

**BIOLOGY, MORPHOMETRY AND DAMAGE ASSESSMENT OF
PAPAYA MEALYBUG, *PARACOCCLUS MARGINATUS* WILLIAMS AND
GRANARA DE WILLINK (HEMIPTERA: PSEUDOCOCCIDAE)**

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Abstract

Two experiments were conducted to study the biology and damage assessment of papaya mealybug in Sher-e- Bangla Agricultural University. In Biology study, each adult female laid one egg sack and per egg sack contained 123 ± 19.52 eggs in average. The female had three instars' nymphs and male had four. Average duration of female and male was 22.4 ± 3.7 and 17.2 ± 2.86 days, respectively. At 1st instar male and female could not be distinguished, average length and breadth was 0.41 ± 0.08 and 0.25 ± 0.03 mm, respectively. Average length and breadth of 2nd, 3rd instar nymph and adult female were 0.69 ± 0.03 , 0.44 ± 0.02 ; 1 ± 0.14 , 0.72 ± 0.05 and 1.94 ± 0.27 , 1.38 ± 0.05 mm, respectively. The average length and breadth of 2nd, 3rd instar, pupa and adult male were 0.70 ± 0.06 , 0.38 ± 0.04 ; 0.85 ± 0.02 , 0.41 ± 0.02 ; 0.94 ± 0.04 , 0.26 ± 0.03 and 0.98 ± 0.03 , 0.26 ± 0.01 mm, respectively. In damage assessment study, papaya plant was covered with fine net and imidacloprid (Admire) 200 SL @ 1ml/L of water was sprayed at 7 days interval and plants also artificially infested by papaya mealybug (100 papaya mealybugs per plant. Mealybug infestation reduced plant height (34.35%), number of leaves per plant (86.08%), petiole length (53.31%), number of flowers per plant (86.23%), number of fruits per plant (89.43%), individual fruit weight (88.01%) as well as total fruit yield per plant (98%). However, some plants showed a total loss in yield, indicating that 100% damage occurred for those plants.

Keywords: Biology, Papaya Mealybug, Damage Assessment, *Paracoccus marginatus*,

Introduction

Papaya (*Carica papaya* L.), a member of the Caricaceae family, is an important fruit crop in Bangladesh. Locally, it is popularly known as 'pepe' cultivated all over the country. Now a days papaya is severely damaged by a pest known as papaya mealybug (*Paracoccus marginatus*) Williams and Granara de Willink (Hemiptera: Pseudococcidae). The papaya mealybug, *P. marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae) is native to Mexico and/or Central America (Miller *et al.*, 1999). It was first described in 1992 (Williams and Willink, 1992) and re-described by Miller and Miller (2002). Papaya mealybug is

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a polyphagous insect. The adult female is yellowish color, and is covered with a white waxy coating. Adult male has well developed wings (Miller and Miller, 2002). The Papaya mealybug has been recorded on over 55 species from 25 families, including a variety of economically important crops (Walker *et al.*, 2003). Economically important crop hosts and weed hosts include papaya, hibiscus, avocado, citrus, cotton, tomato, eggplant, peppers, beans, peas, sweet potato, mango, cherry and pomegranate. The specimens of the pest were collected first in 1992 from the Neotropical region in Belize, Costa Rica, Guatemala, and Mexico. Papaya mealybug became a pest when it invaded the Caribbean region. Since 1994 it has been recorded in 14 Caribbean countries. Both Nymph and adult damage the plant. Papaya mealybug infestation appears on above ground parts on leaves, stem and fruits as clusters of cotton-like masses. The insect sucks the sap by inserting its stylets into the epidermis of the leaf, fruit and stem. While feeding, it injects a toxic substance into the leaves, resulting in chlorosis, plant stunting, leaf deformation or crinkling, early leaf and fruit drop, and death of plants. The honeydew excreted by the bug results in the formation of black sooty mould which interferes in the photosynthesis process and causes further damage to the crops. Heavy infestations are capable of rendering fruit inedible due to the buildup of thick white waxy coating. Honeydew attracted the ant which helps in transfer the mealybug one plant to another (Tanwar *et al.*, 2010). The papaya mealybug has been identified firstly in Bangladesh in the year 2009 (Muniappan *et al.*, 2011). Within the last few years this insect pest spreads many parts of the country very rapidly and has become major concern to papaya growers in Bangladesh (Karim *et al.*, 2012). A significant reduction in papaya production in Bangladesh is recorded in the recent years, and among other factors, it is assumed that mainly infestation of this nonindigenous pest is responsible and causing huge economic losses to farmers (Helemul, 2013). The infestation also depends on the atmospheric condition like temperature, rainfall, humidity. Heavy rainfall reduces the population and damage severity (Galanihe *et al.*, 2010). Sometimes it occurs to assume the status of a major pest and it causes severe damage to economically important crops and huge losses to farmers. A survey on the host range and damage assessment of mealybugs in Bangladesh revealed that, according to farmers, papaya had the highest level of infestation which is 95.5% (Mahmud, 2017). Keeping the above facts in view, the experiment was conducted to study biology and damage assessment of papaya mealybug that can further assist to device appropriate management tactics.

