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Biology of Coconut Scale, *Aspidiotus destructor* Signoret (Hemiptera: Diaspididae), on Mango Plants (*Mangifera* sp.) Under Laboratory and Greenhouse Conditions*

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Abstract.- Biology of the scale insect *Aspidiotus destructor* Signoret (Hemiptera: Diaspididae) was studied on mango cultivar Desi at mean temperature of 30°C and relative humidity (RH) 64 % in the laboratory as well as on four mango cultivars in a greenhouse at 25°C and 60 % RH in Khyber Pakhtunkhwa Province, Pakistan. The pest sucks cell sap from the underside of the leaves and petioles of mango plants causing chlorosis and necrosis. Observations of developmental stages and morphometry of *A. destructor* were conducted using a head lens and an ocular and stage micrometer. In the laboratory, mature females laid 28–65 eggs in 11–13 days under the scale cover; the eggs hatched after 4–6 days. *A. destructor* males passed through two feeding instars with pre-pupal, pupal and adult stages while females had two immature instars with pre-oviposition and oviposition stages. Mean developmental span (egg to adult) of male insect was 27 days and for female, it was 39.5 days. Under greenhouse conditions, eggs laid by mature *A. destructor* hatched after 5–7 days. Mean developmental times on Desi, Langra, Kala Chounsa and Anwar Ratoul cultivars were 39, 39, 41.5 and 43.5 days for males and 50.5, 51.5, 53.5 and 53.5 days for females, respectively. The insect completed 3 to 4 generations between July and December in the field in southern region of Khyber Pakhtunkhwa, Pakistan. This study provides forecast of population dynamics of *A. destructor* for timely management strategies of the pest.

Key words: Coconut scale insect, *Aspidiotus destructor*, developmental stages, mango cultivars.

INTRODUCTION

Mango is attacked by many insect pests in Pakistan, such as fruit flies (*Dacus zonatus* Saunders and *D. darsalis* Hendel), scale insects (*Aspidiotus destructor* Signoret, *Lindingaspis ferrisi* McKenzie, and *Aulacaspis tubercularis* Newstead), mealybug (*Drosicha stebbingi* Green) and mango hoppers (*Idioscopus niveosparsus* Lethierry and *Amritodus atkinsoni* Leth.) (Mohyuddin and Mahmood, 1993). Among these insect pests, 27 species of scale insects have been recorded on mango from Pakistan. Of these, *Aspidiotus destructor* or coconut scale insects in the family Diaspididae were reported to be the most serious pest (Mohyuddin, 1981).

In Pakistan, *A. destructor* was first reported on mango plants from Punjab Province by Rehman and Ansari (1941) and in Sindh Province by Cavin in 1956 (C. I. E., 1960). A short account of the damage caused by *A. destructor* to the mango and its distribution in Pakistan was provided by Ansari (1942). Coconut scale is an important pest of many other tropical crops, especially coconut throughout the world (Taylor, 1935). The pest is found in Africa, Asia, the Pacific region and in some parts of Australia (C. I. E., 1960); it has a wide host range including mango, citrus, sour sop, custard apple, umbrella trees, mulberry and lillypilly.

Diaspidid scale insects reproduce both sexually and asexually, while some species are oviparous, ovoviviparous and viviparous (Koteja, 1990a). In diaspidids, there is division of function among different instars. The crawler stage is the dispersal stage as crawlers have legs and can move up to one meter, but are often carried longer distances by animals, other insects or the wind to

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infest other plants (Greathead, 1990). In females, the main function of first and second instar is feeding and that of third instar is reproduction (Koteja, 1990b) while in males, the first two instars feed, followed by non-feeding pre-pupa, pupa and adult stages. Adult males are provided with single pair of wings for locomotion and antennae to locate pheromones (Moreno, 1972) released by females for mating (Gieselmann, 1990).

