LGJDX ISSN No: 1008-0562 Journal Of Liaoning Technical University Natural Science Edition

# INSIGHTS INTO THE LABORATORY-BASED STUDY ON THE BIOLOGY AND HOST PREFERENCE OF *PHENACOCCUS SOLENOPSIS*, THE COTTON MEALYBUG

**Authors: Muhammad Salman[1]*, Muhammad Javed[2], Inamullah Khan[1] and Muhammad Hamayoon Khan[1]**

[1]Plant Protection Division, Nuclear Institute for Food and Agriculture (NIFA), Peshawar, Pakistan

[2]Department of Plant Protection, The University of Agriculture Peshawar, Pakistan

***Correspondence**: Muhammad Salman

**Abstract:**

Cotton mealybugs (*Phenacoccus solenopsis* Tinsley) are widespread pests, causing extensive infestation across diverse plant species worldwide. Our research aimed to unravel their host preferences, developmental stages, and reproductive behaviors on different host plants. Through no-choice and free-choice tests, assessing host preferences, and a detailed examination of instar stage durations, adult stage durations, and total crawler production per female across distinct hosts, we gained valuable insights. Employing a completely randomized design with three replications, our investigation unveiled okra as the preferred host, drawing the highest number of mealybug crawlers (126.3). Subsequently, bottle gourd (35.2), potato (17.7), and apple gourd (12.8) followed in descending order of attractiveness in the free-choice test. Similarly, the no-choice test confirmed okra's dominance as the preferred host over different exposure times. Examining instar stage durations, okra displayed longer durations for the third instar stage (10.12 to 12.67 days). Furthermore, okra exhibited the highest reproductive output, producing the most crawlers per female (195.4), highlighting its suitability for mealybug reproduction. In contrast, bottle gourd demonstrated the lowest reproductive output among the hosts (48.04). These results emphasize host-specific variations in cotton mealybug behavior and reproductive success, with okra emerging as the most attractive and conducive host, while other hosts exhibited varying degrees of suitability.

**Key Words:** Host preference assays, Okra susceptibility, Crawler production.

## INTRODUCTION

The cotton mealybug, *Phenacoccus solenopsis*, represents a significant threat to global cotton production due to its invasive nature, rapid multiplication, and destructive feeding habits. This polyphagous pest, a member of the Pseudococcidae family, poses a severe challenge to agricultural sectors worldwide. Reports of its impact on cotton crops in India and Pakistan between 2005 and 2009 resulted in yield reductions of up to 30-60% (Fand & Suroshe, 2015). As an invasive species, its presence has gained recognition globally, causing substantial economic repercussions and hindrances in the global cotton industry.

The cotton mealybug, characterized by its cottony appearance and piercing/sucking mouthparts, belongs to the Hemiptera order. Its ability to extract essential nutrients from various plants, including cotton, vegetables, ornamental flora, and fruits, poses a significant threat to agriculture. This pest's capacity for rapid proliferation, development of insecticide resistance, and the ability to cause substantial damage by depleting plant sap highlight the urgency for effective management strategies (Joshi et al., 2010; Rezk et al., 2019).

The origin of *P. solenopsis* traces back to North America, specifically New Mexico, USA, in the late 19$^{th}$ century (Tinsley, 1898). Despite the presumption that it originated in Asia, little was known about the bionomics of the cotton mealybug since it was first recorded in Pakistan and India in 2005. However, the cotton mealybug is native to the USA, and it has now spread to over 43 countries (Waqas et al., 2021). Since then, its distribution has extended to several countries, including China, Bangladesh, Thailand, Indonesia, the United States, Brazil, Egypt, and South Africa (Gullan & Martin, 2003).

The impact of this pest on cotton cultivation has been extensively documented. Notably, it causes a reduction in agricultural output by extracting plant fluids, leading to symptoms such as chlorosis, stunted growth, leaf curling, delayed boll opening, and significant yield losses estimated as high as 50% (Joshi et al., 2010). Additionally, the secretion of honeydew by these pests encourages the growth of sooty mold, further exacerbating plant health (Steven and James, 2010).

Economic losses due to cotton mealybug infestations have been reported globally, with substantial crop losses observed in India, Kenya, Pakistan, and other regions (Halder et al., 2020; Kansiime et al., 2020; Sahito et al., 2022). The pest has achieved a status of serious threat in Pakistan (Abbas,

Arif & Saeed, 2005). The economic repercussions extend beyond reduced yields, impacting revenue, production costs, and the competitive advantage of affected regions in the global cotton industry (Luis and Craig, 1988; Tong et al., 2019).

Understanding the life cycle, host preferences, and ecological behavior of *P. solenopsis* is imperative for devising effective control measures. Various factors influence its physiological characteristics and life cycle, necessitating an integrated pest management approach encompassing cultural, biological, and chemical control methods (Vennila et al., 2010). Comprehensive research into the biology and developmental patterns of cotton mealybugs is pivotal to mitigating their detrimental effects on cotton cultivation.

This study aims to explore the biology, developmental stages and host preferences of *P. solenopsis* under controlled laboratory conditions. By elucidating these aspects, the research endeavors to offer pivotal insights essential for laboratory rearing practices. Additionally, the findings aim to significantly contribute to the advancement of integrated pest management strategies against cotton mealybug.

## MATERIALS AND METHODS

**Study Site and Insect Collection:** The study was conducted at the Plant Protection Division of the Nuclear Institute for Food and Agriculture (NIFA) in Peshawar, Pakistan. Mealybugs in various developmental stages were collected from diverse host plants within NIFA and the University of Agriculture Peshawar. Infested plant twigs were gathered using scissors and plant cutters, stored in perforated containers, and transported to the laboratory for further analysis.

