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Population dynamics of white mango scale, *Aulacaspis tubercularis* Newstead (Hemiptera: Diaspididae) in Western Ethiopia

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Mango (*Mangifera indica* L.) is the third most important fruit crop in the tropics following citrus and banana. It is consumed as a fresh fruit and different forms of preparations for its multifaceted nutritional values. Mango production in Ethiopia is constrained by infestation of white mango scale (WMS), *Aulacaspis tubercularis* Newstead. White mango scale was recorded from Ethiopia for the first time in 2010, in a mango orchard in Loko in the western part of the country. This study was conducted from June 2013 to May 2014 to document the population dynamics of white mango scale in Western Ethiopia. Randomized Complete Block Design was used for the sampling in two mango orchards, Arjo and Bako. Scale population peaked in April at Arjo and in May at Bako showed marked decline with decreasing precipitation. Abundances of eggs, crawlers and sessile stages of the scale showed significant differences among most of the study months (P<0.05). The abundance of sessile scales was significantly higher at Bako than at Arjo (P<0.05). In both study areas, white mango scales were significantly more abundant on the upper leaf surfaces than the lower (P<0.05). At Bako, male scale numbers were significantly higher than those of the females (P<0.05). The study found that the decline and build-up of white mango scale populations are affected by rainfall, whereas the effects of other environmental factors on scale numbers need to be investigated.

Key words: Developmental stages, fluctuation, infestation, orchard, rainfall, sessile.

INTRODUCTION

Mango is the third most important fruit crop in the tropics after citrus and banana (Louw et al., 2008). It is consumed as a fresh fruit and as other kinds of preparations for its high contents of sugar, protein, fats, salts and most of the vitamin types, among others (Griesbach, 2003; Kayode and Sani, 2008; Shah et al., 2010; Nabil et al., 2012). Mango production is constrained by white mango scale, *Aulacaspis tubercularis* Newstead, in countries such as Mexico, India, Pakistan, Italy, Ghana, Kenya, Madagascar, Mauritius, Tanzania, Uganda

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and Zimbabwe, among others (Labuschagne et al., 1995; Pena et al., 1998; El-Metwally et al., 2011; Salem et al., 2015; Hodges and Harmon, 2016). White mango scale inserts its stylets in the soft parts of mango tree and sucks saps. As a result it causes yellowing of leaves, development of conspicuous pink blemish on mature and ripe fruit and dieback to mango plantation (El-Metwally et al., 2011; Abo-Shanab, 2012). Infestation in young trees may lead to excessive fall off leaves, retarded growth and death of the whole plant (Nabil et al., 2012). The development of conspicuous blemishes on mango fruit skin which was infested by white mango scale markedly damages mango fruit export potential and eventually leads to economic loss (USDA, 2006, 2007). Three mineral oils, Diver®, CAPL2® and super masrona®, were tested in field against white mango scale and showed different levels of effectiveness (Abo-Shanab, 2012). In Kenya, deltametrine and pyrethrin were recommended for the control of white mango scale (Findlay, 2003).

Infestation of mango by *A. tubercularis* in Ethiopia was first reported in 2010 in a mango orchard owned by Green Focus Ethiopia Ltd. (Dawd et al., 2012) which used to import mango seedlings from South Asia and hence it is deduced that the pest probably entered Ethiopia accidently on imported seedlings. Within one-year of first record, white mango scale was reported to have dispersed 100 km west of the original site (Fita, 2014). The damages of white mango scale induced panic and frustration in Western Ethiopia for the loss in crop production and indirect sociological consequences, since mango plantation serves as shade for animals and conference hall for the people, in addition to generating income and serving as food in the region (Dako and Degaga, 2015). This study was planned with the objective of understanding the population dynamics of different developmental stages of white mango scale which would be the most important and prior step for the purpose of management of the pest.

