



ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 6229-6235
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www.thepharmajournal.com

Received: 20-10-2022

Accepted: 22-11-2022

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Biology of mealybug, *Maconellicoccus hirsutus* (Green) infesting grapevine

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Abstract

Studies on the biology of grape mealybug, *Maconellicoccus hirsutus* (Green) was carried out under laboratory conditions on pumpkin during the summer (April, 2018) and winter (October, 2018) season, respectively at MPKV., Rahuri. pre-ovipositional period ranged from 3 to 4 and from 6 to 7 days with an average of 3.40 ± 0.52 days and 6.40 ± 0.52 days and the ovipositional period ranged from 5 to 6 days and 7 to 8 days with an average of 5.30 ± 0.48 days and 7.30 ± 0.48 days, respectively. The hatching percentage of eggs varied from 76.67 to 86.67 and 90.00 to 93.33 percent with an average of 83.33 ± 2.80 and 91.33 ± 1.42 percent during summer and winter, respectively. During summer the fecundity ranged from 337 to 428 with an average of 374 ± 40.2 eggs while during winter it ranged from 352 to 496 with an average of 421 ± 49.7 eggs. During summer season the incubation period was 4.20 ± 0.70 and 3.55 ± 0.76 days, the nymphal period was 23.8 ± 1.15 and 21.5 ± 1.13 days, the adult longevity was 8.80 ± 0.68 and 2.40 ± 0.51 days and the total life span was 36.8 ± 1.52 and 27.5 ± 1.44 days in case of female and male, respectively. The incubation period, nymphal period and the adult longevity for female was 7.05 ± 0.83 , 25.2 ± 1.30 and 14.2 ± 1.57 days and for male 6.40 ± 0.50 , 22.6 ± 1.46 and 4.07 ± 0.80 days and thus accounting 46.5 ± 2.20 and 33.1 ± 1.74 days for total life span of mealy bug, respectively during winter season. The total life cycle of grape mealybug was shorter during summer than winter.

Keywords: Grape mealybug, biology, *Maconellicoccus hirsutus*, fecundity, summer and winter season

Introduction

Grape (*Vitis vinifera* L.) is one of the most important fruit crops of temperate zone, which has acclimatized to Indian Sub-Continent (Mani *et al.* 2014) [13]. In world over it is mainly grown for wine making but in India it is mostly consumed as fresh fruit and only small quantity is utilized for the production of raisins and wine. Grapes have a great demand in foreign markets especially in United Kingdom, Saudi Arabia and UAE and fetching valuable foreign exchange. Grape berries are rich in nutrition a 100 g of green or red grapes contains 104 Kcal of energy, 1.09 g of protein, 0.24 g of fat and 27.33 g of carbohydrate. Skins of red grapes contain resveratrol a polyphenol able to slow or prevent the growth of cancer and leukaemia (Ware, 2017) [24]. A study conducted in the North Carolina State University, USA revealed that, phytonutrients present in grapes were able to successfully block the activity of the main protease (MPro) in the novel coronavirus (TOI, Dec 2020) [23].

Commercial viticulture has made considerable progress in Maharashtra during the past decade. Although insect pest ravages is most serious problem in grape cultivation. All commercial grape varieties are prone to various insects. The major insects infesting grapevine are mealybugs, thrips, mites, flea beetles and stem borers (Yadav and Amala, 2013) [25]. 20 species of mealybugs have been reported infesting grape vine in the world (Babu and Azam, 1987) [5]. According to Azam (1983) [3] mealybug alone caused yield loss ranging from 50 to 100 percent. The pink mealybug, *Maconellicoccus hirsutus* (Green) is the most devastating species in India and it regularly occurred every year (Babu and Azam 1989, Mani *et al.* 2008) [4, 12]. Heavily infested clusters shrivel and become sticky; encourages the growth of black sooty mould fungus (Alleyne, 2004) [1]. Severe mealybug infestation in nurseries often killed young vines. Lower (1968) [11] rightly stated that mealybugs are "hard to kill the pest of fruit trees". More area in Western Maharashtra now shifting under custard apple cultivation which serves as an important host plant for pink mealybug invariably demands to restudy its biology contemporarily with the changing climatic conditions.

Materials and Methods

The biology of the grape mealybug, *M. hirsutus* was studied on red pumpkins under the laboratory conditions at Insect Culture Room, Department of Agricultural Entomology, Biocontrol laboratory, MPKV, Rahuri during the summer and winter season *i.e.* in the April, 2018 and October, 2018, respectively.