**Insect Rearing:** Adult cotton mealybugs were housed in circular glass petri dishes (9cm diameter) within rearing cages (30x30x30cm), provided with fresh sprouted potato as a food source. First instar nymphs (crawlers) hatched from adult females were placed in separate plastic vials (1.5x0.5cm) with 90-mesh sieve-equipped lids. Vials were humidified with moistened cotton and maintained at a temperature of 25°C and 70 ± 5% RH, with regular monitoring and adjustments.

**Host Preference of Cotton Mealybug for Various Hosts:** Host preference experiments comprised free choice and no-choice tests using four different fruits (okra, potato, apple gourd and bottle gourd). A completely randomized design with three replications ensured the robustness of results.

**Host Selection:** Four vegetable hosts were selected based on their relevance to the mealybug's natural habitat and local availability.

**No-Choice Test:**

Individual cages (30x30x30 cm) were specifically allocated for each fruit type, accommodating 50 mealybugs per cage and presenting only one fruit option. This setup restricted mealybugs to interact with a single fruit, enabling the study of their preference behavior when presented with limited host choices.

**Free Choice Test:**

Rearing cages (60x60x60cm) housed 200 crawlers and provided access to all four fruits (okra, potato, apple gourd and bottle gourd). Mealybugs had the freedom to move and choose among these fruits, simulating a natural environment to observe their preferences. Both tests were replicated thrice to investigate cotton mealybugs' host preference under varied conditions of host availability.

i. **Preference Measurement:** Mealybug preference was observed by monitoring their movement and distribution on fruit surfaces at 24, 48, and 72-hour intervals.
ii. **Investigation of Cotton Mealybug Biology:** This investigation aimed to understand the developmental stages and reproductive characteristics of *P. solenopsis* under controlled laboratory conditions.
iii. **Nymphal and Adult Stage Observations:** Daily observations were conducted to record nymphal instar durations, morphological characteristics, and adult lifespan.
iv. **Fertility & Fecundity Assessment:** The reproductive capacity of adult mealybugs was evaluated by recording the number of crawlers produced per female during the reproductive period.

**Data Analysis:** Collected data from both tests underwent statistical analysis using statistical package (Statistix 8.1). Analysis of variance (ANOVA) and LSD tests at a 5% significance level were employed to compare means.

LGJDX ISSN No: 1008-0562 Journal Of Liaoning Technical University Natural Science Edition

## RESULTS

### Host Preference of Cotton Mealybug for Various Hosts:

### No-Choice Test

Four host foods (potato, okra, bottle gourd and apple gourd) were tested to find out the best suitable and attractive host food for laboratory rearing. The results on the attraction of mealybug by various host foods are presented in figure 1. The data indicated significant differences among the different hosts tested. It was evident from the data that maximum mean number of mealybug crawlers were recorded on okra (47.4) followed by bottle gourd (32), whereas, minimum number of mealybug crawlers (5.2 and 2.2) were recorded on potato and apple gourd respectively.

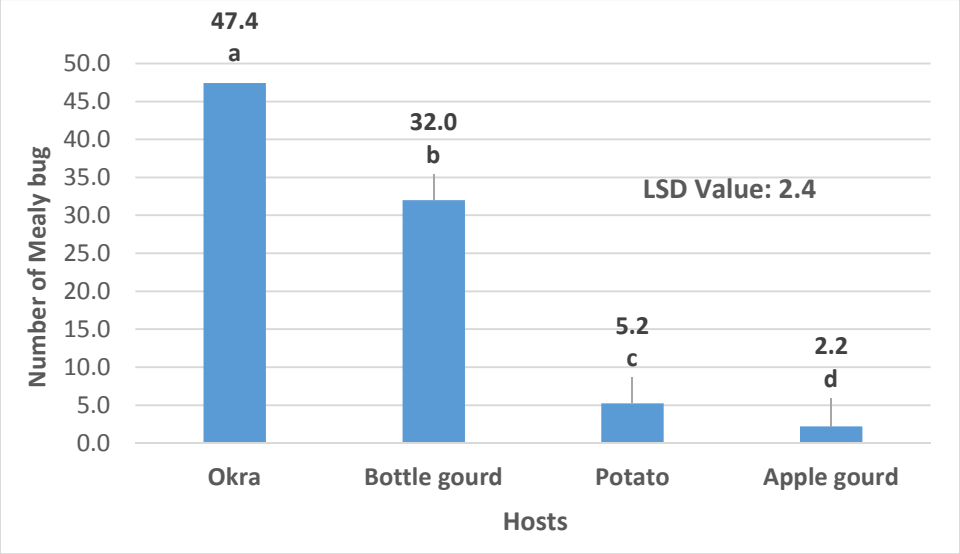


**Figure 1: Assessment of various host foods against cotton mealybug for host preference in no-choice test.**

Figure 2 presents the comprehensive findings regarding the impact of three exposure durations (24, 48 and 72 hours) on the host preference of the cotton mealybug across all hosts. The data clearly demonstrated significant differences among the different exposure times. The data depicted that maximum mean number of mealybug crawlers (30) were attracted to the host food during the maximum time of exposure (72hr) followed by 48hr exposure time (20.8), whereas, minimum number of mealybug crawlers (14.3) were attracted to the host after 24hr time duration.