Materials and Methods

The experiment was conducted during the period from June, 2017 to December, 2018 to study the biology and damage assessment of papaya mealybug. The study on biology of *P. marginatus* was carried out in Entomology laboratory, Sher-e-Bangla Agricultural University. Adult of papaya mealybug used in this study were confirmed to be *P. marginatus* by the insect identification keys provided by Miller

and Miller (2002). The host plants used in this study was papaya. The individual leaves of host plants with petioles were removed and kept in Petri dish lined with moist cotton to prevent desiccation of leaf. Hence, the whole plant with intact root system was used in the study. Three months old seedlings were planted in the pot and fully an expanded young leaf was preferably at the top most position selected for this experiment. Each plant was inoculated with eggs of *P. marginatus* using a camel hair brush. All plants were observed daily for egg hatching. The interval between each moulting was checked by examining exuviae on the leaves using a hand lens (10X magnification) and the exuviae were removed after each moulting. Morphological determination of all the instars was done under a stereo microscope in the laboratory. The number of days to egg hatch, emergence of first instars, duration of second instar males and females, duration of third instar males and females and duration of fourth instar males (pupa) were recorded. The adult female mealybugs were individually transferred to new leaf (leaves of plant lined with moistened cotton) for monitoring the reproductive period (oviposition and incubation). Adult longevity of five male and female mealybugs was observed.

The damage assessment experiment was conducted at agronomy farm of Sher-e-Bangla Agricultural University. The papaya variety used in the experiment was 'Red Lady'. The experiment consisted of two treatments and 10 replications. The two treatments were: T₁= papaya plant covered with fine net and imidacloprid (Admire) 200 SL @ 1ml/L of water was sprayed at 7 days interval and T₂ =Artificially infested by papaya mealybug (100 papaya mealybugs per plant)

The experiment was laid out in Randomized Complete Block Design (RCBD) with ten replications. Data on plant height, leaf number, petiole length, number of inflorescences, fruits per cluster, fruit weight were recorded from the sample plants during the course of experiment. Percent damage due to infestation of mealybug calculated by following formula: Percent damage = $\frac{T_1 - T_2}{T_1} \times 100$; [T₁=Papaya plant covered Papaya plant with fine net and imidacloprid (Admire) 200SL@ 1ml/L of water was sprayed at 7 days interval; T₂= Artificially infested by papaya mealybug (100 papaya mealybugs per plant)]

The recorded data on various parameters were statistically analyzed using SPSS statistical package program. The mean for all the treatments was calculated and analysis of variance (ANOVA) for all the characters were performed by paired t test.

Results and Discussions

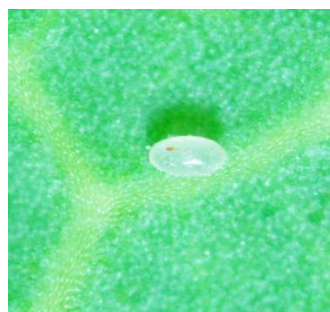
Biology and Morphometry of Papaya Mealybug

Egg sack: The papaya mealybug (*Paracoccus marginatus*) laid eggs in an egg sack. Each female lays one egg sack (Table 1) after laying the eggs female was died. Egg sack was made of whitish cottony layer (Fig.1).

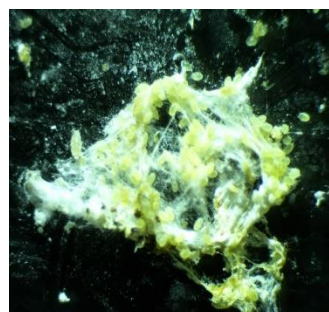


Fig. 1. Egg Sack.