MATERIALS AND METHODS

Description of the study area

This study was conducted in Arjo district of East Wollega Administrative Zone and Bako Tibe district of West Shoa Administrative Zone in Western Ethiopia. Arjo orchard was located at 09° 03´N and 036° 17´E while Bako orchard was located at 09° 07´N and 037° 03´E. Both districts received unimodal rainfall with mean annual precipitation of 1649 and 1219 mm at Arjo and Bako, respectively (Ethiomet, 2016).

Study design, sampling procedure and data analyses

In each orchard, five blocks were specified, one at each of the four corners and the centre. Hence, Randomized Complete Block Design was used. From upper, middle and lower canopies of a mango tree within every block, a total of ten leaves were plucked. Sampling started from the trees at each corner in the blocks and continued toward the centre, and that started from central block continued in the four cardinal directions on successive trees, once within a month for 12 consecutive months, from June 2013 to May 2014. The leaves collected from each tree were placed in a separate cloth bag, labelled, kept in a plastic bag and taken to Addis Ababa University, Science Faculty, Insects and Vector Research Laboratory. The leaves were observed under stereomicroscope and numbers of white mango scales were recorded. In this study, the first instar was recorded as *crawler* whereas all the remaining developmental stages and the adult were collectively considered as *sessile* stage. Male and female sessile stage mango scales were identified and recorded. In this study it was impossible to include fully matured live male scales, as they fly out immediately up on achieving maturity. Accordingly, male mango scale armours were broken open by the use of dissecting needle to avoid counting empty scales. Furthermore, the needle was used to lift the armour of the adult female for ease of counting the eggs underneath. Weather data on rainfall and temperature of the study area were obtained from National Meteorology Agency of Ethiopia (Ethiomet, 2016).

Microsoft Excel was used to summarize data on population fluctuations of white mango scale. Data on scale counts were analysed using Proc ANOVA of SAS software V9 (SAS, 2002). Significant means were separated by Fisher's Least Significant Difference (LSD) at 5% error level. Square root transformation was used to normalize data obtained from white mango scale count prior to running analysis of variance (ANOVA) and was back transformed for reporting.

RESULTS

Population abundance of white mango scale

Population of sessile white mango scale per leaf was significantly abundant ($P<0.05$) at Bako orchard (24.87±0.36) than Arjo (18.55±0.37). Population of male white mango scale was higher than that of the female in the study area in general and the difference was significant ($P<0.0001$) at Bako orchard (Table 1).

Population sizes of all the developmental stages of white mango scale showed statistically significant differences ($P<0.0001$) among most of the study months at both study orchards (Tables 2 to 4).

All developmental stages of white mango scale were found to have been significantly abundant ($P<0.0001$) on upper surface of mango leaf than the lower at both study orchards (Tables 5 to 7).

Population fluctuations of white mango scale

Population fluctuations of eggs, crawlers and sessile mango scales followed a more-or-less similar pattern over the months of the study year. Marked population fluctuations were observed, with a general trend of decline with decreased precipitation. Detectable infestations persisted more-or-less throughout the year at Arjo but scale population fell below detectable levels in some of the dry season months at Bako (Figures 1 to 6).

Table 1. Mean numbers of sessile male and female mango scales present in the study orchards.

Study site	Mean ± SE		LSD
	Male WMS	Female WMS	
Arjo	22.43±0.62[a]	15.00±0.40[a]	1.16
Bako	35.09±0.61[a]	16.34±0.35[b]	0.29

Means followed by the same letter within a row are not significantly different at the 5% level (LSD).

Table 2. Mean numbers of sessile mango scale population present during the study months.

Month	Mean ± SE	
	Arjo	Bako
June	48.32±1.23[b]	16.76±0.34[e]
July	38.20±1.88[b]	11.29±0.55[e]
August	6.95±0.84[c]	2.83±0.25[f]
September	6.47±0.47[c]	0.37±0.15[gh]
October	2.65±0.44[c]	0.07±0.04[h]
November	1.22±0.15[c]	0.23±0.06[gh]
December	4.83±0.41[c]	2.13±0.20[fg]
January	2.69±0.59[c]	2.99±0.24[f]
February	5.38±0.79[c]	52.03±0.96[d]
March	37.41±2.13[b]	92.04±7.23[c]
April	100.07±1.59[a]	150.31±1.33[b]
May	58.36±1.22[ab]	225.22±1.28[a]
LSD	2.83	0.71

Means followed by the same letter(s) within a column are not significantly different at the 5% level, (LSD).