At a mean temperature of 30˚C, male and female *A. destructor* completed their life cycle in 34–35 and 30–34 days, respectively, completing 8–10 generation per year in Fiji (Taylor, 1935). Ahmad and Ghani (1972) had discovered that total life cycle (egg to adult) of male and female *A. destructor* on *Cucurbita maxima* at a temperature of 29°C and RH 55 % was 33 and 27 days, respectively, and the sex ratio was generally 1:1; however, in some cases all males were observed. Taylor (1935) had recorded whole female colonies of coconut scales in Fiji. In one study, life cycle of coconut scale was reported to last for 32 days for females and 27 days for males in greenhouse in Philippines (Tabibullah and Gabriel, 1975).

The present study was aimed to investigate biological characteristics, such as developmental duration, life cycle, fecundity and morphology of coconut scale on desi mango cultivar under laboratory conditions as well as on different mango cultivars in the greenhouse. The study provides useful information for effective monitoring and population management of the pest.

MATERIALS AND METHODS

Laboratory study

Twenty four mango plants (desi cultivar) of uniform age (two years) and size (60–70 cm) were obtained from the Fruit Nursery Farm, Department of Agriculture Extension, Government of Khyber Pakhtunkhwa (KPK), Dera Ismail Khan, KPK, Pakistan. The plants were individually transferred into 19 (height) × 18 (width) cm plastic pots in February and March, 2013. These plants were kept under close supervision as well as similar cultural practices including watering, hoeing and application of farm yard manure (FYM). Holes were made in the sides and bottom of the pots for aeration. After the plants were established in 30 to 40 days, they were marked separately for coconut scale infestation. Crawlers of scale insects emerged in the Fruit Nursery Farm in the first week of July at the termination of dry and hot season and increased humidity conditions due to the beginning of monsoon rains.

The plants were exposed to scale crawlers by placing the pots under mature mango trees that were infested with the insect at the Fruit Nursery Farm. The upper portion of the nursery plants were wrapped with scale-infested leaves so that newly hatched crawlers could attach to the test plants (Fig.1a,b). The plants were exposed to the infested leaves with scale insects for 24 h and thereafter removed to obtain crawlers of uniform age.

Following initial infestation, biology of coconut scale was studied in the laboratory on mango nursery plants in pots at 27.9 to 32.1°C (mean temperature 30°C) and 61.9 to 66.2 % RH (mean 64 %). All life stages were marked separately to observe change in size, color and shape. For these observations, newly laid eggs were examined daily under a binocular microscope. Time of egg laying and number of eggs laid were counted under scale cover. Egg dimensions were measured by an ocular and stage micrometer. Newly hatched crawlers were observed daily with a head lens to determine molting. Morphometry (length and breadth of various instars) was performed using the ocular and stage micrometer.

Data concerning oviposition period, total number of eggs laid, male and female longevity, and sex ratio were recorded throughout the study period. For fecundity, gravid females were observed under the microscope and total number of eggs laid per female was counted. In the same manner, all life stages of males and their width at thorax, length from head to abdomen, antenna and extended wing positions were measured.

Greenhouse study

A second study was conducted in a greenhouse from July to December, 2013 under a temperature range of 23.2°C to 26.8°C (mean 25°C) and RH range of 55.9 and 64.2 % (mean 60 % RH). In this study, biology of the scale insect was studied on desi, langra, kala chounsa and anwar ratoul