Rearing of test insect species

The method standardized by Chacko *et al.* (1978) [6] was followed to study the life history of grape mealybug, *M. hirsutus*. Medium sized semi ripened red pumpkin fruits procured from local market were used for rearing mealybugs within laboratory. The fruits were cleaned with water to get rid of dust and disinfected with 0.1 percent sodium hypochlorite and wiped with cloth. In order to prevent development of moulds and rotting during storage, each fruit was dipped in the bavistin 0.1 percent fungicide suspension for 10-15 seconds and then dried for 4 hours. Treated fruits again washed with water and dried in shade. Wounds, if any on the pumpkins were plugged with wax. The mealybug ovisacs collected from infected grape vineyard were placed on pumpkins kept in specially designed wooden cages (45 x 45 x 45 cm) having the door in the front, and other sides covered with wire mesh. The pure culture was maintained throughout the research period. The observations were recorded on pre-oviposition period, fecundity, incubation period, hatching percentage, duration of nymphal stages, adult longevity, sex ratio and duration of total life cycle.

Observations recorded

Pre-oviposition and oviposition period: Ten gravid female mealybugs were taken from pure culture and kept on each pumpkin with fine camel hair brush to know the pre-oviposition period. The period between the completion of the third instar indicated by the presence of moulted skin and the initiation of the first ovisac was considered as the pre-oviposition period while time taken to complete egg laying considered as oviposition period.

Fecundity: In order to estimate the fecundity randomly selected twenty female crawlers of *M. hirsutus* were released on pumpkins at the rate of two per pumpkin. They were left undisturbed till the formation of ovisacs by the females. The ovisacs from individual females were taken and observed carefully under microscope for the number of eggs present within.

Hatching percentage: Hatching percentage was estimated by transferring five lots of eggs, each containing of freshly laid thirty eggs onto a moist blotting paper kept in petri dishes separately with the help of a camel hair brush. Hatching of crawlers from all the eggs was observed daily and percentage was worked out.

Incubation period: Freshly laid twenty eggs were taken from the culture and placed separately in plastic tubes, the period till they hatched was considered as the incubation period.

Duration of nymphal stages: Mealybugs remain obscure to differentiate in to male and female up to third nymphal instar. Therefore hundred freshly laid eggs were released individually on ten pumpkins. First to third instar nymphal

stages were recorded daily by observing the moulted skin at the end of each instar as suggested by Satpute *et al.* (2011) [17]. After the end of third instar they were observed for the presence of wing buds. If the wing buds found, they were considered as males (Tanwar *et al.* 2007; Katke and Balikai, 2009) [22, 10].

Adult longevity: The daily observations were taken for the adult longevity on individuals developed into male and female from same culture. The duration between the adult emergences till its death was treated as the adult longevity period. The observations on longevity of male and female adults were recorded separately.

Sex ratio Male: Female sex ratio was calculated by counting number of individuals developed in to male and females from the same culture and the duration of total life cycle was worked out. The prevailing temperature and relative humidity during the rearing period were recorded.

Results and Discussion

Pre-oviposition period, oviposition period fecundity and hatching percentage:

The data presented in the Table. 1 indicates that during summer season (April, 2018) pre-ovipositional period ranged from 3 to 4 days with an average of 3.40 ± 0.52 days, ovipositional period ranged from 5 to 6 days with an average of 5.30 ± 0.48 days and the fecundity ranged from 337 to 428 with an average of 374 ± 40.2 eggs per female during this period minimum of 27.5°C and maximum of 31.7°C with an average of $28.9 \pm 1.02^\circ\text{C}$ temperature prevailed with relative humidity range from 23.0 to 41.0 with an average of 31.1 ± 5.34 percent. In winter season (October, 2018) pre-ovipositional period ranged from 6 to 7 days with an average of 6.40 ± 0.52 days and the ovipositional period ranged from 7 to 8 days with an average of 7.30 ± 0.48 days and the fecundity ranged from 352 to 496 with an average of 421 ± 49.7 eggs per female during which minimum of 25.1°C and maximum of 29.0°C with an average of $26.6 \pm 1.11^\circ\text{C}$ temperature prevailed with relative humidity range from 34.5 to 65.0 with an average of 45.4 ± 8.38 percent. The pre-ovipositional period ranged from 3-5, 5-6 and 4-5 days according to (Singh and Ghosh 1970, Ghose 1972 and Mani 1986) [21, 7, 14], respectively. Similarly Katke and Balikai (2009) [10] recorded mealybug; *M. hirsutus* took pre-ovipositional period ranged from (4 to 6 days) and (6 to 7 days), ovipositional period ranged from (6 to 9 days) and (7 to 9 days) and fecundity ranged from (396 to 467 eggs per female) and (426 to 573 eggs per female) when reared on pumpkin during summer and winter season, respectively. Pre-ovipositional period of 3 to 4 days and ovipositional period of 5 to 6 days and fecundity ranged from 179 to 387 eggs during summer on custard apple reported by Karanjekar (2019) [9].