Egg: Adult female lays (97-150) eggs per sac (Table 1). Eggs were yellowish color and oval shape (Fig.2). The length of egg was 0.35 ± 0.01 mm (Table 3) and the breadth was 0.14 ± 0.008 mm (Table 3). The average incubation period of the eggs was 4-7 days (Table 2). The oviposition period of a female was 5-8 days (Table 2). Chellappan *et al.* (2013) reported that the length of egg was 0.34 ± 0.01 mm and the breadth was 0.15 ± 0.01 mm which is also confirmed the present study. They also reported that incubation period was 8.5 ± 0.85 days and oviposition period 7.8 ± 0.63 days is also close to the present study. Females usually lay 150- 600 eggs in an ovisac. The results of the present study are lying between the ranges of these findings. Egg laying usually occurs over the period of 3-4 days, which is lower than the present study. Egg hatch in about ten days which is lower than the present study. However, this variation might be due to the environmental condition (Jithu *et al.*, 2016). The adult female of *P. marginatus* laid about 150 to 200 eggs inside the ovisacs (Al-Hilal *et al.*, 2012) which are close to the present study. Suganthi *et al.* (2011) reported that the period of egg was 6.33 ± 0.58 days and this finding is lying between the present studies. Females usually lay 100 to 600 eggs. Eggs are greenish yellow and are laid in an ovisac and these findings are similar to the present study but they also reported that egg laying usually continues over a period of one to two weeks and eggs hatch in about 10 days, these results are somewhat different to the present study. This variation might be occurred due to environmental condition or host species (Tanwar *et al.*, 2010).



A



B

Fig. 2. A. Egg, B. A mass of egg.

Table 1. Number of eggs per sack, egg sack laid per female during May 2018

Observations	Egg number
1	97.0
2	120.0
3	118.0
4	130.0
5	150.0
Mean± SD	123±19.52

Nymph: Females have three instars' nymphs whereas males have four instars (Table 2). Al-Hilal *et al.* (2012) observed that in case of *P. marginatus*, generally three and four nymphal instars took place in case of female and male mealybug, respectively, this finding is same as the present result.

First instar nymph: At this stage male and female could not be distinguished (Fig. 3). First instar nymph was very active. The length of the nymph was 0.41 ± 0.08 mm (Table 3) and the breadth was 0.25 ± 0.03 mm (Table 3). The average duration of 1st instar nymph was 4-6 days (Table 2). The first instar nymph is yellowish color (Fig. 3). Miller and Miller (2002) reported that in 1st instar gender could not be determined and nymph is yellow color which is similar to the present findings. They also reported that the length and breadth of nymph were 0.4 mm and 0.2 mm which is close to the present findings. 1st instar nymph was 4.6 ± 0.52 days this result is accordance with the present result (Chellappan *et al.*, 2013). Seni and Sahoo (2014) studied the biology of *P. marginatus* on sprouted potato throughout the year revealed that the duration of first instar nymphs ranged from 3-17 days and the present study finding is also lying between the ranges of this findings. The sexes of which could not be distinguished and this finding is same as the present result. The length of first instar nymph were 0.42 ± 0.074 mm and 0.024 ± 0.27 mm in width. This instar appears yellowish in color which is similar to the present findings (Al-Hilal *et al.*, 2012). Suganthi *et al.* (2011) reported that the period of first instar nymph was 4.00 ± 1.00 days and this finding is lying between the present studies.