Table 3. Mean numbers of crawler populations present during the study months.

Month	Mean ± SE	
	Arjo	Bako
June	2.44±0.38[ab]	1.34±0.28[b]
July	2.24±0.37[abc]	0.12±0.23[b]
August	1.42±0.45[abcd]	0.01±0.00[b]
September	0.09±0.27[cd]	0.01±0.00[b]
October	0.34±0.01[d]	0.00±0.00[b]
November	0.00±0.00d	0.00±0.00[b]
December	0.00±0.00[d]	0.00±0.00[b]
January	0.03±0.01[d]	0.45±0.13[b]
February	2.07±0.47[abcd]	0.09±0.03[b]
March	0.88±0.30[abcd]	0.34±0.06[b]
April	3.16±0.50[a]	16.39±0.99[a]
May	0.44±0.11[bcd]	25.34±0.94[a]
LSD	0.77	0.98

Means followed by the same letter(s) within a column are not significantly different at the 5% level (LSD).

Table 4. Mean numbers of egg populations in the study months.

Month	Mean ± SE	
	Arjo	Bako
June	31.28±1.29^{cd}	1.72±0.44^{e}
July	89.24±2.35^{b}	0.55±0.25^{e}
August	42.39±1.28^{c}	0.00±0.00^{e}
September	9.19±0.70^{ef}	0.15±0.07^{e}
October	6.60±0.63^{ef}	0.00±0.00^{e}
November	0.00±0.00^{f}	0.57±0.25^{e}
December	2.45±0.29^{f}	2.95±0.44^{e}
January	7.35±0.52^{ef}	3.43±0.39^{e}
February	41.65±1.40^{c}	21.51±1.28^{d}
March	104.95±1.90^{b}	84.23±1.92^{c}
April	193.94±2.84^{a}	136.15±2.14^{b}
May	16.72± 0.64^{de}	216.59±2.92^{a}
LSD	2.30	2.26

Means followed by the same letter within a column are not significantly different at the 5% level (LSD).

Table 5. Mean numbers of sessile mango scales on upper and lower surfaces of mango leaves at Arjo and Bako orchards.

Study site	Mean ± SE		LSD
	Upper	Lower	
Arjo	33.70±0.90^{a}	7.71±0.56^{b}	1.16
Bako	40.02±0.59^{a}	13.19±0.36^{b}	0.29

Means followed by the same letter within a column are not significantly different at the 5% level (LSD).

Table 6. Mean numbers of crawlers on upper and lower leaf surfaces of mango in Arjo and Bako orchards.

Study site	Mean ± SE		LSD
	Upper	Lower	
Arjo	1.84±0.17^{a}	0.19±0.04^{b}	0.31
Bako	2.87±0.29^{a}	1.02±0.15^{b}	0.40

Means followed by the same letter within a column are not significantly different at the 5% level (LSD).

Table 7. Mean numbers of eggs on upper and lower leaf surfaces of mango in Arjo and Bako orchards

Study site	Mean ± SE		LSD
	Upper	Lower	
Arjo	62.55±0.90 (7.97)^{a}	10.82±0.33 (3.44)^{b}	0.94
Bako	35.80±0.99 (6.10)^{a}	5.55±0.36 (2.56)^{b}	0.92

Means followed by the same letter within a column are not significantly different at the 5% level (LSD).

