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Studies on biology of mealy bug (*Maconellicoccus hirsutus* Green) on custard apple (*Annona squamosa* L.)

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Abstract

The present experiment entitled “Studies on seasonal incidence of mealy bug (*Maconellicoccus hirsutus* Green) and their natural enemies on custard apple (*Annona squamosa* L)” was conducted during *kharif* season in year 2021-22, 2022-23 at Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), India. The experiment was laid out in RBD (Randomized Block Design) with 10 treatments and three replications. The treatment consists of T₁ (*Verticillium lecanii* 5 g/liter), T₂ (*Beauveria bassiana* 7.5 g/liter), T₃ (*Metarhizium anisoplie* 5 g/liter), T₄ (*Verticillium lecanii* 7.5 g/liter), T₅ (*Beauveria bassiana* 5 g/liter), T₆ (*Metarhizium anisoplie* 7.5g/liter), T₇ (Neemark 5ml/liter), T₈ (Buprofezin 2ml /liter), T₉ (Flonicamid 0.5g/liter) and T₁₀ (Untreated plots). The study investigated the biology of the custard apple mealy bug, *M. hirsutus*, under laboratory conditions at room temperature and ambient relative humidity during 2021-2023. The complete life cycle of *M. hirsutus* was observed using cultures maintained on medium sized potatoes and pumpkins. Methodology included collection of field samples, culture maintenance, observation of different developmental stages, determination of fecundity, hatching percentage, duration of developmental stages and morphometrics. Fecundity was studied by recording number of eggs laid per female. Hatching percentage was calculated by observing hatching from eggs kept on blotting paper. Durations of egg, nymphal instars and adult stages were recorded separately for males and females under laboratory conditions. Morphometric measurements of body length and width were taken for different stages using an ocular micrometer. The study provides information on life history and developmental parameters of *M. hirsutus*, an important pest of custard apple.

Keywords: *Maconellicoccus hirsutus*, custard apple, *Annona squamosa*, mealybug, life cycle, developmental stages, morphology, fecundity, hatching percentage, instars, nymphs

1. Introduction

Custard apple, *Annona squamosa* L (Family, Annonaceae) having chromosome number $2n = 14$, is a lowland or marginally subtropical crop, growing between latitudes of 23° north and south and native of the Tropical America and West Indies. This crop is cultivated throughout the tropics and warmer subtropics for its edible fruit, and has become naturalized throughout the world and India even at an altitude of 900 m. It is probably the most droughts tolerant among other species of Annonaceae family as it grows and produces poorly where rains are frequent. (Argo forestry Database 4.0) Temperature is a limiting factor, with frost killing young trees, but older trees show some tolerance. Seedlings have high photosynthesis activity at 30°C and show vigorous shoot growth (Yang *et al.* 1998) [74]. It is also called as sugar- apple, sweetsop, or sugarpineapple in English, Sharifa or Sitaphal in Hindi and Sitaphala in Kannada. In India, sugar apple is cultivated in rainfed orchards mainly in Maharashtra, Gujarat, Andhra Pradesh, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Bihar, Assam, Rajasthan, Orissa and Tamil Nadu (Singh, 1992) [66]. The plant are potentials to tolerate a range of conditions, from saline soils to droughts and allowing farmers to leverage non-farm land for income generation. In India this is an important dryland fruit, grown well in arid zones throughout the plains, at elevations of upto 4,000 ft. and it prefers a tropical climate. The tree displays yellow trumpet shaped flowers that emit a pleasant sweet smell, the fruits are variable in shape with the inside containing a custard like flesh (Pinto *et al.* 2005) [54].

Fruits are considered nutritionally valuable in dry regions due to their sweet and delicate flesh. Dates contain approximately 28-55% edible portion comprising of 73.30% moisture, 1.60% protein, 0.30% fat, 0.70% minerals, and 23.90% carbohydrates. They also contain modest amounts of calcium (17mg/100g), phosphorus (47 mg/100g), iron (1.5 mg/100 g), and carotene (0.007mg/100 g). Additionally, dates have sugar content ranged from 12.4-18.15% and acidity from 0.26-0.65%. They possess good caloric value as well

2 it maintains the water balance in our body, which aids in removing acids from the joints and reduces the symptoms of rheumatism and arthritis (Saha, 2011) ^[60].

2. Material and Method

The field experiment was conducted during *Kharif* 2021-22, 2022-23 at Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), India. The experiment was laid out in a Randomized Block Design with three replications.

2.1 Methodology

2.1.1 Collection of the culture of mealy bug (*Maconellicoccus hirsutus* Green)

The mealy bug samples was collected in plastic bags from the custard apple plants with the help of fine camel hair brush from the orchard located at commercial custard apple orchard, Ramprasad Potai College of Agriculture and Research Station, Kanker, Chhattisgarh and farmers field in Nawagaon bhagveer, Kanker.

