female oriental fruit flies to the odour of papayas at three ripeness stages in laboratory confirmed that females spent more total time and a higher maximum density on ripe fruit than green fruit odours (Jang and Light, 1991). The current study did not address the reason why female white mango scale infested mango fruit more as compared to the male.

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