LGJDX ISSN No: 1008-0562 Journal Of Liaoning Technical University Natural Science Edition

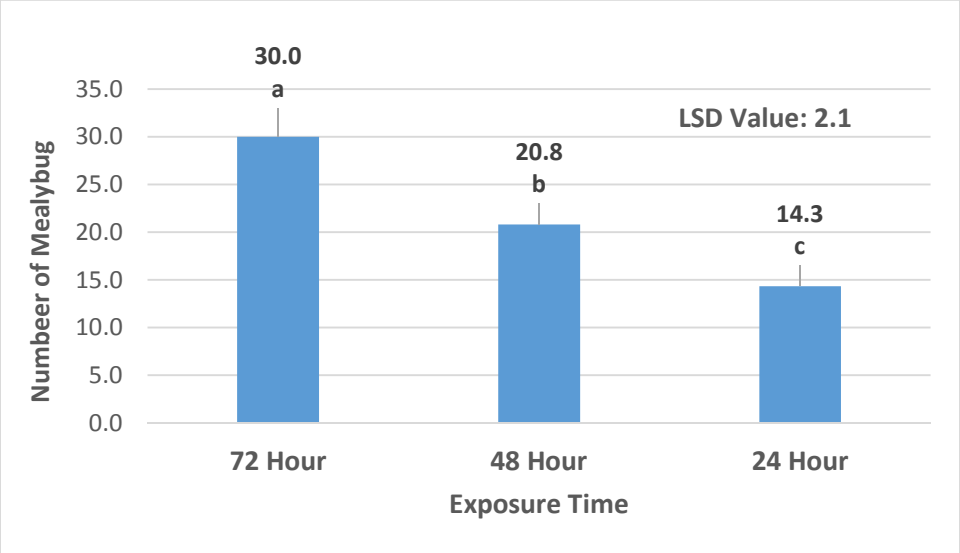


**Figure 2: Effect of exposure time on the host preference of cotton mealybug in no-choice Test.**

**Table 1: Assessment of various host foods and exposure times against cotton mealybug for host preference in no-choice Test.**

| S. No | Host | Exposure Time (Mean number of crawlers) ± SE | | |
|---|---|---|---|---|
| | | **24 hour** | **48 hour** | **72 hour** |
| **1.** | **Okra** | 36.33 ± 2.03 c | 46.66 ± 1.67 b | 59.33 ± 0.67 a |
| **2.** | **Bottle gourd** | 17.33 ± 1.45 e | 31.00 ± 2.08 d | 47.66 ± 3.71 b |
| **3.** | **Potato** | 2.0 ± 0.58 g | 4.0 ± 0.58 g | 9.66 ± 1.20 f |
| **4.** | **Apple gourd** | 1.66 ± 0.88 g | 1.66 ± 0.88 g | 3.33 ± 0.88 g |
| | **LSD Value (Host*Exposure Time)** | 4.19 | | |

**Note:** Means followed by the same letter(s) in columns within each level of [Host] and [Exposure Time] are not significant at the 5% level of probability.

The results of the no-choice Test, evaluating the host preference of cotton mealybug under different exposure times, are presented in Table 1. The mean number of crawlers attracted to each host food at 24 hours, 48 hours, and 72 hours is provided. Okra exhibited a significant increase in

attractiveness over time, with mean crawler numbers of 36.33 at 24 hours, 46.66 at 48 hours, and reaching a peak at 59.33 at 72 hours. These findings suggest a consistent and increasing preference for okra as a host food for cotton mealybug.

Bottle gourd showed a gradual increase in attractiveness, with mean crawler numbers of 17.33 at 24 hours, 31.00 at 48 hours, and a further rise to 47.66 at 72 hours. While not as preferred as okra, the data indicates a noteworthy attractiveness of Bottle gourd to cotton mealybugs, especially over an extended exposure period. Potato exhibited the lowest attractiveness among the tested hosts, with mean crawler numbers of 2.0 at 24 hours, 4.0 at 48 hours, and 9.66 at 72 hours. The gradual increase in attraction over time suggests a delayed response compared to the more preferred hosts. Apple gourd showed the least attractiveness, with consistently low mean crawler numbers across all exposure times (1.66 at 24 hours, 1.66 at 48 hours, and 3.33 at 72 hours). The data indicates a minimal preference for apple gourd as a host for cotton mealybug.

**Free-Choice Test**

Four host foods (potato, okra, Bottle gourd and apple gourd) were tested to find out the best suitable and attractive host food for laboratory rearing. The results on the attraction of mealybug by various host foods are presented in figure 3. The data indicated significant differences among the different hosts species tested. It was evident from the data that maximum mean number of mealybug crawlers were recorded on okra (126.3) followed by Bottle gourd (35.2), whereas, minimum number of mealybug crawlers (17.7 and 12.8) were recorded on potato and apple gourd respectively.

LGJDX
ISSN No: 1008-0562
Journal Of Liaoning Technical University
Natural Science Edition