The data on hatching percentage of eggs presented in the Table. 1 revealed that during the summer season (April, 2018) the hatching percentage of eggs varied from 76.67 to 86.67 percent with an average of 83.33 ± 2.80 percent eggs, during which minimum of 28.0°C and maximum of 31.7°C with an average of $29.5 \pm 1.37^\circ\text{C}$ temperature prevailed with relative humidity range from 31.00 to 41.0 with an average of 35.0 ± 3.72 percent. During winter season (October, 2018) hatching percentage of eggs was varied from 90.00 to 93.33 percent with an average of 91.33 ± 1.42 percent eggs, during which minimum of 25.0°C and maximum of 27.2°C with an

average of 26.2 ± 0.63 °C temperature prevailed with relative humidity range from 33.0 to 44.5 with an average of 39.2 ± 3.98 percent. Present findings with close agreement of Shelke (2001) ^[19] who reported hatching percentage varied from 80 to 83.33 percent with an average of 82.67 percent, Serrano and Lapointe (2002) ^[18] 91.2 ± 8.0 percent and Katke and Balikai (2009) ^[10] 85.4 to 87.2 and 92.6 to 94.3 percent and during summer and winter season, respectively. The hatching percentage of eggs varied from 70.00 to 83.33 percent with an average of 76.67 percent at average temperature of $29.5 + 0.32$ °C with relative humidity of 47.9 ± 1.55 percent reported by Karanjekar (2019) ^[9] at Rahuri during summer the slight deviations observed in hatching percentage from the present findings may be due to differences in the temperatures and relative humidity during observation period.

Incubation period: Initially the freshly laid eggs were appeared translucent and yellowish or light orange in colour. They were elongated and oval in shape. As the time lapsed translucent eggs became pinkish in colour towards hatching during both the seasons. It could be seen from the data presented in Table 2 that, the incubation period varied from 3 to 5 days for female and 5 to 6 days for male in summer season (April, 2018) with an average of 4.20 ± 0.70 and 3.55 ± 0.76 days, respectively. During this observation period minimum of 28.0 °C and maximum of 31.7 °C with an average of 29.5 ± 1.37 °C temperature and relative humidity range from 31.00 to 41.0 with an average of 35.0 ± 3.72 percent were recorded, respectively. During the winter season (October, 2018) incubation period varied from 6 to 8 days for female and 6 to 7 days for male with an average of 7.05 ± 0.83 and 6.40 ± 0.50 days, respectively. During same period minimum of 25.0 °C and maximum of 27.2 °C with an average of 26.2 ± 0.63 °C temperature and relative humidity range from 33.0 to 44.5 with an average of 39.2 ± 3.98 percent were recorded, respectively.

Present findings are in agreement with Mani (1986) ^[14] and Babu and Azam (1987) ^[5] who reported that, average incubation period was 5.15 ± 0.59 days at temperature of 24-28 °C and 10.9 days at 25 °C and 5.1 days at 31 °C for grape mealy bug on pumpkin, respectively. Jadhav (1993) ^[8] reported incubation period of 5-7, 4-6 and 3-5 days with mean of 6.10, 4.70 and 3.93 days at 21.5, 25.0 and 30.0 °C, respectively on sprouted potato. According to Katke and Balikai (2009) ^[10] the incubation period on pumpkin varied from 5 to 7 days for mealybug, *M. hirsutus* in winter with an average of 5.5 ± 0.48 days. The above reports support the findings of present investigation.

Duration of nymphal stages: The data on duration of different nymphal instars of *M. hirsutus* observed during summer season (April, 2018) and winter (October, 2018) is presented in Table 3.