DISCUSSION

Populations of white mango scales in Arjo and Bako begin to build up in February and reach their peaks in April in Arjo and in May in Bako. Population peaks of scale crawlers were also evident in these months. This is

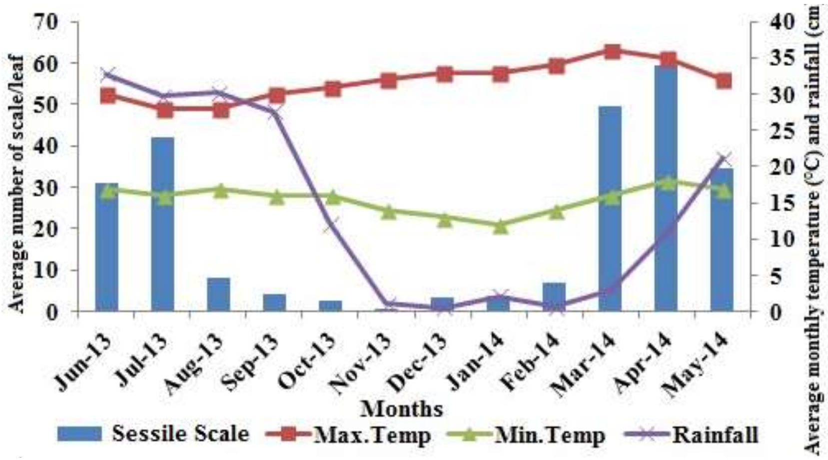

Figure 1. Population fluctuations of sum of male and female sessile stages mango scale at Arjo.

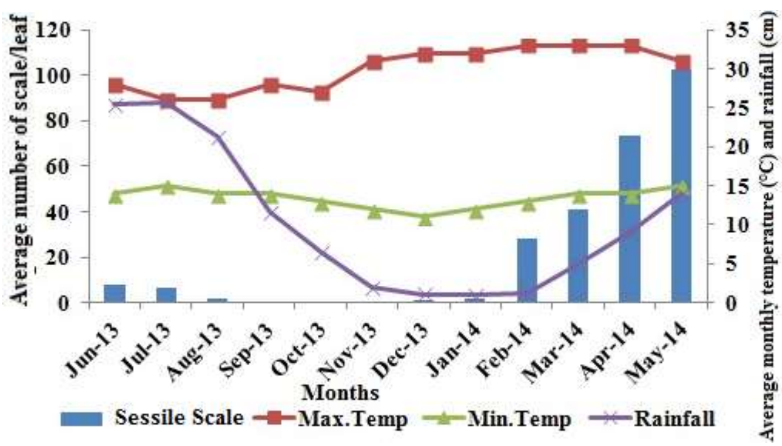

Figure 2. Population fluctuations of sum of male and female sessile stage mango scale at Bako.

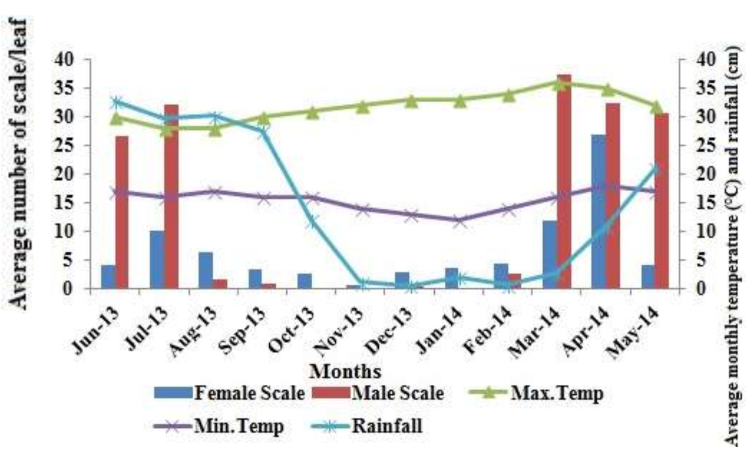

Figure 3. Population fluctuations of males and females mango scale at Arjo.