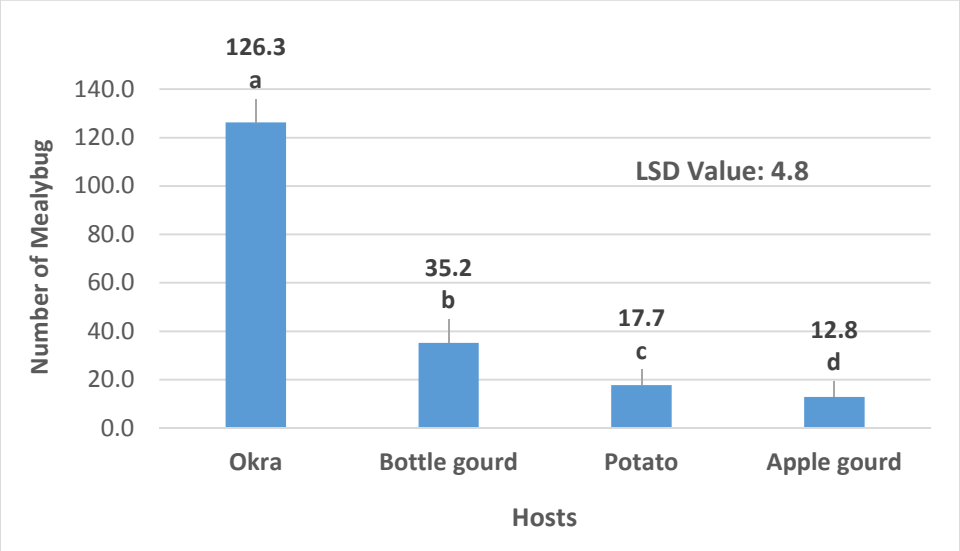


**Figure 3: Assessment of various host foods against cotton mealybug for host preference in free-choice test.**

Figure 4 presents the comprehensive findings regarding the impact of three exposure durations (24, 48 and 72 hours) on the host preference of the cotton mealybug across all hosts. The data demonstrated no significant differences among 72hr and 48hr exposure times, however the results were significantly different from 24hr. The data depicted that maximum mean number of mealybug crawlers (49.9) were attracted to the host food during the maximum time of exposure (72hr) followed by 48hr exposure time (48.9), whereas, minimum number of mealybug crawlers (44.2) were attracted to the host after 24hr.

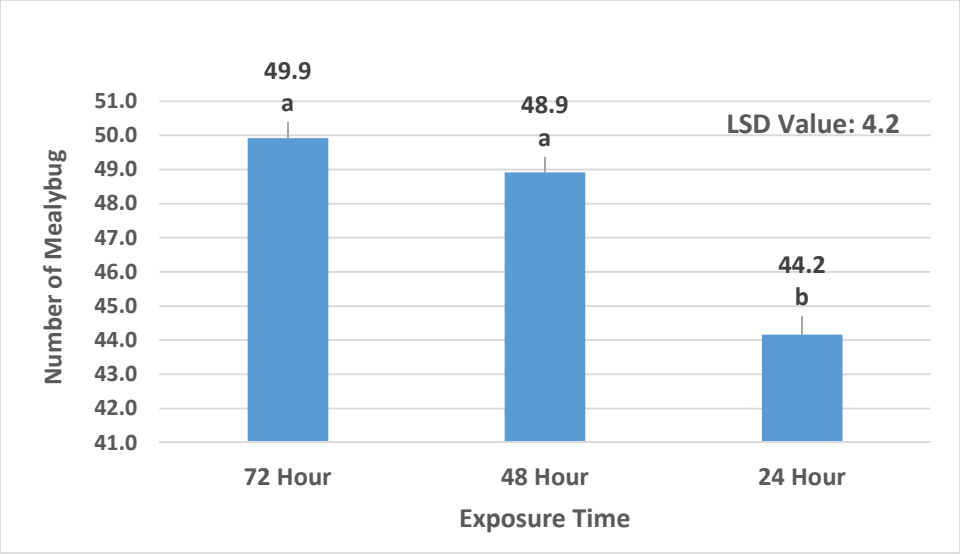


**Figure 4: Effect of exposure time on the host preference of cotton mealybug in free-choice test.**

**Table 2: Assessment of various host foods and exposure time against cotton mealybug for host preference in free-choice Test.**

| S. No | Host | Exposure Time (Mean number of crawlers) ± SE | | |
|---|---|---|---|---|
| | | 24 hour | 48 hour | 72 hour |
| 1. | Okra | 114.67 ± 1.73 b | 132.33 ± 2.85 a | 132.00 ± 4.73 a |
| 2. | Bottle gourd | 31.67 ± 4.18 c | 37.00 ± 3.06 c | 37.00 ± 1.53 c |
| 3. | Potato | 17.67 ± 1.45 d | 17.67 ± 1.73 d | 17.67 ± 1.20 d |
| 4. | Apple gourd | 12.67 ± 1.20 d | 12.67 ± 1.45 d | 13.00 ± 0.58 d |
| | LSD Value (Host*Exposure Time) | 8.34 | | |

**Note:** Means followed by the same letter(s) in columns within each level of [Host] and [Exposure Time] are not significant at the 5% level of probability.

The results of the free-choice Test, evaluating the host preference of cotton mealybug under different exposure times, are presented in Table 2. The mean number of crawlers attracted to each host food at 24 hours, 48 hours, and 72 hours is provided. Okra demonstrated a significant preference, with mean crawler numbers of 114.67 at 24 hours, increasing to 132.33 at 48 hours, and maintaining a high level at 132.00 at 72 hours. These findings underscore the strong and consistent preference of cotton mealybug for okra, even when multiple host options are available.

Bottle gourd exhibited a relatively lower but consistent attractiveness, with mean crawler numbers of 31.67 at 24 hours, 37.00 at both 48 hours and 72 hours. While not as preferred as okra, the data indicates a sustained attraction to bottle gourd throughout the duration of the test. Potato showed a consistent mean crawler number of 17.67 across all exposure times (24 hours, 48 hours, and 72 hours). Although lower compared to okra and bottle gourd, the data suggests a moderate and stable preference for potato by cotton mealybugs. Apple gourd exhibited the lowest attractiveness, with mean crawler numbers of 12.67 at 24 hours and 48 hours, slightly increasing to 13.00 at 72 hours. The data suggests a minimal preference for apple gourd as a host for cotton mealybug, similar to the findings in the no-choice test.