A



B

Fig. 3. A. A mass of 1st Instar Nymph, B. 1st instar nymph

Second Instar Nymph: The 1st instar nymph was moulted to 2nd instar nymph and casted their exuviae. The 2nd instar female was yellowish color (Fig.4) and male was pink color (Fig.4) Female length was 0.69 ± 0.03 mm and breadth was 0.44 ± 0.02 mm and the male was 0.70 ± 0.065 mm long and 0.38 ± 0.04 mm wide (Table 3). Average duration of 2nd instar female nymph was 3-5 days and the 2nd instar male nymph was 3-4 days (Table 2). Miller and Miller (2002) reported that the 2nd instar female was yellowish color and male was pink color which is similar to the present study. They also reported that 2nd instar female length and breadth was 0.7 mm and 0.04 mm which is close to the present study. But the 2nd instar male nymph 0.4 mm long and 0.02 mm wide which is somewhat different to the result. Chellappan *et al.* (2013) find that 2nd instar male nymph was 0.75 ± 0.02 mm long and 0.44 ± 0.02 mm wide, which is similar to this study. They also observed that 2nd instar female nymph average duration was 4.2 ± 0.63 days and 2nd instar male nymph average duration was 4.3 ± 0.67 days. Al-Hilal *et al.* (2012) observed that the length of second instar female nymph was 0.6 ± 0.054 mm and 0.089 ± 0.4 mm in width. Body color appeared yellow in field conditions. Length of second instar male nymph was 0.62 ± 0.044 mm and 0.09 ± 0.3 mm in width. Body looks like yellow in color during field observation. The length of second instar male and female is close to the present result but the width showed different result and this might be due to the environmental condition or host species. The period of second instar nymph was 3.67 ± 0.58 days (Suganthi *et al.*, 2011) and this finding is lying between the present studies.

Table 2. Duration of different life stages of *Paracoccus marginatus* during May 2018

Life stage	Observation	Period in Days Average $\pm$ SD	Temperature (°C)	Relative Humidity (%)
Oviposition	5	6.00 ± 1.22		
Incubation period	5	5.80 ± 1.09		
1 st instar gender is not identified	5	4.80 ± 0.83	21-36	45-97
2 nd instar female	5	4.20 ± 0.83		
3 rd instar female	5	3.40 ± 0.54		
Adult female	5	10.0 ± 2.00		
2 nd instar male	5	3.60 ± 0.54		
3 rd instar male	5	2.80 ± 0.83		
Pupa	5	3.60 ± 0.54		
Adult male	5	2.40 ± 0.54		
Total lifespan male	5	17.2 ± 2.86		
Total lifespan female	5	22.4 ± 3.70		

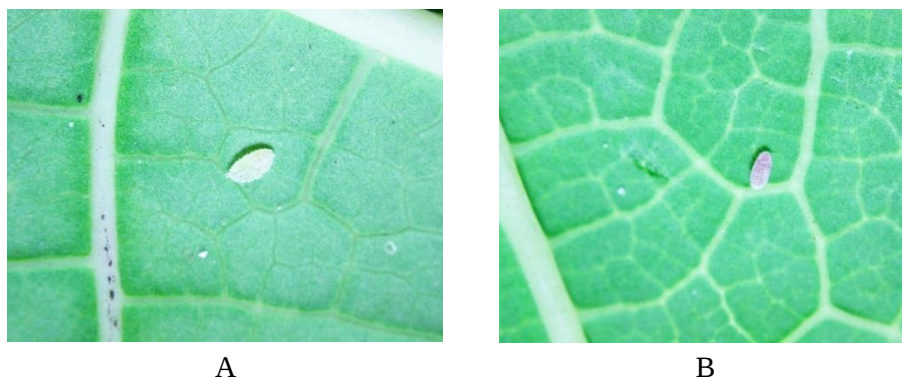


Fig. 4. A. 2nd Instar nymph female B. 2nd Instar nymph male.

Third instar nymph: The 2nd instar female moulted after 3-4 days and male was moulted after 2-4 days into 3rd instar nymph (Table 2). The 3rd instar male was pink color (Fig.5) and the female was yellowish color (Fig.5). Female length was 1 ± 0.14 mm and breadth was 0.72 ± 0.05 mm and male 3rd instar nymph was 0.85 ± 0.02 mm long and 0.41 ± 0.02 mm wide (Table 3). Miller and Miller (2002) reported that the 3rd instar female was yellowish color and male was pink color which is confirmed the present study. They also reported that 3rd instar female length and breadth were 1.1 mm and 0.7 mm and male were 0.9 mm and 0.4 mm which is similar to the present result. Studies made by Chellappan *et al.* (2013) observed that 3rd instar female and male average duration were 5.1 ± 0.32 days and 2.6 ± 0.52 days, which also confirmed the present study. Al-Hilal *et al.* (2012) observed that the length of third instar nymph was 0.89 ± 0.11 mm and it was 0.12 ± 0.51 mm in width. Body appears yellow in color during field observation. Length of third instar male nymph was 1.05 ± 0.23 mm and 0.156 ± 0.59 mm in width. Body looks like yellow in color during field observation. This is result somewhat different from the present result and this might be due to the environmental condition or host species. The period of third instar nymph was 5.00 ± 1.00 days (Suganthi *et al.*, 2011). and this finding is higher than the present study. This variation might be due to the environmental condition or host species.