2.1.2 Maintenance of the culture of mealy bug (*Maconellicoccus hirsutus* Green)

The culture was maintained on medium sized ripped pumpkins (*Cucurbita moschata* D.) in the laboratory in specially prepared for insect rearing cages of 70 x 55 x 38 cm size. The pumpkin was selected having ridges and grooves with small stalk for easy handling. The well ripened pumpkins was selected and cleaned with water to get rid of dust and wiped with cloth. The pumpkin fruits was treated with 0.2 percent carbendazim 50 WP in order to prevent rotting and mould development. The pumpkin was dipped in the fungicide suspension for 10 seconds and dried for 4 hours. Then pumpkin was again washed with water and dried in shade. Wounds, if any on the pumpkin was plugged with wax. The ovisacs of *M. hirsutus* was collected from initial culture with the aid of fine moist brush and gently place on pumpkins and sprouted potatoes and allowed to multiply. The culture was used as stock culture for the studies.

2.1.3 Observation

For the study of complete life cycle of *M. hirsutus* (Green), sprouted potatoes was used for rearing. The uniform size potatoes was washed thoroughly with clean water, dried and disinfected with 0.2 percent carbendazim 50 WP. The potatoes was wrapped in moist gunny bag for sprouted at mean room temperature of 25.10 ± 1.26 °C for 8 days with average relative humidity of 55.8 ± 3.48 percent. The life cycle was studied at ambient temperature and relative humidity in summer season. A well developed and gravid female of mealy bug was transferred on to sprouted potatoes with the help of fine camel hair brush. Only single female of *M. hirsutus* was released on each sprouted potato. The observation on females for initiation of oviposition was under taken with binocular microscope regularly in laboratory condition.

2.1.4 Fecundity: For the studies on fecundity of females of *M.*

hirsutus the crawlers was released on sprouted potatoes, left undisturbed till the formation of ovisac. The ovisac from individual female was taken and observed under microscope.

2.1.5 Hatching percentage

Five lots of freshly laid eggs was transferred separately on moist blotting paper kept in petridishes. Each lot comprised of 30 eggs. The hatching of crawler from all the eggs was observed and percentage was worked out.

2.1.6 Duration of different stages

The freshly laid 100 eggs was released individually on duly numbered sprouted potatoes and observed for their incubation period, durations of first to third instar nymph in case of female and first to fourth instar nymph in case of male. The temperature and relative humidity during the rearing period was recorded. Average duration of 50 individual in summer season at an average temperature of 25-30 degree celsius with relative humidity of 45 to 50 percent was recorded. Longevity of similar number of adult individuals developed into male and female from the same culture was recorded along with their sex. Finally, the duration of total life cycle was worked out.

2.1.7 Morphometrics of mealy bug (*M. hirsutus* L)

Few individuals of each nymphal instar was collected and preserved in separate vials containing 70 percent ethyl alcohol for making morphometric measurements of their body length and breadth and also to study other morphological features. The measurement was made by using ocular micrometer after standardizing it with a stage micrometer at 40x magnification. Similarly, the length and breadth of adult male female was also measured, in order to know the influence of host plants on the growth parameters of the insect.

3. Result

The data regarding studies on biology of mealy bug (*Maconellicoccus hirsutus* Green) on custard apple (*Annona squamosa* L) has been presented in Table 1, Table 2, Table 3 and Table 4.

3.1 Studies on biology of mealy bug (*Maconellicoccus hirsutus* Green) on custard apple (*Annona squamosa* L)

3.1.1 Studies on biology of mealy bug on custard apple during 2021-22

The results of present investigation on Studies on seasonal incidence, biology, management of custard apple (*Annona squamosa* L) mealy bug (*Maconellicoccus hirsutus* Green) and its effect on nutritional content of custard apple in Kanker District of Chhattisgarh are presented in this chapter and discussed in the light of the research reported by the earlier workers.

3.1.2 Biology of mealy bug, *M. hirsutus* (Green)

The studies on biology of mealy bug, *M. hirsutus* (Green) was carried out under laboratory conditions at Ramprasad Poai College of Agriculture and Research Station, Kanker, Chhattisgarh during the autumn season both years 2021-2022 and 2022-2023.

3.1.3 Mass Multiplication of Mealy Bug, *M. hirsutus*

The adult female mealy bugs, *M. hirsutus* collected from the infested custard apple fruit was reared on pumpkin and it was observed that the mealy bug reproduced better on pumpkin as compare to custard apple.

3.1.3.1 Life stages of mealy bug, *Maconellicoccus hirsutus* (Green) in laboratory condition on custard apple during 2021-22

The growth parameters on developmental periods of Adult female pink mealy bug have five life stages: egg, first instar (crawler), second instar (nymph), third instar (nymph), and adult. Adult male pink mealy bug have six life stages: egg, first instar (crawler), second instar (nymph), third instar (prepupal), fourth instars (pupal), and adult are shown in Table 2.

3.1.3.2 Incubation period of eggs

The data on incubation period of eggs recorded during last week of November 2021 revealed that, the incubation period ranged from 4 to 8 days with an average of 5.76 ± 1.23 days in case of female and from 3 to 7 days with an average of 5.76 ± 1.36 days in case of male at 29.5 ± 0.32 °C with relative humidity of 47.9 ± 1.55 percent.