**Investigation of Cotton Mealybug Biology:**

This study aimed to compare the durations of different instar stages (1st instar, 2nd instar and 3rd instar) and the adult stage among four host fruits: potato, okra, apple gourd, and bottle gourd. The

mean durations of each instar and adult stage were calculated, along with the total number of crawlers produced. The results provide insights into the developmental dynamics of cotton meal bug on four different host fruits.

**Table 3: Effect of four different hosts on the development of cotton mealy bug.**

| S. No. | Hosts | | Developmental Duration (days) ± SE | | | | Total No. crawlers produced ± SE |
|---|---|---|---|---|---|---|---|
| | | | 1st Instar | 2nd Instar | 3rd Instar | Adult Duration | |
| | Common Name | Scientific Name | | | | | |
| **1.** | Potato | *Solanum tuberosum* | 5.27 ± 0.14 **a** | 5.05 ± 0.08 **a** | 12.54 ± 0.24 **a** | 9.40 ± 0.70 **a** | 709.67 ± 41.86 **b** |
| **2.** | Okra | *Abelmoschus esculentus* | 5.20 ± 0.22 **a** | 6.08 ± 0.09 **a** | 12.67 ± 0.33 **a** | 9.42 ± 0.42 **a** | 1563.3 ± 14.33 **a** |
| **3.** | Apple gourd | *Praecitrullus fistulosus* | 4.17 ± 0.68 **a** | 4.35 ± 0.88 **a** | 10.12 ± 0.13 **b** | 8.67 ± 0.67 **a** | 233.33 ± 19.10 **c** |
| **4.** | Bottle gourd | *Lagenaria siceraria* | 5.38 ± 0.33 **a** | 4.82 ± 0.95 **a** | 12.20 ± 0.80 **a** | 8.00 ± 0.00 **a** | 272.00 ± 40.34 **c** |
| | **LSD Value** | | 1.31 | 2.12 | 1.48 | 1.72 | 186.58 |

**Note:** Means followed by the same letter(s) in columns are not significant at the 5% level of probability.

The mean durations of the instar stages and adult stage, along with the total number of crawlers produced, are presented in the table 03. The 1st instar durations ranged from 4.17 to 5.38 days, with the longest duration observed in bottle gourd and the shortest in apple gourd. The 2nd instar durations varied from 4.35 to 5.05 days, again with bottle gourd showing the longest duration and apple gourd the shortest. The 3rd instar durations ranged from 10.12 to 12.67 days, with bottle

gourd having the shortest duration and okra the longest. The adult stage duration ranged from 8.00 to 9.42 days, with apple gourd exhibiting the longest duration and potato the shortest. Regarding the total number of crawlers produced, okra had the highest production (1563.3 crawlers), followed by potato (709.67 crawlers), bottle gourd (272.00 crawlers) and apple gourd (233.33 crawlers).

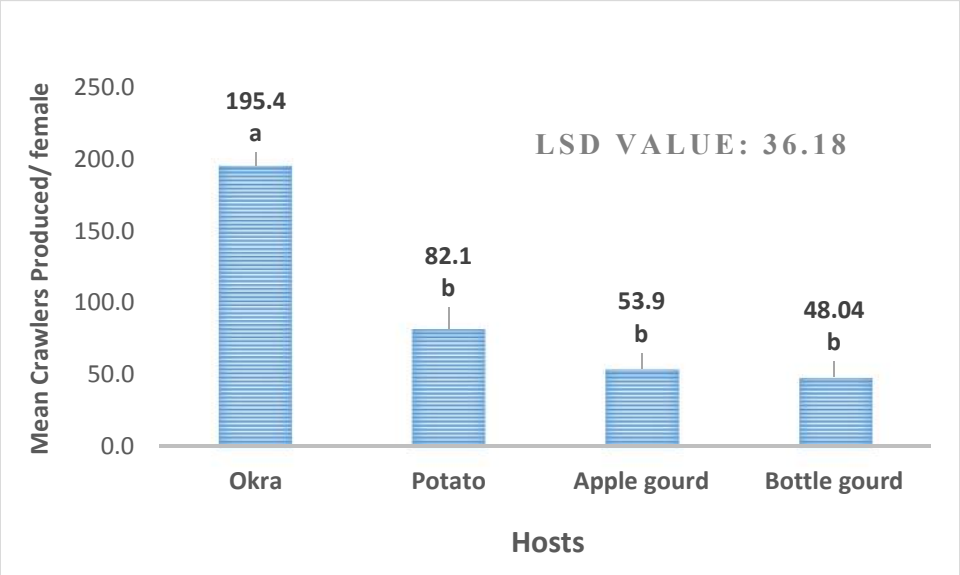


**Figure 05: Comparative analysis of mean crawlers produced per female by cotton mealybug across different host plants**

The presented data in figure 05, exhibits the mean number of crawlers produced per female by cotton mealybugs across different host plants. The results provide valuable insights into the reproductive potential of cotton mealybugs concerning their preferred host plants.