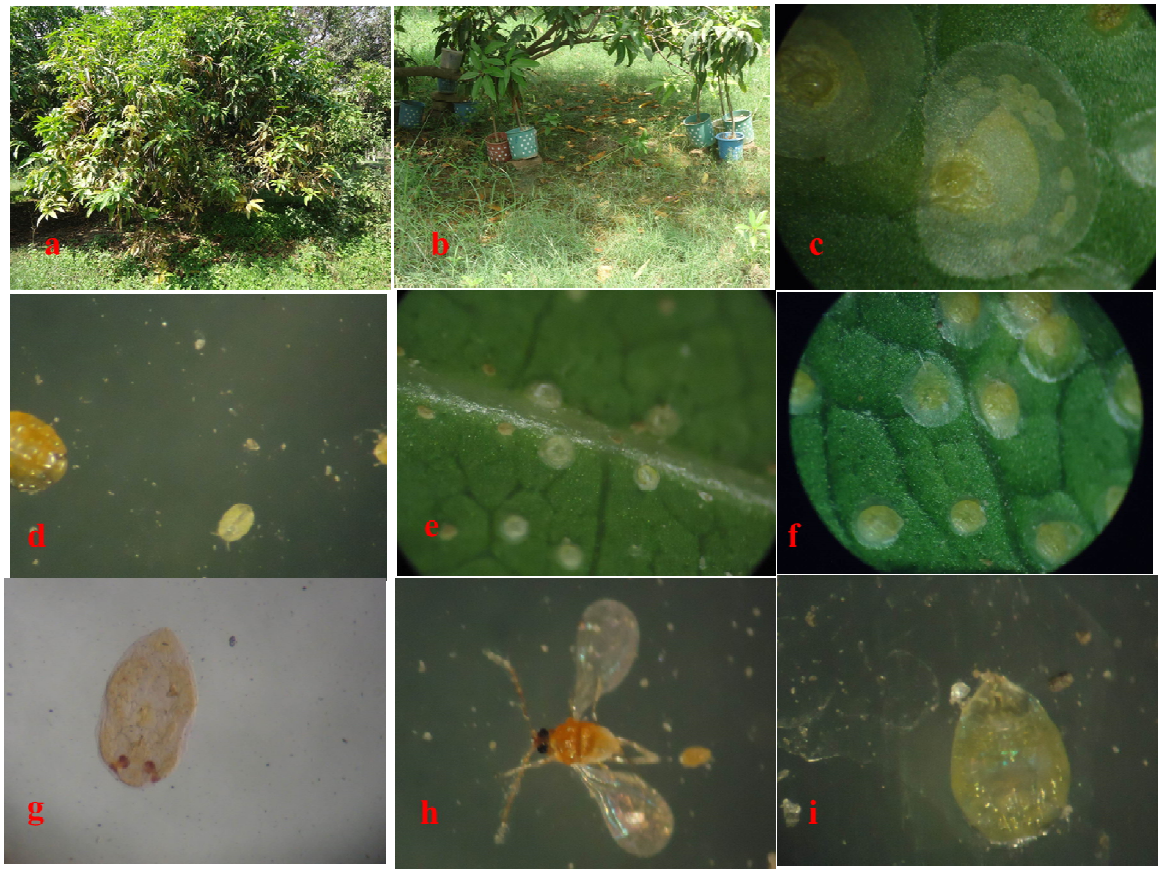

Fig. 1. Life cycle of *A. destructor*; a, *A. destructor* infested mango plant; b, transferring crawlers from infested mango plants to nursery plants; c, *A. destructor* eggs under scale cover; d, crawler; e, white cap stage; f, second instar; g, pupa; h, adult male and i, adult female.

mango cultivars. Three nursery plants were selected from each cultivar. Temperature and RH data were obtained from the nearby meteorological station at Arid Zone Research Institute, Pakistan Agriculture Research Council, Ratta Kulachi, Dera Ismail Khan, KPK, Pakistan. The procedure for infestation of nursery plants with scale insects was the same as described above for the laboratory study.

RESULTS

Developmental stages of Aspidiotus destructor

Eggs

Mature females laid eggs in concentric circles in 3–4 batches with 10–17 eggs per batch which were easily observed under scale cover (Fig. 1c). Newly laid eggs were whitish, smooth and elongate. Mean length and width of freshly laid eggs were 0.22 mm and 0.09 mm, respectively (Table I). The eggs hatched after 4–6 days in the laboratory at 30°C and 64 % RH.

Crawlers

Crawlers emerged from underneath the scale cover and moved on the leaf for 24-48 h in search of a suitable place for fixation. At this stage, the body of the crawler was light green, cylindrical and somewhat oblong (Fig. 1d). Mean length and width were 0.23 mm and 0.11 mm, respectively (Table I). They had most characteristics of a typical larva including legs, antennae and segmented body. More than 98 % of the crawlers settled on the lower surface of mango leaf, the remainder settled on petioles and stems and upper surfaces of the nursery plants.