3.1.3.3 Hatching percentage

The data on hatching percentage of eggs revealed that, the hatching percentage of eggs varied from 80.00 to 96.00 percent with an average of 89.04 ± 4.92 percent at average temperature of 29.5 ± 0.32 °C with relative humidity of 47.9 ± 1.55 percent.

3.1.4 Duration of different mealy bug nymphal stages

The data on duration of different nymphal instars of *M. hirsutus* observed during November 2021-22 are presented in Table

3.1.4.1 1st Instar nymph

Freshly hatched, nymph was yellow to orange in colored with reddish compound eyes. The antennae was fillitorm type, six segented and both the antennae held diagonally in front of the head. The neonate nymph was oval in shape and they was highly mobile with three pairs of legs. During this stage female and male was indistinguishable and the body was not covered with mealy matter.

The duration of first instar nymph ranged from 4 to 7 days with an average of 5.48 ± 0.96 days for female and 4 to 8 days with an average of 6.72 ± 1.48 days for male at an average temperature of 30.1 ± 0.20 °C with relative humidity of 47.75 ± 2.25 percent. As the stage advanced colour changed from orange to pink and entered second instar.

3.1.4.2 2nd instar nymph

The duration of second instar nymph lasted for 8 to 10 days with an average of 9.80 ± 0.50 days for female and 9 to 11 days with an average of 10.44 ± 0.71 days for male at average temperature of 31.1 ± 0.54 °C with relative humidity of 48.47 ± 2.0 percent.

The results of the present study are more or less in agreement with the findings of Sahito *et al.* (2012) [61] and Katke *et al.* (2009) [34-35] the second instar nymph lasted for 8 to 11 days with an average of 7.52 ± 0.90 days for female and 8-13 days for male.

3.1.4.3 3rd instar nymph

The third instar nymph was oval to oblong in shape, orange or pinkish in colour and the whole body was fully covered with whitish cotton waxy powder. The duration of third instar of female nymph lasted for 9 to 11 days with an average of 10.44 ± 0.71 days for female and 8 to 12 days with an average of 10.48 ± 1.80 days for male at average temperature of 32.13 ± 0.17 °C with relative humidity of 48.25 ± 2.3 percent.

The third instar nymph of male was yellowish brown to orange in colour and smaller in size than that of third instar female nymph. Antennae was clearly visible and seven segented.

Two waxy caudal filaments was visible at the end of abdominal segent. At the end of this period third instar male nymph shade the cast and entered in the fourth instar of the nymph. The duration of this instar lasted for 1 to 2 days with an average of 1.5 days, at minimum of 15.63 Cand maximum of 33.76 °C temperature along with relative humidity ranged between 18.50 and 51.58 percent.

According to Shelke *et al.* (2001) [64] the duration of third nymphal instar of female was 7 to 8 days with a mean of 7.3 days while for male it was 1 to 2 days with a mean of 15 days at 33-34 °C, during summer on sprouted potatoes, which is almost in line with the present findings are supported by the results published by Sahito *et al.* (2012) [61].

3.1.3.5 Total nymphal period

The female and male was passed through three nymphal instars. The total nymphal periods of female and male was 21 to 28 and 21 to 31 with an average of 25.08 ± 2.41 and 26.48 ± 2.75 days, respectively at average temperature of 31.53 ± 1.32 °C with relative humidity of 47.5 ± 2.37 percent.

The above finding is more or less similar with Sahito *et al.* (2012) [61] and Katke *et al.* (2009) [34-35] who reported that, the total nymphal period of female was 19 to 23 days with a mean of 22.1 ± 0.95 days while for male it was 17 to 22 days with a mean of 20.4 ± 0.79 on sprouted potato during summer. Likewise according to Shelke (2001) [64] the duration of total nymphal period of female was 18-22 days with a mean of 19.4 days while for male it was 17-23 days with a mean of 19.4 days at 30-35°C, during summer. But the present results are contrary to the findings of Naik *et al.* (2017) [48] who reported that, the duration of total nymphal period of female was 22-28 days with a mean of 26.00 ± 2.05 days while for male it was 20-26 days in winter and summer, respectively.

3.1.3.6 Ovipositional and Pre-ovipositional period

The data revealed that, the pre-ovipositional period varied from 3 to 8 days with an average of 7.08 ± 1.22 days and the ovipositional period ranged from 3 to 12 days with an average of 12.28 ± 2.28 days and the fecundity ranged from 285 to 500 with an average of 400.88 ± 36.71 eggs at an average temperature of 33.91 ± 0.42 °C with relative humidity of 47.54 ± 2.12 percent.

The present investigations are more or less similar with research finding of Shelke *et al.* (2001) [64] who reported that, the pre-oviposition and oviposition period was ranged between 3 to 4 days and 5 to 6 days with a mean of 3.3 days and 5.3 days, respectively on potato sprouts during summer. The female laid eggs in the ovisacs in the ranged of 185 to 410 with mean of 271 per female. Contrary to the present findings Katke *et al.* (2009) [34-35] reported that the total nymphal duration of male in winter and summer was 23.3 ± 1.07 and 21.6 ± 0.89 days, respectively. The slight variation in the nymphal developmental time could be due to the differences in climatic conditions, particularly temperature and relative humidity. These results are more or less similar with findings of the Mani (1986) [43], who reported the average fecundity of 510.52 ± 30.24 and 432.18 ± 21.68 eggs by female of *M. hirsutus* on pumpkin and grapevine, respectively.