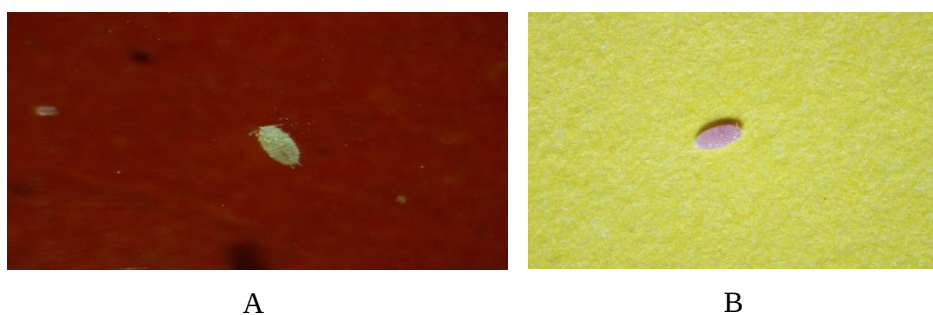


Fig 5. A. 3rd Instar nymph female, B. 3rd Instar nymph male

Table 3. Measurement of different stages of *Paracoccus marginatus*

Stage	Length (mm) Average $\pm$ SD	Breadth (mm) Average $\pm$ SD
Egg	0.35 $\pm$ 0.03	0.14 $\pm$ 0.01
1 st instar (gender not identified)	0.41 $\pm$ 0.08	0.25 $\pm$ 0.03
2 nd instar female	0.69 $\pm$ 0.03	0.44 $\pm$ 0.02
3 rd instar female	1 $\pm$ 0.14	0.72 $\pm$ 0.05
Adult female	1.94 $\pm$ 0.27	1.38 $\pm$ 0.05
2 nd instar male	0.7 $\pm$ 0.06	0.38 $\pm$ 0.04
3 rd instar male	0.85 $\pm$ 0.02	0.41 $\pm$.02
Pupa	0.94 $\pm$.04	0.26 $\pm$ 0.03
Adult male	0.98 $\pm$.03	0.26 $\pm$ 0.01

Pupa: The 4th instar nymph occurred only in case of male *P. marginatus*. It is the pupal stage. The duration of this stage was 3-4 days (Table 2). The length of pupa was 0.94 $\pm$ 0.04 mm and breadth were 0.26 $\pm$.03 mm (Table 3). Pupal stage occurred in a cocoon. The cocoon was made of whitish cotton like thread. The color of pupa was pink (Fig. 6). The pupa was pink color and length and breadth of pupa were 1.0 mm and 0.03 mm (Miller and Miller, 2002) which also supported the present result. Average duration of pupa was 4.2 $\pm$ 0.63 days, almost similar to that determined by Chellappan *et al.* (2013). Al-Hilal *et al.* (2012) observed that the length of fourth instar nymph was 0.98 $\pm$ 0.075 mm and 0.02 $\pm$ 0.49 mm in width. Body color appeared pink but occasionally yellowish. Only width is different from the present result but length and color support the current finding.

**Fig. 6. Pupa.**

Adult female: Body is yellowish color, dusted with mealy wax not thick enough to hide body color (Fig.7) without discrete bare areas on dorsum, with many short waxy filaments around body margin. Body was 1.94 $\pm$ 0.27 mm long and 1.38 $\pm$ 0.05 mm wide (Table 3). The antennal segment of this adult female was 8. The average duration of adult female was 8-13 days (Table 2). The adult female was yellow color and 2.2 mm long and 1.4 mm wide (Miller and Miller, 2002), and the present findings close to that. Chellappan *et al.* (2013a) studied that the average duration

of adult female was 22.4 ± 1.35 days somewhat different to the current result. The length of adult female was 2.08 ± 0.354 mm and it was 1 ± 0.063 mm in width. Body was yellow in color during field observation (Al-Hilal *et al.*, 2012). The length of this finding also supports the present finding but the width is less than the present finding. Suganthi *et al.* (2011) reported that adult longevity of females was 20.33 ± 1.53 days, which is higher than the present finding as their host species was different which was sunflower and their temperature and relative humidity were also different that was 25-30 °C and 75-80%. On the other hand, during this experiment temperature range was 21-36°C and relative humidity was 45-95%.