Table I.- Morphometry (length and width) and developmental rate (days) of male and female coconut scale developmental stages on mango nursery plants in laboratory at temperature 30 ˚C and RH 64 %.

Scale Stages	Length (mm)		Width (mm)		Developmental rate (days)	
	Range	Mean ± SE	Range	Mean ± SE	Range (days)	Mean ±SE
Egg	0.2–0.3	0.2±0.006	0.1–0.2	0.1±0.002	4–6	5.0 ± 0.15
Crawlers	0.2–0.3	0.2±0.006	0.1–0.2	0.1±0.002	1–2	–
White Cap.	0.2–0.3	0.2±0.006	0.2–0.3	0.2±0.006	4–6	5.0±0.15
Nipple Stage.	0.3–0.4	0.3±0.004	0.3–0.4	0.3±0.002	3–5	4.0±0.16
2nd Instar	0.4–0.5	0.4±0.004	0.3–0.4	0.3±0.004	4–6	5.0±0.15
Pre-oviposition	0.6–0.8	0.7±0.016	0.5–0.7	0.6±0.012	7–9	8.0±0.16
Oviposition	0.6–0.8	0.7±0.014	0.5–0.8	0.7±0.012	10–12	11±0.17
Total life cycle	–	–	–	–	33–46	39.5
♂ Pupae	0.3–0.4	0.3±0.004	0.1–0.2	0.1±0.002	3–5	4.0±0.17
♂ Adult	–	–	–	–	2–3	2.5±0.10
Width at thorax	0.2–0.3	0.2±0.006	–	–	–	–
Head to abdomen	0.5–0.6	0.5±0.004	–	–	–	–
Antenna	0.5–0.6	0.5±0.006	–	–	–	–
Extended wings	1.2–1.5	1.4±0.040	–	–	–	–
Total life cycle	–	–	–	–	21–33	27

SE, Standard error; RH, Relative Humidity.
Data based on 25 individuals.

Table II.- Developmental rate (days) of male and female scale insects on different cultivars of mango nursery plants in greenhouse at temperature 25 ˚C and RH 60 %.

Stage	Cultivars							
	Desi mango		Langra		Kala Chounsa		Anwar Ratoul	
	Range (days)	Mean ± SE	Range (days)	Mean ± SE	Range (days)	Mean ± SE	Range (days)	Mean ± SE
Egg	5–7	6.0±0.17	5–7	6.0±0.17	5–7	6.0±0.17	5–7	6.0±0.17
Crawlers	1–2	–	1–2	–	1–2	–	1–2	–
White Cap	5–8	6.2±0.24	5–8	7.0±0.17	7–9	5.9±0.17	7–9	5.9±0.17
Nipple Stage	7–9	8.0±0.17	7–9	8.0±0.17	8–9	8.5±0.10	8–9	8.5±0.10
2nd Instar	6–8	7.0±0.17	7–9	5.9±0.17	7–9	5.9±0.17	7–9	5.9±0.17
Pre–Pupae	2–3	2.5±0.10	2–3	2.5±0.10	2–3	2.5±0.10	2–3	2.9±0.10
Pupae	4–6	5.0±0.15	4–5	4.0±0.16	4–7	5.7±0.22	4–7	5.7±0.22
Adult	2–3	2.5±0.10	2–3	2.5±0.10	2–3	2.5±0.10	2–3	2.5±0.10
Total life cycle of male	32–46	39	32–46	39	36–47	41.5	37–50	43.5
3rd Instar female	8–11	9.3±0.23	8–11	9.3±0.23	8–11	9.3±0.23	8–11	9.3±0.23
Oviposition	11–13	12.0±0.17	11–13	12.0±0.17	11–13	12.0±0.17	11–13	12.0±0.17
Total life cycle of female	43–58	50.5	44–59	51.5	47–60	53.5	47–60	53.5

SE, Standard error; RH, Relative Humidity.
Data based on 25 individuals.