3.1.3.7 Pre pupal period and pupal period

The male mealybug had three nymphal instars, besides the prepupal and pupal stages. Mean duration of first, second and third instar nymph was 5.48 ± 0.96 , $6.72 \pm 1.9.80$, 10.44 ± 0.71 , 10.44 ± 0.71 and 10.48 ± 1.80 days, respectively. At the end of third nymphal instar, the male nymph produced puparia over their bodies. The pre pupal period ranged from 2 to 4 days, with a

mean of 2.7 ± 0.81 days; pupal duration ranged from 3 to 5 days, with an average of 5.0 ± 0.71 days. The total developmental period of male nymphs ranged from 21 to 28 days. The longer nymphal duration of males as compared to that of the females was due to additional pre-pupal and pupal stages. The present findings are supported by the results published by Sahito *et al.* (2012) [61]. Contrary to the present findings Katke *et al.* (2009) [34-35] reported that the total nymphal duration of male in winter and summer was 23.3 ± 1.07 and 21.6 ± 0.89 days, respectively. The slight variation in the nymphal developmental time could be due to the differences in climatic conditions, particularly temperature and relative humidity.

3.1.3.8 Longevity of adult

Adult female was larger than male and the body was soft oval and distinctly segmented. The female longevity ranged from 25 to 30 days with an average of $25.24 + 1.69$ while male longevity ranged from 3 to 6 days with an average of $3.92 + 0.81$. Besides head, totally 13 segments were clearly visible which comprised of 3 thoracic and 10 abdominal segments. The head was covered with white mealy secretions. The adults were stationary. Adult male was easily distinguishable from adult female by smaller size and presence of one pair of wings and two caudal filaments on last abdominal segment. Caudal filament was as long as body length. Adult male was orange coloured, minute and very active. Wings were thin transparent and ash coloured.

3.1.3.9 Total life span

The data on the total life span of *M. hirsutus* are revealed that, the development period of the adult female varied from 46 to 49 days with an average mean of $50.32 + 4.10$ days; while, the male development period varied between 31 to 46 days with a mean of $38.05 + 2.70$ days. Similar more or less observation was also reported by Sahito *et al.* (2012) [61]. On the other hand, Katke *et al.* (2009) [34-35], reported that the total life cycle duration for 32.8 ± 1.72 and 45.9 ± 1.92 days for male and female, respectively during winter season on pumpkin. According to the developmental period of the adult female varied from 49 to 58 days, with an average of 53.5 ± 2.01 days; while, the male developmental period varied between 31 to 40 days with a mean of 36.7 ± 2.71 days. Similar observations were also reported by Sahito *et al.* (2012) [61]. On the contrary, Katke *et al.* (2009) [34-35], reported that the total life cycle duration accounted for 32.8 ± 1.72 and 45.9 ± 1.92 days for male and female, respectively during winter season on pumpkin.

3.1.4 Morphometrics measurement of different life stage of *M. hirsutus* on custard apple during 2021- 2022.

The morphometric measurements on egg, nymphal instars, pupae and adults (both male and female) of *M. hirsutus* on custard apple are shown in Table 4. The growth parameters on developmental periods of egg, nymphal instars, pupae, adult (both male and female), pre-oviposition, oviposition, fecundity and post-oviposition period are shown.

3.1.4.1 Egg

The length (mm) and width (mm) of eggs of *M. hirsutus* varied from 0.47 to 0.50 and 0.18 to 0.24 with an average of $0.50 + 0.01$ and $0.21 + 0.03$ mm, respectively.

3.1.4.2 1st Instar nymph

The length (mm) and width (mm) of 1st Instar nymph varied from 0.42 to 0.48 and 0.21 to 0.26 with an average of $0.44 + 0.02$ and $0.25 + 0.02$ mm, respectively.

3.1.4.2 2nd instar nymph

The length (mm) and width (mm) of 2nd Instar nymph varied from 0.68 to 0.84 and 0.29 to 0.32 with an average of $0.76 + 0.06$ and $0.30 + 0.01$ mm, respectively.

3.1.4.3 3rd Instar nymph

The length (mm) and width (mm) of 3rd Instar nymph varied from 1.61 to 1.91 and 0.65 to 0.75 with an average of $1.70 + 0.08$ and $0.70 + 0.04$ mm, respectively.

3.1.4.4 Pupa

The length (mm) and width (mm) of pupae varied from 1.64 to 1.98 and 0.67 to 0.80 with an average of $1.79 + 0.15$ and $0.73 + 0.05$ mm, respectively.

3.1.4.5 Adult

The length (mm) and width (mm) of female adult varied from 3.22 to 3.92 and 1.54 to 1.79 with an average of $3.47 + 0.24$ and $1.55 + 0.09$ mm, respectively. The length (mm) and width (mm) of female adult varied from 0.30 to 0.36 and 0.15 to 0.22 with an average of $1.33 + 0.04$ and $0.20 + 0.02$ mm, respectively.