Cotton mealybugs displayed the highest reproductive output when hosted on okra, producing an average of 195.4 crawlers per female. This host plant appears to be highly conducive to the reproductive success of the mealybugs, indicating a favorable environment for their development and population growth. Mealybug reared on potato exhibited a notably lower but still substantial mean of 82.1 crawlers per female. Although lower than the reproductive output observed on okra, this data suggests that potato serves as a moderately suitable host for cotton mealybug reproduction. The data revealed a further decrease in the mean number of crawlers produced per female when hosted on apple gourd, with an average of 53.9 crawlers. This host demonstrated a relatively less supportive environment for cotton mealybug reproduction compared to okra and potato. Among the tested hosts, bottle gourd exhibited the lowest mean number of crawlers produced per female at 48.04. Cotton mealybug reared on bottle gourd showed the least

reproductive output, indicating that this host may be less conducive to their successful reproduction compared to other tested hosts.

## DISCUSSION

The *Phenacoccus solenopsis* Tinsley, commonly known as the cotton mealybug (Hemiptera: Pseudococcidae), is recognized as a highly concerning polyphagous herbivorous insect pest. Its remarkable adaptability allows it to thrive across various climates and exploit multiple host plants (Fand and Suroshe, 2015). The main objective of this study was to investigate the food preference of cotton mealybug towards selected hosts and explore its developmental biology on various hosts. Four host foods (potato, okra, Bottle gourd and applegourd) were tested to find out the best suitable and attractive host food for laboratory rearing in no-choice and free-choice tests. These hosts were also investigated for further biological studies.

The conducted experiments evaluating the attraction of cotton mealybug to various host foods and exposure times, yielded crucial insights into the preferences of this pest. Both No-Choice and Free-Choice tests depicted significant variations in the attractiveness of different host species, highlighting distinct preferences among cotton mealybug for various hosts.

### Host Preference of Cotton Mealybug for Various Hosts:

The findings explicitly demonstrate substantial differences in both host preferences and exposure durations, providing comprehensive insights into how various hosts and timeframes affect the attraction of mealybugs. Our findings reveal a direct correlation between the duration of exposure and the level of mealybug attraction to the host plants. Throughout the study, okra emerged as the most preferred host for cotton mealybug, displaying a substantial increase in attraction over time. The results from the Free-Choice Test aligned with those of the No-Choice Test, emphasizing the consistent preference for okra among cotton mealybugs. Okra showed a clear increase in attractiveness, initially recording a moderate level of attraction after 24 hours and demonstrating a substantial rise by the 72-hour mark. Our results are in agreement with Mohamed, Taha & Adam (2019) who documented that okra appeared to be highly preferred over the selected host species compared with the control followed by Cotton and Hambouk. Similarly, Bottle gourd exhibited an upward trend in mealybug attraction, starting with a modest level after 24 hours and notably increasing in attractiveness after 72 hours. Conversely, both potato and applegourd consistently

demonstrated minimal appeal to cotton mealybugs across the entire 24-hour and 72-hour intervals. Their low levels of attractiveness remained relatively unchanged over time, indicating a consistent lack of preference for these host plants among the mealybugs compared to okra and Bottle gourd. Other researchers also reported similar results. According to Finch and Collier (2000), the pest's selection of a host plant is typically classified as 'host plant finding' and 'host plant acceptance', in which volatile chemicals play a crucial role in guiding phytophagous insects towards their host plants.

The observed trend indicates a clear preference hierarchy among the tested hosts, with okra and Bottle gourd being more attractive to cotton mealybugs compared to potato and apple gourd. Moreover, the progressive increase in attraction over time for okra and Bottle gourd suggests that prolonged exposure enhances their allure to the mealybugs, potentially indicating a positive correlation between exposure duration and host attractiveness. These results are supported by many researchers. Abbas et al. (2010) affirmed *Phenacoccus solenopsis*'s inclination towards the Malvaceae family by demonstrating that host plants within this family (such as cotton, okra, and china rose) exhibited a higher count of crawlers per female. Similarly, analysis of the data from Shehata and Moussa (2018) reveals varying degrees of infestation among the tested plants. Okra, eggplant, and purslane were heavily infested, while ivy, cotton, and potato showed moderate infestation. Cowpea and pepper exhibited mild infestation by the cotton mealybug. Moreover, Mohamed, Taha & Adam (2019) tested plant preferences of cotton mealybug, finding higher infestation on Malvaceae plants like okra (*Hibiscus esculentus*). Plants from Solanaceae and Aizoaceae families showed lower attractiveness to the mealybugs.

The observed differences in the host preference might be due to many factors. As per Chapman (2009), insects evaluate a plant's suitability as a host species based on both its overall suitability and nutritional value. Nonetheless, the behavioral response of insects to plant secondary compounds significantly and primarily influences their selection of a host plant. Hence, the diversity in host plant species as a food source and their chemical composition impacts the feeding preferences, survival, and reproductive patterns of polyphagous insect pests (Du et al., 2004). According to Shehata, Mostafa & Salama (2020), okra's heavy infestation correlates with high levels of acetogenins, mono- and tri-terpenes, and alkaloids compared to other plants. Cowpea and pepper, mildly infested, have more tetra-terpenes. Okra's mono- and tri-terpenes and alkaloids likely attract pests, while tetra-terpenes in cowpea and pepper may repel insects. Furthermore,

Shehata, Mostafa & Salama (2020) found that heavy infestation of cotton mealybug on certain hosts correlates with released olfactory compounds, influencing cotton mealybugs' host preference.

These findings hold significant implications for understanding the host selection behavior of cotton mealybug. Okra and Bottle gourd, being more favorable hosts, could play crucial roles in pest management strategies or in optimizing rearing conditions for laboratory colonies due to their pronounced attractiveness. The consistent low attraction to potato and apple gourd reaffirms their limited suitability as preferred hosts for cotton mealybugs. These insights are pivotal for devising targeted pest control strategies and refining rearing protocols in agricultural and research settings.