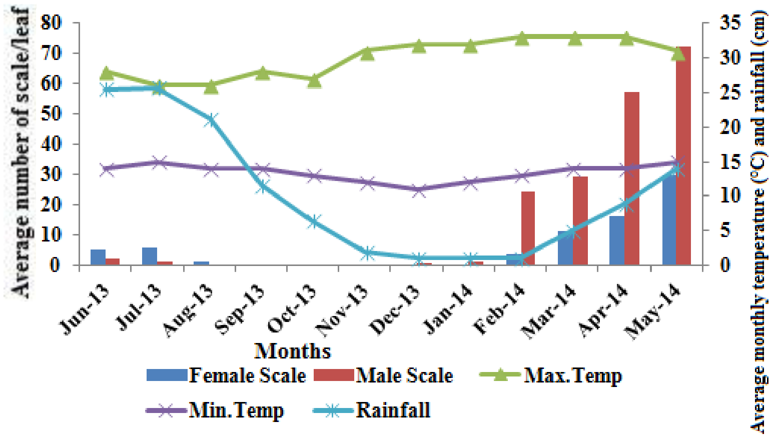

Figure 4. Population fluctuations of mango scale males and females at Bako.

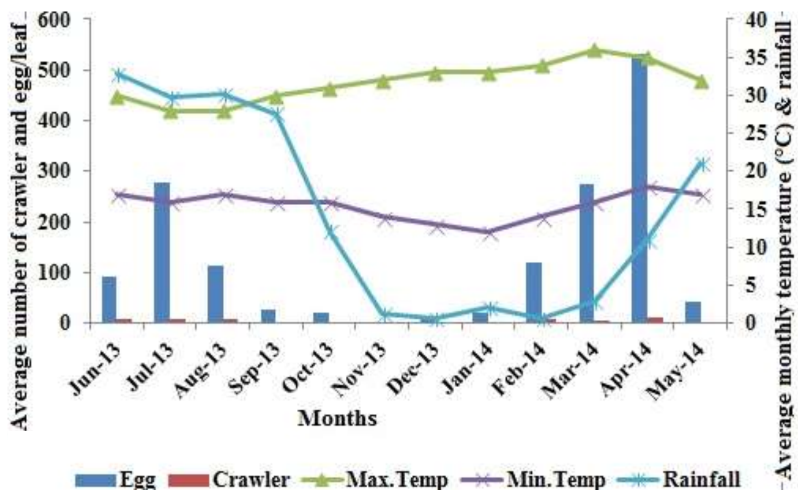

Figure 5. Population fluctuations of the scale crawlers and eggs at Arjo.

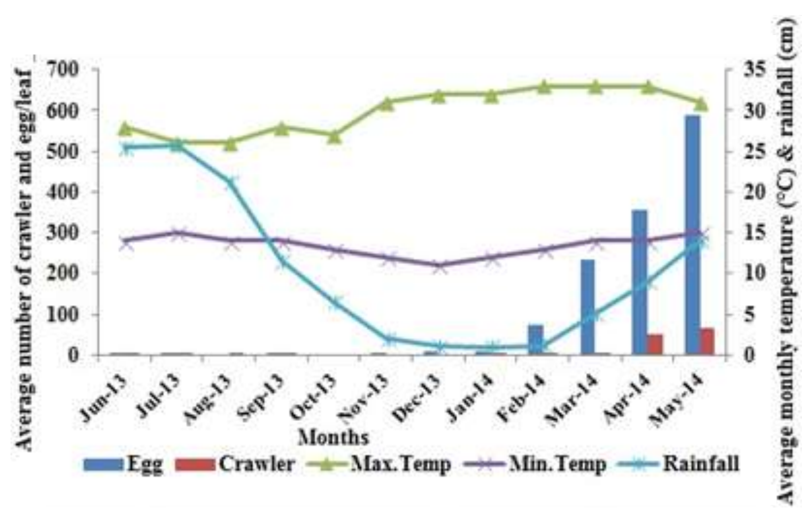

Figure 6. Population fluctuations of the scale crawlers and eggs at Bako.

an essential finding for control of the pest through targeting the crawler stage, which is sensitive to both systemic and contact insecticides (Buss and Turner, 2006). Population of white mango scale remained at an extremely low level when average monthly rainfall was below 10 mm, implying that white mango scale is highly affected by drought.