Ist instar nymph

Freshly hatched nymphs were usually yellow to orange coloured; they possessed reddish colour compound eyes. The six segmented filiform antennae were held diagonally in front of the head. Neonate nymphs were oval in shape, dorsoventrally flattened and highly mobile. In this stage males and females were undistinguishable. During the summer season the duration of first instar nymph lasted for 7 to 9 days

with an average of 8.10 ± 0.77 days for female and 7.92 ± 0.76 days for male when minimum and maximum temperatures were 29.0 and 32.1 °C with an average of 30.4 ± 1.15 °C temperature prevailed with relative humidity range from 19.0 to 43.0 with an average of 28.7 ± 9.31 percent. During winter season the duration of first instar nymph lasted for 7 to 9 days with an average of 8.06 ± 8.80 days for female and 8.14 ± 0.78 days for male when minimum and maximum temperatures were 22.2 and 27.2 °C with an average of 24.2 ± 1.55 °C temperature prevailed with relative humidity range from 33.0 to 47.5 with an average of 40.1 ± 5.78 percent. According to Mani (1986) ^[14] duration of first instar female nymph of *M. hirsutus* was 6.71 ± 0.47 days on pumpkin. Jadhav (1993) ^[8] shown that, the duration of first nymphal instar of female was 8-13, 7-11 and 6-9 days with a mean of 9.76, 8.72 and 7.50 while for male it was 0, 7-10 and 7-9 days with a mean of 0, 8.14 and 7.38 under 21.5, 25.0 and 30.0 °C, respectively. Shelke (2001) ^[19] reported that, the duration of first nymphal instar of female was 8-11 and 5-7 days with a mean of 9.1 and 5.7 days while for male it was 8-10 and 6-9 days with a mean of 8.6 and 7.0 days at 21-23 and 30-32 °C, during winter and summer respectively. Results of the present study are in line with the above reports.

IInd instar nymph

The second instar nymphs were slightly larger than first instar nymphs. The body was pinkish in colour with white thin waxy secretions on the body. It was sluggish and become stationary on suitable feeding spot. The male and female nymphs could not be distinguished till the time of ecdysis. It became faint pink before moulting and shaded whitish exuviae. During the summer season the duration of second instar nymph lasted for 6 to 8 days with a mean of 7.25 ± 0.69 for female and 7.22 ± 0.68 days for male when minimum and maximum temperatures were 28.6 and 32.3 °C with an average of 30.0 ± 1.35 °C temperature prevailed with relative humidity range from 17.0 to 32.5 with an average of 21.8 ± 5.06 percent. During the winter season the duration of second instar nymph lasted for 6 to 8 days with a mean of 7.20 ± 0.70 for female and 7.06 ± 0.79 days for male when minimum and maximum temperatures were 23.0 and 27.8 °C with an average of 24.4 ± 1.60 °C temperature prevailed with relative humidity ranged from 37.0 to 64.0 with an average of 53.4 ± 9.62 percent. Shelke (2001) ^[19] reported that, the duration of second nymphal instar of female was 7-8 and 6-7 days with a mean of 7.4 and 6.4 days while for male it was 6-8 and 5-6 days with a mean of 6.5 and 5.5 days at 22-23 and 32-33 °C, during winter and summer, respectively. Similar findings proposed by Katke and Balikai (2009) ^[10] on second instar nymphs on pumpkin during summer season it was lasted for 6 to 8 days with a mean of 7.3 ± 0.51 days for female and 7.2 ± 0.72 days for male, respectively while during winter season it took 6 to 8 days with a mean of 7.5 ± 0.56 for female and 7.4 ± 0.45 days for male, respectively.

IIIrd instar nymph

The third instar female nymphs were oval to oblong in shape, orange or pinkish in colour and the whole body was fully covered with white mealy wax. During the summer season the duration of third instar lasted for 8 to 9 days with an average of 8.42 ± 0.50 days, when minimum and maximum temperatures were 30.2 and 32.9 °C with an average of 31.0 ± 0.85 °C temperature prevailed with relative humidity

range from 22.0 to 33.0 with an average of 27.3 ± 3.34 percent. During the winter season the duration of third instar females lasted for 9 to 11 days with an average of 9.94 ± 0.75 days, when minimum and maximum temperatures were 22.3 and 25.2 °C with an average of 23.3 ± 1.02 °C temperature prevailed with relative humidity range from 29.0 to 45.5 with an average of 36.1 ± 5.30 percent.