**Investigation of Cotton Mealybug Biology:**

The results provide crucial insights into the developmental stages and reproductive capacity of cotton mealybugs across different host plants. Observing the durations of instar stages, it's apparent that the 1$^{st}$ and 2$^{nd}$ instar durations varied notably among the host plants. Bottle gourd exhibited the longest durations for both stages, while apple gourd displayed the shortest durations. This variance in duration suggests potential differences in the suitability of these hosts for mealybug development during the early stages. Ata (2019) reported that the reproduction rate of the cotton mealybug showed notable variations depending on the type of host plant.

Moving to the 3$^{rd}$ instar stage, the durations showed a wider range, with bottle gourd having the shortest duration and okra exhibiting the longest. This suggests potential variations in the quality of hosts for sustaining mealybug growth during the later developmental stages. Radadia et al. (2008) stated there were three nymphal instars in female, while male had four nymphal instars. Huang et al. (2012) studied *Phenacoccus solenopsis*, emphasizing the tomato plant. They found male nymphs lasted 16.3 ± 0.2 days versus 15.4 ± 0.5 days for females. Males lived an average of 1.8 ± 0.2 days, significantly shorter than females (42.6 ± 1.1 days). The mean fecundity per female was 134.6 ± 16.3 crawlers.

The differences in duration among these hosts might indicate varying nutritional values or environmental factors influencing mealybug development. Kalaitzaki et al. (2023) conducted a study on the nymphal development of *Closterotomus trivialis*, discovering that the development of the nymphs was notably impacted by both temperature and the host plant. According to

Chapman (2009), insects evaluate a plant's suitability as a host species based on both its overall suitability and nutritional value.

Regarding the adult stage duration, apple gourd presented the longest duration, while potato displayed the shortest. These variations in adult stage durations among different hosts imply potential differences in reproductive fitness or environmental factors impacting the mealybug's lifecycle and breeding capacity. Many researchers have worked out the biological studies regarding the cotton mealybug and found different results. Kamariya (2009) conducted a study on the biology of *P. solenopsis* in a laboratory setting. The findings revealed that the duration of the first (crawler), second and third instar nymphs were 4.82 ± 1.12, 5.64 ± 1.14, and 6.42 ± 1.14 days, respectively. The total nymphal period ranged from 12 to 21 days, with an average of 16.88 ± 2.11 days.

Considering the total number of crawlers produced, okra emerged as the most productive host, followed by potato, bottle gourd and apple gourd, respectively. Vennila et al (2010) demonstrated that female mealybugs displayed variable fecundity, with an average of 344 crawlers produced per female. Ata (2019) reported that adult females laid an average of 163.3±48.5, 212.8±55.1, and 265.8±57.7 eggs per female when reared on potato, tomato, and cotton plant leaves, respectively.

Okra's significantly higher production of crawlers underscores its suitability as an ideal host, potentially offering favorable conditions for mealybug reproduction and population growth compared to other hosts. Overall, the variations observed in the durations of instar stages, adult stage, and the total number of crawlers produced across different hosts highlight distinct host-dependent influences on cotton mealybug development and reproductive capacity. Muthulingam and Vinobaba (2013) observed that under controlled lab conditions, *P. solenopsis* exhibited extended developmental periods during the 2nd instar compared to the remaining instars. Female lifespan ranged from 32 to 55 days, averaging 34.3 ± 2.64 days. The entire life cycle persisted for approximately 55 to 60 days, with a mean duration of 58.3 ± 2.64 days. Each female laid a variable number of eggs, ranging from 212 to 772 during her lifespan, averaging 574 ± 82 eggs. Pawar et al. (2017) documented oviposition behavior of the female resulted in an average deposition of 328.70 ± 120.07 eggs. Hassan A. Nabil (2019) found that the females exhibited varied fecundity rates, as evidenced by the range of 120 to 385 crawlers produced per individual, with a mean of 227.

These observations underscore the host-dependent variations in the reproductive success of cotton mealybugs, highlighting the differential suitability of various hosts for their development and population growth. The differing reproductive outputs among these hosts imply potential variations in nutritional quality, environmental factors, or other host-specific conditions influencing mealybug fertility. Understanding these host-specific variations is crucial for devising effective pest management strategies and optimizing rearing conditions in agricultural settings.

**Acknowledgements**

This study was supported by the International Atomic Energy Agency (IAEA) under the IAEA CRP (RC-24975) Project. We extend our gratitude to the IAEA for their financial and technical assistance which made this research possible.

**References**

1. Abbas G, Arif, MJ, & Saeed S (2005). Systematic status of a new species of the genus *Phenacoccus Cockerell* (Pseudococcidae), a serious pest of cotton, *Gossypium hirsutum* L., in Pakistan. Pak Entomol 27: 83–84.
2. Abbas G, Arif MJ, Ashfaq M, Aslam M, & Saeed S (2010). The impact of some environmental factors on the fecundity of *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae), a serious pest of cotton and other crops. Pak. J. Agric. Sci 47(4): 321-325.
3. Ata TE (2019). Biological Studies on the Cotton Mealybug *Phenacoccus solenopsis* Tinsley, (Hemiptera: Pseudococcidae) under the Laboratory Condition. Plant Prot. and Path., Mansoura Univ 10 (3): 195–198.
4. Chapman RF (2009). Foraging and food choice in phytophagous insects Chemical Ecology, Encyclopedia of life support system (EOLSS). Available at: http://www. Eolss-net/EOLSS-sample All chapter.aspx.
5. Du L, Ge F, Zhu S, & Parajulee MN (2004). Effect of the cotton cultivar on development and reproduction of *Aphis gossypii* (Homoptera: Aphididae) and its predator *Propylaea japonica* (Coleoptera: Coccinellidae). J. Econ. Entomol 97: 1278-1283.
6. Fand BB, & Suroshe SS (2015). The invasive mealybug *Phenacoccus solenopsis* Tinsley, a threat to tropical and subtropical agricultural and horticultural production systems–a review. Crop Protection 69: 34-43.
7. Finch S, & Collier RH (2000). Host plant selection by insects – a theory based on 'appropriate in-appropriate landing' by pest insects of cruciferous plants. J. Entomologia Experimentalis et Applicata 96: 91-102.