Fig. 7. Adult female.

Adult male: Adult male was winged (Fig.8). Antennae 10 segmented. The length of the adult male was 0.98 ± 0.03 mm and the breadth were 0.26 ± 0.01 mm (Table 3). The wings are white color. The longevity of adult male was 2-3 days (Table 2).

According to Miller and Miller (2002), the adult male had wings and measured 1.0 mm in length and 0.03 mm in width. These measurements are similar to the current findings.

Chellappan *et al.* (2013) observed that the average duration of adult male was 2.7 ± 0.48 days which is accordance with the present result. The length of adult male was 1.5 mm and was 0.5 mm in width. Body color appeared pink, but occasionally yellowish; these findings different from the present findings. This variation might be due to the environmental condition or host species (Al-Hilal *et al.*, 2012). Suganthi *et al.* (2011) reported adult longevity of males was 1.67 ± 1.15 days and this finding supports the present investigation.



Fig. 8. Adult male.

Damage Assessment of papaya field after infestation papaya mealybug

Plant Height: The result indicated that papaya plant height increased progressively with the advancement of time and growth stages. At early stage, average plant height was 49.6cm in T₁ and 23.80cm in T₂. At middle stage the plant height in T₁ was 83.6cm per plant and in case of T₂ that was 48.20cm per plant. At later stage, average height of plant in T₁ was 114.70cm per plant and average height of plant in T₂ was 75.30cm per plant. The result indicated that T₁ showed the higher plant height and T₂ became stunted. This finding reveals that in early, mid and late-stage infested plant (T₂) height was reduced 52.01%, 42.6%, 52.25% respectively comparing with the healthy plant (T₁) due to infestation of papaya mealybug (Fig.9).

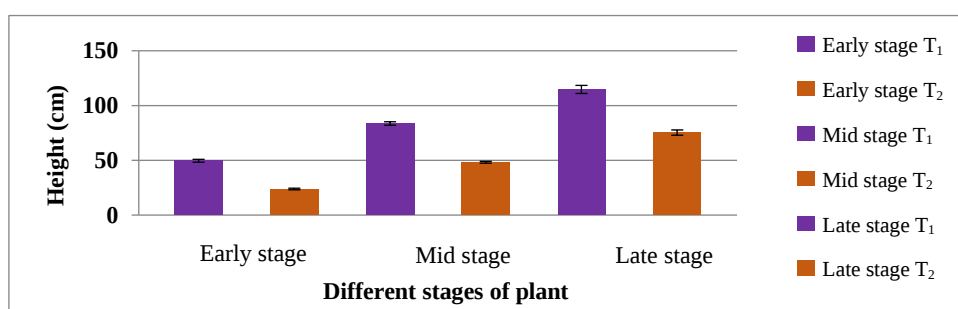


Fig. 9. Effect of papaya mealybug infestation on plant height of papaya plant at different stages of plant.

Leaf number: In early stage, the leaf number of plant in case of T₁ was 10.5 and in case of T₂ plant which was infested with mealybug showed lower number of leaves that was 3.2. In mid stage, the leaf number of plant in T₁ treatment was increasing rapidly and that was 21 but in the case of T₂ plant showed very poor number of leaves that was 2.8. In late stage, the leaf number of plant in T₁ also had leaf number increasing that was 23 on the other hand leaf number of T₂ plant was 3.1 which was very lower than that of T₁ plant. This result indicated that in early, mid and late-stage leaf number reduced 69.5%, 86.6%, 86.08% respectively due to infestation of papaya mealybug (Fig.10)