The third instar male nymphs were slender and smaller in size than that of third instar female nymph. Its colour was yellowish brown to orange. Seven segmented antennae on head and two waxy caudal filaments at the end of abdominal segment were visible; at the end of this instar male nymph shade the cast and entered in the fourth instar. During summer season duration of third instar male nymphs lasted for 1 day with an average of 1.00 ± 0.00 day, when minimum and maximum temperatures were 30.2 and 32.9 °C with an average of 31.0 ± 0.85 °C temperature prevailed with relative humidity range from 22.0 to 33.0 with an average of 27.3 ± 3.34 percent. During the winter season the duration of third instar male nymphs lasted for 1 to 2 days with an average of 1.40 ± 0.49 days, when minimum and maximum temperatures were 22.3 and 25.2 °C with an average of 23.3 ± 1.02 °C temperature prevailed with relative humidity range from 29.0 to 45.5 with an average of 36.1 ± 5.30 percent. The present findings are almost in line with Mani (1986) [14] who reported that, the duration lasted for the third instar female and male nymphs was 7.90 ± 0.79 and 1.00 ± 0.00 days, respectively. Shelke (2001) [19] reported that, the duration of third nymphal instar of female was 7-8 and 8-9 days with a mean of 7.3 and 8.4 days while for male it was 1-2 and 2-3 days with a mean of 1.5 and 2.3 days at 33-34 °C and 23-24 °C during summer and winter season respectively.

IVth instar nymph (male)

The fourth instar male nymphs were formed the flimsy white cottony cocoon around the body and lived inside. If the cocoon torned open, a nymph with well developed wing pads were visible and it almost looked like its adult. During summer season fourth instar male nymphs duration was lasted for 5 to 6 days with an average of 5.37 ± 0.49 days, when minimum and maximum temperatures were 30.2 and 32.9 °C with an average of 31.2 ± 1.00 °C temperature prevailed with relative humidity range from 25.5.0 to 33.0 with an average of 28.9 ± 2.67 percent. During the winter season fourth instar male nymphs duration was lasted for 5 to 7 days with an average of 6.05 ± 0.82 days, when minimum and maximum temperatures were 22.3 and 25.2 °C with an average of 23.3 ± 1.10 °C temperature prevailed with relative humidity range from 29.0 to 45.0 with an average of 37.9 ± 6.15 percent. According to Shelke (2001) [19] fourth nymphal instar of male lasted for duration of 5-6 and 5-7 days with a mean of 5.6 and 5.4 days at 33-34 and 23-24 °C, during summer and winter respectively. Katke and Balikai (2009) [10] reported that, during the summer season the duration of fourth instar males lasted for 5 to 6 days with a mean of 5.6 ± 0.73 days. Whereas, during winter season fourth instar males lasted for 5 to 7 days with a mean of 6.3 ± 0.54 days on pumpkin. The above findings of various researchers are almost in accordance with the present investigations.

Total nymphal period

During summer season the total nymphal periods of female and male were 21 to 26 and 19 to 24 days with an average of

23.8 ± 1.15 and 21.5 ± 1.13 days, respectively. During this period minimum and maximum temperatures were 28.6 and 32.9 °C with an average of 30.5 ± 1.17 °C temperature prevailed with relative humidity range from 17.0 to 43.0 with an average of 26.6 ± 6.95 percent. During the winter season the total nymphal period of female and male were 22 to 28 and 19 to 26 days with an average of 25.2 ± 1.30 and 22.6 ± 1.46 days, respectively. During this period minimum and maximum temperatures were 22.2 and 27.8 °C with an average of 23.9 ± 1.41 °C temperature prevailed with relative humidity range from 29.0 to 64.0 with an average of 42.4 ± 9.84 percent. The results of the present study corroborate with the Katke and Balikai (2009) [10] reported that, the total nymphal periods of female and male were 21-26 and 19-24 with an average of 23.6 ± 1.02 and 21.6 ± 0.89 days, respectively when reared on pumpkin during summer season. Whereas, during winter season it was 21-27 and 19-26 with an average of 24.8 ± 1.17 and 23.3 ± 1.07 days for female and male, respectively. Similarly Shinde (2012) [20] reported that, the total nymphal periods of female and male were ranged between 21-25 and 19-23 days with an average of 22.42 ± 1.12 and 20.86 ± 0.76 days, respectively. Angu (2015) [2] observed that, female grapevine mealybug reared on pumpkin took a total nymphal period of 20 to 29 days with an average of 25.7 ± 1.19 during, February and March. Naik *et al.* (2017) [15] recorded total nymphal period of female on custard apple 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.