8. Gullan PJ, & Martin JH (2003). Sternorrhyncha (jumping plant-lice, whiteflies, aphids, and scale insects). Insects of Australia. Volume 1. CSIRO Publishing.
9. Halder J, Waluniba, Joshi S, Jha A., & Rai AB (2020). New host record of *Formicococcus polysperes* Williams (Hemiptera: Pseudococcidae): an emerging pest of taro *Colocasia esculenta* (L.) Schott from India. Natl Acad Sci Lett 43: 467-472.
10. Nabil HA (2019). Biological Studies on Cotton Mealybug *Phenacoccus solenopsis* TINSLEY under Laboratory Conditions. Zagazig J Agric Res 46(2): 385-389.
11. Huang J, Zhang J, Yu, YM, Lu YB, & Luan JB (2012). Biological Characteristics and Chemical Control of the Invasive Mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) on Tomato in the Laboratory. J Kansas Entomol Society 85(3): 179–185.
12. Joshi MD, Butani PG, Patel VN, & Jeyakumar P (2010). Cotton Mealy Bug, *Phenacoccus Solenopsis* Tinsley–A Review. Agric Reviews 31(2): 113-119.
13. Kansiime MK., Rwomushana, I, Mugambi I., Makale F, Lamontagne-Godwin, J, Chacha, D, & Day R (2023). Crop losses and economic impact associated with papaya mealybug (*Paracoccus marginatus*) infestation in Kenya. Int J Pest Management 69(2): 150-163.
14. Kamariya NM (2009). Biology and control of mealy bug, *Phenacoccus solenopsis* Tinsley infesting cotton. M. Sc. thesis Junagadh Agricultural University, Junagadh.
15. Kalaitzaki A, Amara A, Dervisoglou S, Perdikis D, Tzobanoglou D, Koufakis I, & Tsagkarakis A (2023). Effect of host plant species and temperature on the development and survival of the plant bug *Closterotomus trivialis* (Costa) (Hemiptera: Miridae). Phytoparasitica 51(1): 19-28.
16. Suguiyama LF, & Osteen CD (1988). The economic importance of cotton insects and mites (No. 599). US Department of Agriculture, Economic Research Service.
17. Mohamed NA, Taha AK, & Adam AHM (2019). Laboratory Studies on the Host Preference of Cotton Mealybug '*Phenacoccus solenopsis*' Tinsely (Hemiptera: Pseudococcidae) in Khartoum State, Sudan. J Agronomy Research 1(3): 35-43.
18. Pawar SR, Desai HR, Bhanderi GR, & Patel CJ (2017). Biology of the Mealybug, *Phenacoccus solenopsis* Tinsley Infesting Bt Cotton Int J Curr Microbiol App Sci 6(8): 1287-1297.
19. Muthulingam P & Vinobaba M (2013). Life cycle of the cotton mealybug *Phenacoccus solenopsis* in shoe flower plants under the Laboratory conditions. Proceedings of the Third International Symposium, SEUSL: 6-7 July 2013, Oluvil, Sri Lanka.
20. Radadia GG, Pandya HV, Patel MB, & Purohit MS (2008). Kapasana Mealy bugs (Chikto) ni Sankalit Niyantran Vyavastha, an information bulletin published in Gujarati by Main Cotton research Station, Navsari Agricultural University, Presented on 7th August, 2008, at Navsari.
21. Rezk M, Hassan ANT, El-Deeb MF, Shaarawy N, & Dewer Y (2019). The impact of insecticides on the cotton mealybug, Phenacoccus solenopsis (Tinsley): Efficacy on potato, a new record of host plant in Egypt. J Plant Protec Res 50-59.

22. Shehata IE, Mostafa MEH, & Salama HS (2020). Biology and host preference of the cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on different host plants. Plant Archives 20(1): 461-471.
23. Frank S, Baker J (2010). NC State Extension Publications. https://content.ces.ncsu.edu/mealybugs.
24. Tinsley JD (1898b). Notes on Coccidae, with descriptions of new species. Canadian Entomologist 30(12): 317–320. DOI: https://doi.org/10.4039/Ent30317-12.
25. Tong HJ, Yan, AO, Li ZH, Ying WANG, & Jiang MX (2019). Invasion biology of the cotton mealybug, Phenacoccus solenopsis Tinsley: current knowledge and future directions. J Integrative Agric 18(4): 758-770.
26. Vennila S, Deshmukh AJ, Pinjarkar D, Agarwal M, Ramamurthy VV, Joshi S, & Bambawale OM (2010). Biology of the mealybug, Phenacoccus solenopsis on cotton in the laboratory. J Insect Science 10(1): 115.
27. Waqas MS, Shi Z, Yi TC, Xiao R, Shoaib AA, Elabasy AS, & Jin DC (2021). Biology, ecology, and management of cotton mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae). Pest Management Sci 77(12): 5321-5333.