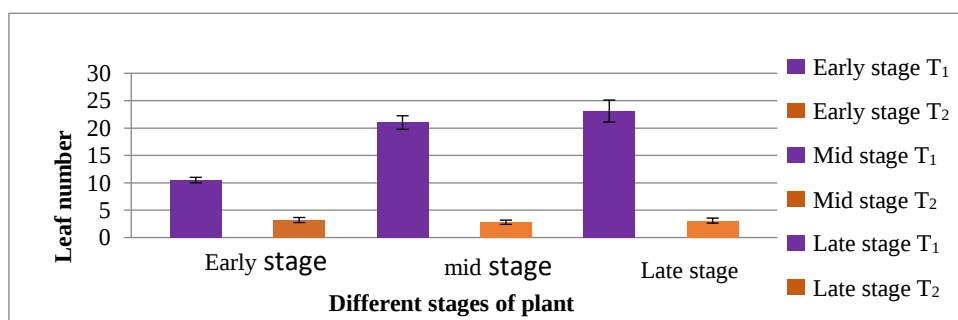


Fig. 10. Effect of papaya mealybug infestation on average leaf number of papaya plant at different stages of plant.

Petiole Length: At early stage, average petiole length of T_1 was 16.65 cm and the average petiole length of T_2 was 7.52 cm. At middle stage, petiole length in T_1 was 35.85 cm and 15.17 cm in T_2 . At later stage, average petiole length of T_1 was 55.61 cm and average petiole length of T_2 was 25.96 cm. The result indicated that T_1 showed longer petiole length than T_2 . This result indicated that in early, mid and late-stage petiole length reduced 54.83%, 57.68%, 53.31% respectively comparing with the healthy plant (T_1) due to infestation of papaya mealybug (Fig.11).

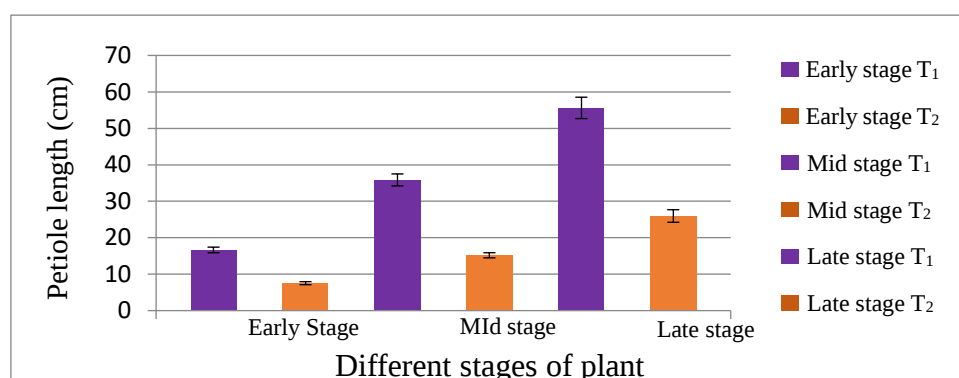


Fig. 11. Effect of papaya mealybug infestation on average petiole length of papaya plant at different stages of plant.

Inflorescence Number: No of inflorescence in T_1 was 13.80 but T_2 showed very lower number of inflorescences. Average inflorescence number for T_2 was 1.90. This result indicated that in reproductive stage inflorescence number reduced 86.23% comparing with the healthy plant (T_1) due to infestation of papaya mealybug (Fig.12).

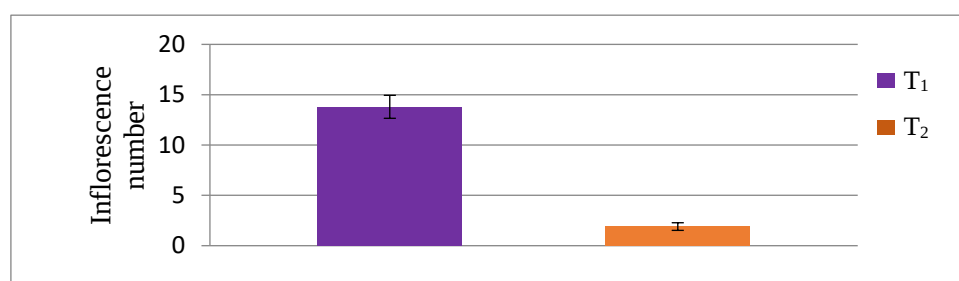


Fig. 12. Effect of papaya mealybug infestation on average inflorescence number of papaya plant.

Fruit Number: In the case of T_1 average number of fruits per plant recorded was 12.30. On the other hand, the average number of fruits in T_2 recorded was 1.30. This result indicated that in reproductive stage fruit number reduced 89.43% comparing with the healthy plant (T_1) due to infestation of papaya mealybug (Fig.13).