Adult longevity: Unlike other insects there were no physical resemblance was observed in adult male and female individuals of mealybug. Females were larger than males and the body was soft oval and distinctly segmented. Besides head, totally 13 segments were easily visible which comprised of 3 thoracic and 10 abdominal segments. The head was covered with white mealy secretions. The adult females were stationary. On the other hand adult males were readily distinguishable from adult female by smaller size, fragile body and presence of one pair of opaque wings and two caudal filaments on last abdominal segment. Adult males were orange coloured, minute and very active. It could be seen from the data presented in Table 2 that, the longevity period in summer season varied from 8 to 10 days for female with an average of 8.80 ± 0.68 days, when minimum of 30.6 °C and maximum of 34.1 °C with an average of 32.3 ± 1.29 °C temperature and relative humidity range from 22.00 to 33.0 with an average of 26.5 ± 3.77 percent. For the males longevity period recorded was ranged between 2 to 3 days with an average of 2.40 ± 0.51 days, when minimum of 30.6 °C and maximum of 32.9 °C with an average of 31.4 ± 1.33 °C temperature and relative humidity range from 24.5 to 29.0 with an average of 26.5 ± 2.29 percent. During winter season longevity period varied from 12 to 16 days for female with an average of 14.2 ± 1.57 days, when minimum of 20.1 °C and maximum of 27.2 °C with an average of 22.4 ± 2.05 °C temperature and relative humidity range from 26.0 to 65.0 with an average of 47.5 ± 10.49 percent. For the males longevity period recorded was ranged between 3 to 5 days with an average of 4.07 ± 0.80 days, when minimum of 22.3 °C and maximum of 24.3 °C with an average of 23.1 ± 1.06 °C temperature and relative humidity range from 32.0 to 59.0 with an average of 38.9 ± 11.39 percent. Shelke (2001) [19] reported that, during summer season female mealybug adult

survived for 8 to 10 days with the average of 8.7 days at 34.88 ± 0.58 °C and $45.9 \pm 1.88\%$ R.H. while in winter it was survived for 17 to 20 days with the average of 18 days at 24.47 ± 0.52 °C and $51.17 \pm 3.92\%$ R.H. Similarly, adult male survived for and 2 to 3 days with the averages of 2.3 days at 34.88 ± 0.58 °C with R.H. of $45.9 \pm 1.88\%$ and 4 to 5 days with the averages of 4.4 at 24.47 ± 0.52 °C with R.H. of $51.17 \pm 3.92\%$ during Summer and Winter season, respectively. Karanjekar (2019) ^[9] reported that, the longevity of adult female ranged between 8 to 10 days with a mean of 8.9 days and for adult male, it was ranged between 2 to 3 days with a mean of 2.6 days at average temperature of 33.91 ± 0.42 °C with relative humidity of 47.54 ± 2.12 percent. The results of the present study of adult longevity are almost in agreement with the above reports. Perhaps slight variation may be due to the difference in climatic condition.

Sex ratio: It could be seen from the data presented in Table 2 that in summer season the male (77 individuals) to female (23 individuals) ratio was 3.35:1, when minimum of 30.6 °C and maximum of 34.1 °C with an average of 32.3 ± 1.29 °C temperature and relative humidity range from 22.0 to 33.0 with an average of 26.5 ± 3.77 percent. During winter season the male (26 individuals) to female (74 individuals) ratio was 1:2.85, when minimum of 20.1 °C and maximum of 27.2 °C with an average of 22.4 ± 2.05 °C temperature and relative humidity range from 26.0 to 65.0 with an average of 47.5 ± 10.49 percent. The sex ratio found was found to be at most reversed during the winter which in turn resulted in the production of more female mealybugs which primarily entailed the damage. The present findings in corroboration with the findings of Shelke (2001) ^[19] who reported that, male to female sex ratio was 4 : 1 at 34.88 ± 0.58 °C with R.H. of $45.9 \pm 1.88\%$ and 1 : 3 at 24.47 ± 0.52 °C with R.H. $51.17 \pm 3.92\%$ during summer and winter season, respectively. Shinde (2012) ^[20] reported that, on pumpkin the male to female sex ratio of grape mealy bug, *M. hirsutus* was 1:3.17. Further, Karanjekar (2019) ^[9] also observed that the male to female ratio was 4 : 1 at an average temperature of 33.91 ± 0.42 °C with relative humidity of 47.54 ± 2.12 percent.