3.1.5 Studies on biology of mealy bug on custard apple during 2022-2023

The results of present investigation on Studies on seasonal incidence, biology, management of custard apple (*Annona squamosa* L) mealy bug (*Maconellicoccus hirsutus* Green) and its effect on nutritional content of custard apple in Kanker District of Chhattisgarh are presented in this chapter and discussed in the light of the research reported by the earlier workers.

3.1.6 Biology of mealy bug, *M. hirsutus* L

The studies on biology of mealy bug, *M. hirsutus* (Green) was carried out under laboratory conditions at Ramprasad Potai College of Agriculture and Research Station, Kanker, Chhattisgarh during the autumn season in the month of November and December, 2022 and 2023.

3.1.7 In second year of Life stages of mealy bug, *Maconellicoccus hirsutus* (Green) in laboratory condition on custard apple during 2022-23

3.1.7.1 Incubation period of eggs

The adult females of *M. hirsutus* laid eggs in a loose whitish cottony ovisac attached at the anal end of the abdomen. Freshly laid eggs were translucent and yellowish or pale orange in colour. They were elongated and oval in shape. As the incubation period advanced, the translucent eggs became pinkish in colour towards hatching.

The data on incubation period of eggs recorded during second year last week of December 2022-23 presented in Table revealed that, the incubation period ranged from 3 to 7 days with an average of $4.52 + 1.26$ days in case of female and from 3 to 5 days with an average of $4.08 + 0.86$ days in case of male at 29.5 ± 0.32 °C with relative humidity of $47.9 + 1.55$ percent.

The incubation period of 3 to 5 days with an average of days in case of female and 3.8 days in case of male was observed in present investigations in summer was more or less similar to the finding of Katke *et al.* (2009) [34-35] who reported that, the incubation period of *M. hirsutus* was 4.3 to 0.5 days on sprouted potato during summer season. But the present results are contradictory to the findings of Naik *et al.* (2017) [48] as they had reported that, the incubation period of 5.8 ± 1.31 days at mean maximum and minimum temperature was 25.9 and 18.7°C,

respectively on custard apple fruits. The slight variation found may be due to the difference in host and climatic conditions. Jadhav (1993) reported incubation period of 5-7, 4-6 and 3-5 days.

3.1.7.2 Pre-oviposition period, oviposition period and fecundity of *M. hirsutus*

The data presented that, the pre-ovipositional period ranged from 3 to 5 days with an average of 4.0 days and the ovipositional period ranged from 5 to 7 days with an average of 6.0 days with a mean of 4.20 ± 0.86 days and the fecundity ranged from 180 to 382 with an average of 281 eggs with a mean of 264.88 ± 77.08 . The present investigations are more or less similar with research finding of Bhadani *et al.* (2016a) [8] and Katke *et al.* (2009) [34-35]. The preoviposition period ranged from 6 to 7 days with an average of 6.4 ± 0.56 days and the oviposition period of 7 to 9 days with an average of 8.7 ± 0.72 days. The fecundity ranged from 426 to 573 with an average of 543 ± 42.16 eggs respectively on potato sprouts during summer.

3.1.7.3 Hatching percentage

The data on hatching percentage of eggs presented in Table 4 revealed that, the hatching percentage of eggs varied from 70.00 to 87.00 percent with average mean of 77.80 ± 6.33 days

The present investigations are more or less similar with research finding of Bhadani *et al.* (2016a) [8]. The average egg laying capacity of a female was 455.2 ± 38.93 eggs at an average temperature of 24.6°C and relative humidity of 61.8 percent and average hatching percent was 88.44 ± 4 and hatching percent 93.3 with range of 92.6 to 94.3. The slight deviations in hatching percentage from the present investigations may be due to differences in the temperatures and relative humidity that prevailed at different locations. On the contrary Shelke *et al.* (2001) [64] reported that, the mean hatching percentage of *M. hirsutus* was 70.0 percent on sprouted potato during summer season. The slight deviations in hatching percentage from the present investigations may be due to differences in the temperatures and relative humidity that prevailed at different locations.

3.1.7.4 Duration of nymphal stages

1st Instar nymph

Freshly hatched, nymph was yellow to orange in coloured with reddish compound eyes. The antennae was filliform type, six segmented and both the antennae held diagonally in front of the head. The neonate nymph was oval in shape and they was highly mobile with three pairs of legs. During this stage female and male was indistinguishable and the body was not covered with mealy matter.

The duration of first instar nymph for female and 6 to 9 days with an average mean of 6.56 ± 0.96 days for male 6 to 9 days with an average of 6.36 ± 0.90 As the stage advanced colour changed from orange to pink and entered second instar.

According to Bhadani *et al.* (2016a) [8] the duration of first nymphal instar nymph was the duration of the first instar nymph was 7 to 9 days with an average of 8.2 ± 0.72 days for female and 7.92 ± 0.77 for male. However, it was also found to 7 to 9 days with a mean of 8.9 ± 0.31 for female and 8.2 ± 0.36 days for male during winter. The results of the present study are more or less in line with the above reports. On the contrary Katke *et al.* (2009) [34-35] the duration of first nymphal instar nymph was 6-8 days with an average of 7.6 ± 0.67 days for female and 7.3 ± 0.72 days for male on sprouted potatoes 18 during summer season.