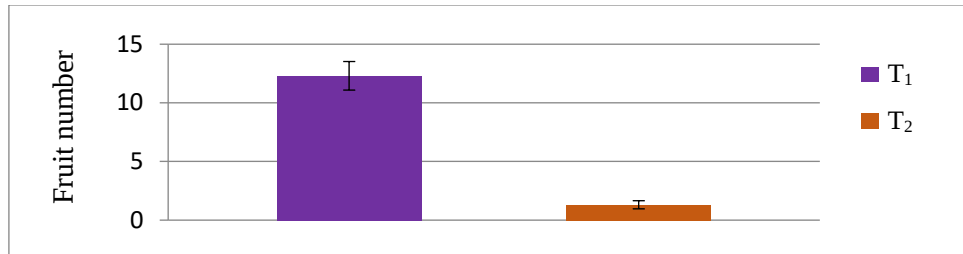


Fig. 13. Effect of papaya mealybug infestation on average fruit number of papaya plant.

Average Fruit Weight: Average weight of fruit in T₁ was 559.7gm on the contrary average weight fruit was 67.1gm in T₂. This result indicated that fruit weight reduced 88.01% comparing with the healthy plant (T₁) due to infestation of papaya mealybug (Fig.14).

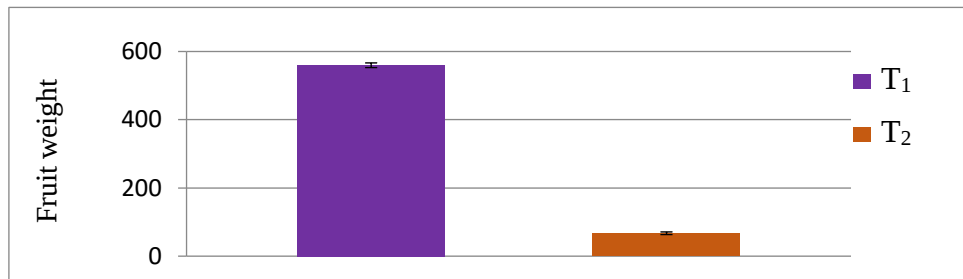


Fig. 14. Effect of papaya mealybug infestation on average fruit weight (g) of papaya plant.

Total fruit yield per plant: Total fruit yield per plant in T₁ was 6.88 kg on the contrary total fruit yield 0.087 kg in T₂. This result indicated that total fruit yield per plant reduced comparing with the healthy plant (T₁) 98% comparing with the healthy plant (T₁) due to infestation of papaya mealybug (Fig.15).

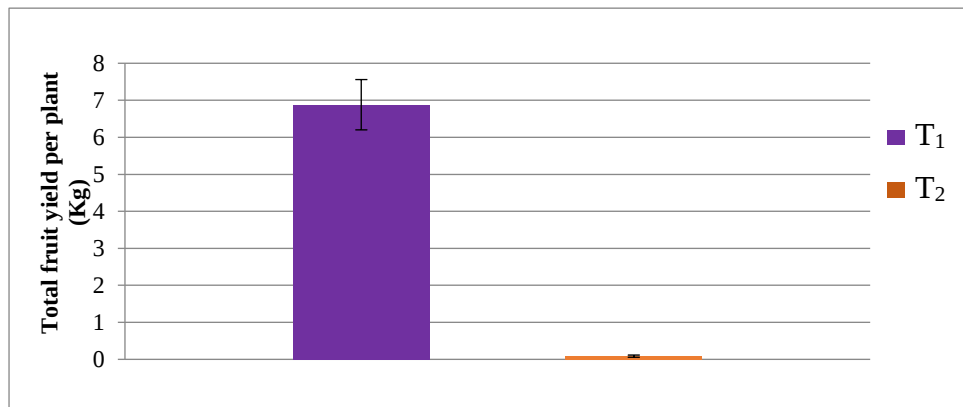


Fig. 15. Total fruit yield per plant (Kg).

Conclusion

In this experiment the characteristics of eggs, larvae, pupae and adult were studied. This information will be very helpful in predicting its development, emergence, distribution and abundance, which will also help in developing effective management strategies. Moreover, damage assessment revealed that due to infestation of papaya mealybug, papaya field was severely damaged. The damage percent was more than 80%, and thus it caused great losses in papaya production in Bangladesh.

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