Total life span: The data on the total life span of *M. hirsutus* are presented in Table 2. During summer season the incubation period, nymphal period and adult longevity of

female were 4.20 ± 0.70 , 23.8 ± 1.16 and 8.80 ± 0.68 days, respectively and thus accounting 36.8 ± 1.52 days with an average of 32-41 days for total life span, when minimum of 31.8 °C and maximum of 34.1 °C with an average of 30.8 ± 1.53 °C temperature and relative humidity range from 27.5 to 43.0 with an average of 27.4 ± 6.27 percent. Whereas, the incubation period, nymphal period and adult longevity of male were 3.55 ± 0.76 , 21.5 ± 1.11 and 2.40 ± 0.51 days, respectively and thus accounting 27.5 ± 1.44 days with an average of 24-32 days for total life span, when minimum of 28.0 °C and maximum of 32.9 °C with an average of 30.3 ± 1.24 °C temperature and relative humidity range from 17.0 to 43.0 with an average of 27.6 ± 6.90 percent. During winter season the incubation period, nymphal period and adult longevity of female were 7.05 ± 0.83 , 25.2 ± 1.30 and 14.2 ± 1.57 days, respectively and thus accounting 46.5 ± 2.20 days with an average of 40-52 days for total life span, when minimum of 20.1 °C and maximum of 27.8 °C with an average of 23.8 ± 2.03 °C temperature and relative humidity range from 26.0 to 65.0 with an average of 44.0 ± 9.78 percent. Whereas, the incubation period, nymphal period and adult longevity of male were 6.40 ± 0.50 , 22.6 ± 1.46 and 4.07 ± 0.80 days, respectively and thus accounting 33.1 ± 1.74 days with an average of 28-38 days for total life span, when minimum of 22.2 °C and maximum of 27.8 °C with an average of 24.4 ± 1.63 °C temperature and relative humidity range from 29.0 to 64.0 with an average of 42.5 ± 9.44 percent. Shelke (2001) ^[19] reported that, total life span of female was 29-35 and 45-54 days with a mean of 31.2 and 49.7 days and for male it was 23-28 and 31-37 days with a mean of 25.4 and 33.9 days during summer and winter, respectively on pumpkin. Angu (2015) ^[2] recorded that total lifespan of female mealybugs reared on pumpkin during the month of February and March was 41.7 ± 3.12 days. Katke and Balikai (2009) ^[10] reported that, during summer season on pumpkin the total life span in case of female took 42.5 ± 1.54 and 29.0 ± 1.23 days for male, respectively while the total life span of female and male occupied 45.9 ± 1.92 and 32.8 ± 1.72 days, respectively when reared on pumpkin during winter season. Sahito *et al.* (2012) ^[16] noticed that mealybug, *M. hirsutus*, males completed its life cycle in 32-35 days, while females took 41-52 days at 25 ± 2 °C, under laboratory condition. Present outcomes are in almost close agreement with findings reported by the above workers.

Table 1: Pre-oviposition period, oviposition period, fecundity and hatching percentage of grape mealybug, *M. hirsutus* in Summer (April, 2018) and Winter (October, 2018).

Season	Pre-oviposition period (days)		Oviposition Period (days)		Fecundity (eggs/female)		Temperature (°C)		Relative Humidity (%)		Hatching (Percentage)		Temperature (°C)		Relative Humidity (%)	
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Avg.	Range	Avg.	Range	Mean±SD	Range	Avg.	Range	Avg.
Summer (Apr, 2018)	3-4	3.40±0.52	5-6	5.30±0.48	337-428	374±40.2	27.5-31.7	28.9±1.02	23.0-41.0	31.1±5.34	76.67-86.67	83.33±2.80	28.0-31.7	29.5±1.37	31.0-41.0	35.0±3.72
Winter (Oct, 2018)	6-7	6.40±0.52	7-8	7.30±0.48	352-496	421±49.7	25.1-29.0	26.6±1.11	34.5-65.0	45.4±8.38	90.00-93.33	91.33±1.42	25.0-27.2	26.2±0.63	33.0-44.5	39.2±3.98

Table 2: Incubation period, nymphal period, adult longevity, total life span and sex ratio of grape mealybug, *M. hirsutus* in Summer (April, 2018) and Winter (October, 2018).