Shelke *et al.* (2001) [64] reported that, the duration of first nymphal instar of female was 5-7 days with a mean of 5.7 days while for male it was 6-9 days with a mean of 7.0 days at $30-32^\circ\text{C}$, during summer. The results of the present study are more or less in line with the above report.

3.1.7.5 2nd instar nymph

The second instar nymph was larger than first instar nymph. The body was pinkish in colour with white thin waxy secretions on the body. It observed sluggish and become stationary at suitable spot. The male and female nymph could not be distinguished till the time of ecdysis.

The duration of second instar nymph of female 6 to 7 days with an average mean of 6.60 ± 0.50 days and total development period of male ranged from 5 to 7 days with a mean 5.44 ± 0.50 . The results of the present study are more or less in agreement with the findings of Shelke *et al.* (2001) [64] who reported that, the duration of second nymphal instar of female was 6 to 7 days with a mean of 6.4 days while for male it was 5 to 6 days with a mean of 5.5 days on sprouted potatoes at $32-33^\circ\text{C}$ during summer with the findings of Katke *et al.* (2009) [34-35] the duration of second instar nymph observed 6 to 8 days with a mean of 7.5 ± 0.56 for female and 7.4 ± 0.45 days for male during winter.

3.1.7.6 3rd instar nymph

The third instar nymph was oblong in shape and dark yellow in colour than the earlier instar. White, puffy waxy coating on dorsal surface of the body was observed. The duration of third instar of female nymph lasted for 7 to 10 days with an average of 9.12 ± 1.09 days and male ranged from 8 to 12 days with an average of 9.04 ± 1.05 days. The third instar nymph of male was yellowish brown to orange in colour and smaller in size than that of third instar female nymph. Antennae was clearly visible and seven segment.

Two waxy caudal filaments was visible at the end of abdominal segment. At the end of this period third instar male nymph shed the cast and entered in the fourth instar of the nymph.

According to Balikai *et al.* (2009). The duration of last instar of female nymph lasted for 8 to 10 days with a mean of 8.4 ± 0.67 during winter. Third instar male nymph was recognized by denuding the puparia, with the presence of two small wing buds. This instar lasted for 1 to 2 days with an average of 1.4 ± 0.23 days during winter. Likewise according to Shelke *et al.* (2001) [64] the duration of third nymphal instar of female was 7 to 8 days with a mean of 7.3 days while for male it was 1 to 2 days with a mean of 1.5 days at $33-34^\circ\text{C}$, during summer on sprouted potatoes, which is almost in line with the present findings.

3.1.7.7 Total nymphal period

In second year, females and males was passed through three nymphal instars. The total nymphal periods of female and male was 19 to 28 and 18 to 28 with an average of 25.08 ± 2.41 and 26.48 ± 2.75 days respectively. almost in line with the present findings. The above finding is more or less similar with finding of Katke *et al.* (2009) [34-35] who reported that, the total nymphal period of female was 19 to 23 days with a mean of 22.1 ± 0.95 days while for male it was 17 to 22 days with a mean of 20.4 ± 0.79 on sprouted potato during summer. Likewise according to Shelke (2001) [64] the duration of total nymphal period of female was 18-22 days with a mean of 19.4 days while for male it was 17-23 days with a mean of 19.4 days at $30-35^\circ\text{C}$, during summer. But, the present results are contradictory to the

findings of Naik *et al.* (2017) [48] who reported that, the duration of total nymphal period of female was 22-28 days with a mean of 26.00 ± 2.05 days while for male it was 20-26 days with a mean of 24.7 ± 3.01 days on custard apple fruits with mean maximum and minimum temperature was 25.9 and 18.7°C. The slight variation found may be due to the difference in host and climatic conditions.

3.1.7.8 Pre pupal period and pupal period

At the end of third nymphal instar, the male nymph produced puparia over their bodies. The pre pupal period ranged from 2 to 5 days, with a mean of 3.5 ± 0.81 days; pupal duration ranged from 5 to 7 days, with an average of $6.0 + 0.74$ days. The longer nymphal duration of males as compared to that of the females was due to additional pre-pupal and pupal stages. The present findings are supported by the results published by Sahito *et al.* (2012) [61]. Contrary to the present findings Katke *et al.* (2009) [34-35] reported that the total nymphal duration of male in winter and summer was 23.3 ± 1.07 and 21.6 ± 0.89 days, respectively. The slight variation in the nymphal developmental time could be due to the differences in climatic conditions, particularly temperature and relative humidity.

3.1.7.9 Adult “Description of Body”

An adult female was larger than male and the body was soft oval and distinctly segmented. Besides head, totally 13 segments were clearly visible which comprised of three thoracic and ten abdominal segments. The head was covered with white mealy secretions. The adults were stationary. Adult males were easily distinguishable from adult female by smaller size and presence of one pair of wings and two caudal filaments on last abdominal segment. Wings were thin transparent and ash coloured. A caudal filament was as long as body length. An adult male was orange coloured, minute and very active while, female was wingless.