The current study identified three phases of mango scale population. In Arjo, the first phase was from February to July, when the population began to build up towards its peak. The second phase, in August, September and October was characterized by sharp decline of the population. The last one was from November to January during which the population remained low and inconspicuous. In Bako, the first phase began in February as in Arjo but continued to May only. In June, July and August, the population declined abruptly, denoting the second phase. The last phase in which population remained low to undetectable was between September and January in Bako.

This study, therefore, indicates that the decline and build-up of mango scale population is affected by rainfall in two ways, though other contributing factors need to be investigated further.

Firstly, a minimum average monthly rainfall of about 50 mm is required to initiate build-up of the scale population. The optimum rainfall for the insect to reach its peak population may vary spatially and temporally, as it was found to be 110 mm in April at Arjo and 140 mm in May at Bako. The build-up of the scale population coincides with the physiological maturity of mango fruit, both happening at the beginning of the rainy season in the study area. Dako and Degaga (2015) reported that maturation and ripening of mango fruit begin during the first months of rainy season, that is, in March to April and continues for few months, vis-à-vis significant infestation of mango fruits by white mango scale, in Western Ethiopia.

Secondly, prolonged heavy rainfall may affect mango scale population negatively. A swift population decline of mango scale followed prolonged heavy rain probably because the rain washes the scale off mango leaves. This finding agrees with Salem et al. (2015) who recorded low population density of white mango scale from the end of rainy season in Egypt. El-Metwally et al. (2011) also recorded low population of white mango scale during the rainy season. It is evident that strong rain can kill small or immobile stages of insects (Moran et al., 1987).

Crawler and sessile stages of mango scale populations were more abundant at Bako than at Arjo. One possible explanation, among others, may be associated with the negative impact of high heavy rain intensity on the scale population at Arjo, as this site receives a higher amount of annual rainfall than that at Bako (Ethiomet, 2016).

Both minimum and maximum temperatures at the current study sites were more or less stable; and this study did not evaluate the impact of extreme temperatures on the population dynamics of white mango scale. However, the size of the scale population was higher during the months with relatively more extreme maximum and minimum temperatures. Peak populations were recorded in the months with maximum monthly temperatures of 35 and 31°C at Arjo and Bako, respectively, indicating that *A. tubercularis* tolerates higher temperatures. This record does not agree with the conclusion of Labuschagne et al. (1995) which found that white mango scale had a low tolerance to high temperature, and as a result its population declined in temperatures above 30°C. In all observed cases during this investigation, crawler-stage population of mango scale was much smaller than any of the other developmental stages. One possible explanation for this would be that white mango scale stays as crawler stage for shorter period of time compared to sessile stages (Labuschagne et al., 1995). Moreover, crawlers move to different parts of the host plant in search of suitable settling sites and may also be dispersed away from the plant by various factors all of which would reduce their numbers on the sampled leaves.

All developmental stages of mango scale were found to be more abundant on the upper leaf surfaces in both study orchards. This finding agrees with the study by Nabil et al. (2012) on mango in Egypt which also recorded that *A. tubercularis* preferred the upper leaf surface compared to the lower one. Investigations as to why the scale prefers the upper leaf surface to the lower seems to have been overlooked. However, Beardsley and Gonzalez (1975) said that McLaren (1971) associated the settlement of the majority of California red scale crawlers, *Aonidiella aurantii* (Maskell), on the upper surfaces of citrus leaves with geotaxis behavioural response. On the other hand, the male crawler of Florida red scale (*Chrysomphalus ficus* Ashmead) was associated with a positive response to light direction (Beardsley and Gonzalez, 1975).

Conclusions

This study confirmed that white mango scale is present in Ethiopia throughout the year, with its population fluctuation being highly influenced by the amount of rainfall. It was observed that white mango scale attained population peaks at temperatures as high as 31 to 35°C with the scales being more concentrated on the upper leaf surfaces and the population is male-biased.

RECOMMENDATIONS

The best period for application of insecticide for the control of white mango scale is from April to June, when white mango scales in general and the vulnerable crawlers in particular are the most abundant in Western Ethiopia.

To better understand the optimum temperature range for white mango scale, controlled experiments, under laboratory conditions, may be required.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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