Period	Sex	Incubation period (days)		Nymphal period (days)		Adult longevity (days)		Total Life span (days)		No. of individuals produced	Sex ratio	Temperature (°C)		Relative Humidity (%)	
		Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD			Range	Avg.	Range	Avg.
Summer (Apr, 2018)	Female	3-5	4.20±0.70	21-26	23.8±1.16	8-10	8.80±0.68	32-41	36.8±1.52	23	3.35:1	31.8-34.1	30.8±1.53	27.5-43.0	27.4±6.27
	Male	3-5	3.55±0.76	19-24	21.5±1.11	2-3	2.40±0.51	24-32	27.5±1.44			77	28.0-32.9	30.3±1.24	17.0-43.0
Winter (Oct, 2018)	Female	6-8	7.05±0.83	22-28	25.2±1.30	12-16	14.2±1.57	40-52	46.5±2.20	74	1:2.85	20.1-27.8	23.8±2.03	26.0-65.0	44.0±9.78
	Male	6-7	6.40±0.50	19-26	22.6±1.46	3-5	4.07±0.80	28-38	33.1±1.74			26	22.2-27.8	24.4±1.63	29.0-64.0

Table 3: Duration of nymphal stages of grape mealybug, *M. hirsutus* in Summer (April, 2018) and Winter (October, 2018).

Summer (Apr, 2018)								
Instar	Nymphal period (days)				Temperature (°C)		Relative Humidity (%)	
	Female		Male		Range	Avg.	Range	Avg.
	Range	Mean±SD	Range	Mean±SD				
I	7-9	8.10±0.77	7-9	7.92±0.76	29.0-32.1	30.4±1.15	19.0-43.0	28.7±9.31
II	6-8	7.25±0.69	6-8	7.22±0.68	28.6-32.3	30.0±1.35	17.0-32.5	21.8±5.06
III	8-9	8.42±0.50	1	1.00±0.00	30.2-32.9	31.0±0.85	22.0-33.0	27.3±3.34
IV	-	-	5-6	5.37±0.49	30.2-32.9	31.2±1.00	25.5-33.0	28.9±2.67
Total	21-26	23.8±1.15	19-24	21.5±1.13	28.6-32.9	30.5±1.17	17.0-43.0	26.6±6.95
Winter (Oct, 2018)								
Instar	Nymphal period (days)				Temperature (°C)		Relative Humidity (%)	
	Female		Male		Range	Avg.	Range	Avg.
	Range	Mean±SD	Range	Mean±SD				
I	7-9	8.06±0.80	7-9	8.14±0.78	22.2-27.2	24.2±1.55	33.0-47.5	40.1±5.78
II	6-8	7.20±0.70	6-8	7.06±0.79	23.0-27.8	24.4±1.60	37.0-64.0	53.4±9.62
III	9-11	9.94±0.75	1-2	1.40±0.49	22.3-25.2	23.3±1.02	29.0-45.5	36.4±5.30
IV	-	-	5-7	6.05±0.82	22.3-25.2	23.3±1.10	29.0-45.5	37.9±6.15
Total	22-28	25.2±1.30	19-26	22.6±1.46	22.2-27.8	23.9±1.41	29.0-64.0	42.4±9.84

Conclusion

Laboratory studies on biology of mealybug, *M. hirsutus* carried out during summer season (April, 2018) and winter season (October, 2018) revealed that the pre oviposition and oviposition periods were shorter by almost 3 and 2 days in both female and male, respectively during summer compared to winter season. The fecundity and hatching percentage were also less by 56 eggs per female and 6.62 percent, respectively during summer season. Similarly the total life span was shorter by an average of 8-10 days and 4-6 days in case of female and male respectively during summer compared to winter season. Thus, the total life cycle of grape mealybug took fewer days during summer than winter season. This might be one of the reason for more damage by mealybugs at harvesting stage which might coincides with late winter/early summer when temperature gradually rising.

Acknowledgments

The authors are dully acknowledging the Chhatrapati Shahu Maharaj Research, Training and Human Development Institute (SARTHI), Pune, for awarding the national level fellowship "CMSRF-2019" for pursuing Ph.D. in Entomology and Head, Department of Entomology, Mahatma Phule Krishi Vidyapeeth, Rahuri, District-Ahmednagar, Maharashtra, India for provided necessary facility during the investigation.

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