3.1.7.10 Longevity of adult

An adult female was larger than male and the body was soft oval and distinctly segmented. The female longevity ranged from 12 to 16 days with an average of $14.0 + 0.90$ while male longevity ranged from 3 to 5 days with an average of $4.64 + 0.63$. Besides head, totally 13 segments were clearly visible which comprised of 3 thoracic and 10 abdominal segments. The head was covered with white mealy secretions.

The adult was stationary. An adult male was easily distinguishable from adult female by smaller size and presence of one pair of wings and two caudal filaments on last abdominal segment. A caudal filament was as long as body length. Adult males were orange coloured, minute and very active. Wings were thin transparent and ash coloured. The present findings are supported by the results published by Katke *et al.* (2009) [34-35]. The longevity of adult for female ranged between 13 to 16 days with a mean of 15.6 ± 0.81 days and for male it ranged between 3 to 5 days with a mean of 4.1 ± 0.53 days during winter season. Likewise according to Shelke (2001) [64] reported that, longevity of female was 8-10 days with a mean of 8.70 days and for male it was 2-3 days with a mean of 2.30 days on potato sprouts during summer. The results of the present study of adult longevity are almost in agreement with the reports by Shelke (2001) [64].

3.1.7.11 Total life span

The data on the total life span of *M. hirsutus* are presented in table 4 revealed that, the development period of the adult female

varied from 31 to 42 days with an average mean of $34.0 + 2.19$ days; while, the male development period varied between 28 to 40 days with a mean of $34.10 + 3.18$ days.

Similar more or less observation was also reported by Balikai *et al.* (2009) reported that the average total life span of female was 45.36 ± 1.52 days and average total life span for the male was 32.06 ± 2.17 days recorded at the average laboratory temperature 23.9 °C and average relative humidity 59.9 percent. The total life span of mealy bug accounted 45.9 ± 1.92 and 32.8 ± 1.72 days for female and male, respectively during winter season. The variation in the total life span of the mealy bug reported by the scientist might be due to variation in prevailing rearing weather conditions. On the contrary Shelke *et al.* (2001) [64] reported that, the total life span of female was 29-35 days with a mean of 31.2 days and for male it was 23-28 days with a mean of 25.4 days during summer on sprouted potato. Katke *et al.* (2009) [34-35] reported that, total life span of female was $39.1 + 1.86$ days and for male was $27.2 + 1.62$ days on sprouted potato during summer season. The results of the present study are in agreement with findings reported by Shelke *et al.* (2001) [64] and Katke *et al.* (2009) [34-35].

3.1.8 Morphometrics measurement of different life stage of *M. hirsutus* on custard apple during 2022-2023 (second year)

3.1.8.1 Egg

The length (mm) and width (mm) of eggs of *M. hirsutus* varied from 0.45 to 0.54 and 0.16 to 0.23 with an average of $0.50 + 0.03$ and $0.20 + 0.02$ mm, respectively.

3.1.8.2 First instar nymph

The length (mm) and width (mm) of first instar nymph varied from 0.41 to 0.46 and 0.20 to 0.24 with an average of $0.42 + 0.02$ and $0.22 + 0.01$ mm, respectively.

3.1.8.3 Second instar nymph

The length (mm) and width (mm) of 2nd Instar nymph varied from 0.66 to 0.84 and 0.30 to 0.32 with an average of $0.76 + 0.08$ and $0.31 + 0.01$ mm, respectively. 4.2.4.4 Third instar nymph The length (mm) and width (mm) of third Instar nymph varied from 1.60 to 2.11 and 0.65 to 0.71 with an average of $1.82 + 0.09$ and $0.69 + 0.02$ mm, respectively.

3.1.8.5 Pupa

The length (mm) and width (mm) of pupae varied from 1.64 to 1.96 and 0.67 to 0.80 with an average of $1.79 + 0.14$ and $0.73 + 0.05$ mm, respectively.

3.1.8.6 Adult

The length (mm) and width (mm) of female adult varied from 3.23 to 3.93 and 1.52 to 1.78 with an average of $3.61 + 0.30$ and $1.64 + 0.09$ mm, respectively. The length (mm) and width (mm) of female adult varied from 1.29 to 1.35 and 0.16 to 0.20 with an average of $1.32 + 0.02$ and $0.18 + 0.01$ mm, respectively.

Similar both morphometrics observations were recorded by Katke *et al.* (2009) [34-35] Mani (1986) [43] and Shelke *et al.* (2001) [64]. The Egg length varied from 0.46 - 0.52 mm with a mean $0.50 + 0.04$ mm and width 0.19-0.24 mm with a mean $0.21 - 0.03$ mm and first second and third instar nymph length of 0.43 - 0.47 mm, 0.67 - 0.84 mm, 1.61- 2.13 mm with width range from 0.21 - 0.24 mm, 0.30-0.33 mm, 0.66 - 0.74 mm respectively, and pupa was range from length of 1.62-1.98 mm and width 0.68 - 0.82 mm. Adult (both male and female) length ranged from 1.30 - 1.38 with a width 0.17 - 0.21 respectively.