White cap stage

Crawlers feeding through their rostrum started to secrete a waxy substance over their body which gave them white color (Fig. 1e). The ‘white cap’ stage began after 24 h of settlement and could be observed by naked eye. Mean length and width were 0.23 mm and 0.21 mm, respectively (Table I). White cap stage continued for 4–6 days in the laboratory at 30°C and 64 % RH.

Nipple stage

At nipple stage, the external surface of the

scales changed from white grey to pale green and concentric ridges appeared on their body. Total time taken by the insect from emerging crawlers to nipple stage was 9–14 days. At the termination of nipple stage, 1st instar stage was completed and molting process started. Molting process continued for 4–5 days before 2nd instar started. At the molting stage, color changed to light green and the body became oblong with one end pointed and pygidium developed.

Second instar

Second instar of the scale insect was marked with re-insertion of rostrum into the leaf surface for feeding purpose and remained for 4–6 days (Table I). The main diagnostic character of this stage was the presence of orange molt ring (Fig. 1f).

Male

After second instar, the body of males elongated and the color changed to brown/orange with two black spots of eyes appearing at one end. Males transformed to pre-pupa, pupa and then adult. At the pupal stage, eyes could be clearly identified, genitalia were well developed and the body tapered (v-shaped) towards the posterior end (Fig. 1g). After 4–5 days, adult males emerged from pupae having slender body (Fig. 1h), orange brown head, two well-developed black eyes, one pair of long membranous wing, three pairs of jointed legs and filiform antennae. Total adult life stage of males lasted for 2–3 days and the entire life cycle (eggs to adult) was completed in 21–33 days (Table I).

Female

Sexual variation in *A. destructor* started after the second molt, when male developed into pre-pupa and pupa, while female transformed to mature adult (pre-oviposition and oviposition stages). The third instar was characterized by pale green body, circular with internal ridges and concentric pale rings with ridges in the body (Fig. 1i). After 1 to 2 days, female body and its cover separated. At this stage, mating with males occurred. Fully mature females were apterous (without wings), apodeous (without legs), soft bodied, light green in color, and tapered anteriorly. Mean length and width of mature female were 0.66 mm and 0.61 mm, respectively (Table I). Pre-oviposition stage remained for 7–9 days at 30°C and 64 % RH. At oviposition stage, female increased in size and started egg laying.

Reproduction

Oviposition stage lasted for 10–12 at 30°C and 64% RH conditions (Table I). Females laid 28–65 (mean 47) eggs in 3–4 batches in lines near the posterior end under the scale cover. The recorded sex ratio on nursery plants was 1:2.1 (male: female); amongst a total of 2710 post 2nd instar nymphs, 1840 were female and 870 were male. Total life cycle (from eggs to gravid female) lasted for 33–46 days at 30°C and 64 % RH.

Greenhouse study

Developmental durations of different stages of *A. destructor* on desi and langra cultivars were similar, whereas on kala chounsa and anwar ratoul, the life span of the insect was prolonged by 2 to 3 days (Table II). In greenhouse, egg, white cap, 2nd instar, 3rd instar and oviposition stages remained for 5–7, 5–8, 6–8, 8–11 and 11–13 days, respectively at 25°C and 60 % RH on Desi mango cultivar. Total duration of life span from egg to adult stage on desi, langra, kala chounsa and anwar ratoul was 32–46, 32–46, 36–47 and 37–50 days for males, and 43–58, 44–59, 47–60 and 47–60 days, for females.

DISCUSSION

A. destructor is a serious pest of mango in Pakistan having 3–4 overlapping generations on the host plants from July to December each year (author's unpublished data). Heavy infestations were recorded at several localities in coastal and subcoastal areas of Punjab and Sindh provinces of Pakistan (Ahmad and Ghani, 1972). The pest developed and survived under moderately hot (20–35°C) and humid (50–70 % RH) climatic conditions in our study area. Developmental variations in males and female life stage at varying temperature and relative humidity were observed during the course of our study. Findings of this study are compatible with those of Chiu (1986) who showed changes in population of *A. destructor* with seasonal variation in Hawaii on guava plants. Wright and Diaz (2005) reported a positive relationship between rainfall and

A. destructor population expansion on banana in Hawaii. Elwan (2005) and Trencheva *et al.* (2004) observed that two species of scale insects, *Lepidosaphes pallidula* (Williams) and *Pseudaulacaspis pentagona* (Targioni Tozzetti) had four and three generations per year on mango (*Mangifera indica*) in Egypt. Waterhouse and Norris (1987) and Taylor (1935) had reported 8–10 generations of *A. destructor* per year in tropical regions depending upon climatic conditions.

Results of the present study revealed that after settlement on leaf surface, female *A. destructor* remained sessile throughout her life but its male in the last stage had well-developed wings and were able to fly. Females passed through three instars while males had two feeding instars with pre-pual, pupal and adult stages. The results of this study agree with those of Dekle (1965) who reported that all the appendages of crawlers in coconut scales were lost once they settled on leaves. Similar results were reported by Tabibullah and Gabriel (1973), Koteja (1990b) and Gieselmann (1990) who studied biology of *A. destructor*.

During development, color, shape, length and width of *A. destructor* changed as the insect developed to the next stage. Overall, male and female ranged from 0.2 mm to 1.16 mm and 0.2 mm to 0.8 mm, respectively. These observations agree with those of Williams and Watson (1988) who reported that slide-mounted adult female *A. destructor* were 0.7–1.2 mm in length with pyriform and membranous body.

A. destructor laid 65–110 (average 90) eggs in Fiji at a mean temperature of 30°C. However; in China on Actinidia, as a host, the female laid 32–43 eggs. Watson and El-Serwy (2007) discovered the egg laying range of 39–48 eggs per female in *Acanthomytilus sacchari* Hall under scale cover. In the present study, relatively high fecundity (28–65 eggs) with long oviposition period (10–12) in *A. destructor* was noted on mango plants. Crawlers emerged from early laid eggs while the pest still continued eggs laying. Continuous reproduction enables the pest to have multiple overlapping generations during its peak season from July to December. Rashid *et al*. (2012) reported maximum fecundity of 265 eggs/female of cotton mealybug, *Phenacoccus solenopsis* on cotton.

In the present investigation the crawlers that emerged from July to October were mostly females with male to female sex ratio of 1:2.1; however, from October onwards male crawlers were dominant. Nur (1990) also reported 1:1 male to female ratio during July to August in diaspidid scale insects but late in the season, number of males increased to as many as twice the number of females. Bonafonte (1981) discovered that fecundity of *Chrysomphalus aunidum* (L) was influenced by temperature and humidity. Quayle (1911a) had reported that male *Aonidiella aurantii* Maskell armored scales were more common in spring in southern California, USA, compared to autumn, summer and winter seasons; sex ratio of the insect was 1:0.6 (male: female) from January to July, and 1:1 from mid-summer to mid-winter. Sex ratio in coconut scale was much influenced by temperature and RH variations.

Developmental duration of *A. destructor* life stages did not generally differ amongst different mango varieties in the present study. These results are in agreement with those of Ahmad and Ghani (1972) who found that duration of different life stages of *A. destructor* on squash, *Cucurbita maxima* was not significantly different from coconut palms, studied by Taylor (1935). Tabibullah and Gabriel (1975) also studied the biology of *A. destructor* in the field and greenhouse in the Philippines on three coconut cultivars: Laguna, Coco nino and Tambuliid, and reported no significant differences in the developmental duration of *A. destructor* on the three coconut cultivars.

From results of the present study, it can be concluded that *A. destructor* has a rather high reproductive capacity on mango plant as compared to Actinidia in China and has many overlapping generations from July to December in Pakistan each year. The results of the study of biology at various temperatures and RH should be helpful in predicting population explosions of the pest insect for timely adopting of population management strategies.

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