Table 1: Morphometrics measurement of different life stage of *M. hirsutus* on custard apple (*n=10) during 2021-2022.

SL. No.	Insect Stages	Length (mm)			Width (mm)		
		Range		Mean SD	Range		Mean + SD
1	Egg	0.47	0.50	0.50 + 0.01	0.18	0.24	0.21 + 0.03
Nymph							
2	I	0.42	0.48	0.44 + 0.02	0.21	0.26	0.25 + 0.02
3	II	0.68	0.84	0.76 + 0.06	0.29	0.32	0.30 + 0.01
4	III	1.61	1.91	1.70 + 0.08	0.65	0.75	0.70 + 0.04
5	pupa	1.64	1.98	1.79 + 0.15	0.67	0.80	0.73 + 0.05
Adult							
6	Female	3.22	3.92	3.47 + 0.24	1.54	1.79	1.55 + 0.09
7	Male	0.30	0.36	1.33 + 0.04	0.15	0.22	0.20 + 0.02

Table 2: Life stages of mealy bug, *Maconellicoccus hirsutus* (Green) in laboratory condition. (*n=25) during 2021-2022.

Stage of life cycle	Female (Duration in days)			Male (Duration in days)		
	Min	Max	Mean ± SD	Min	Max	Mean ± SD
Egg						
Incubation	4	8	5.76±1.23	3	7	5.76±1.36
Pre oviposition	3	8	7.08±1.22	-	-	-
Oviposition	3	12	12.28±2.28	-	--	-
Fecundity	285	500	400.88±36.71	-	-	-
Hatching Percent	80	96	89.04±4.92	-	-	-
Nymph						
First	4	7	5.48±0.96	4	8	6.72±1.48
Second	8	10	9.80±0.50	9	10	10.44±0.71
Third	9	11	10.44±0.71	8	12	10.48±1.80
Total	21	28	25.08±2.41	21	31	26.48±2.75
Pre- pupal period	-	-	-	2	4	2.7±0.81
Pupal period	-	-	-	3	5	5.0±0.71
Adult						
Longevity	25	30	25.24±1.69	3	6	3.92±0.81
Total Life span	46	49	50.32±4.10	31	46	38.05±2.70

Table 3: Morphometrics measurement of different life stage of *M. hirsutus* on custard apple (*n=10) during 2022-23.

SL. No.	Insect Stages	Length (mm)			Width (mm)		
		Range		Mean SD	Range		Mean ± SD
1	Egg	0.45	0.54	0.50±0.03	0.16	0.23	0.20±0.02
Nymph							
2	I Instar	0.41	0.46	0.42±0.02	0.20	0.24	0.22±0.01
3	II Instar	0.66	0.84	0.76±0.08	0.30	0.32	0.31±0.01
4	III Instar	1.60	2.11	1.82±0.09	0.65	0.71	0.69±0.02
5	pupa	1.64	1.96	1.79±0.14	0.67	0.8	0.73±0.05
Adult							
6	Female	3.23	3.93	3.61±0.30	1.52	1.78	1.64±0.09
7	Male	1.29	1.35	1.32±0.02	0.16	0.20	0.18±0.01

Table 4: In second year, life stages of mealy bug, *Maconellicoccus hirsutus* (Green) in laboratory condition. (*n=25) during 2022-23.

Stage of life cycle	Female (Duration in days)			Male (Duration in days)		
	Min	Max	Mean ± SD	Min	Max	Mean ± SD
Egg						
Incubation	3	7	4.52±1.26	3	5	4.08±0.86
Pre oviposition	3	5	4.20±0.86	-	-	-
Oviposition	5	7	4.08±0.81	-	--	-
Fecundity	180	382	264.88±77.08	-	-	-
Hatching Percent	70	87	77.80±6.33	-	-	-
Nymph						
First	6	9	6.56±0.96	6	9	6.36±0.90
Second	6	7	6.60±0.50	5	7	5.44±0.50
Third	7	10	9.12±1.09	7	12	9.04±1.05
Total	19	26	25.08±2.41	18	28	26.48±2.75
Pre- pupal period	-	-	-	2	5	3.5±0.81
Pupal period	-	-	-	5	7	6.0±0.74
Adult						
Longevity	12	16	14.0±0.90	3	5	4.64±0.63
Total Life span	31	42	34.00±2.19	28	40	34.10±3.18

4. Conclusion

The study elucidated important biological aspects of the custard apple mealy bug, *M. hirsutus*. Sprouted potatoes proved effective for culturing and studying the lifecycle of this polyphagous pest under laboratory conditions. A single female exhibited high fecundity, laying over 100 eggs during its lifespan. Developmental durations of different instars and overall lifecycle were recorded. Morphometrical analysis showed variations in body size of immature stages and between adult male and female. Such information on biology and basic morphology of *M. hirsutus* gained from this investigation will help in devising appropriate integrated pest management strategies for this globally invasive agricultural threat. Further research focusing on additional hosts, influences of abiotic factors and natural enemies can aid effective control.

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