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FIRST REPORT ON SPROUTED POTATO MEDIATED REARING OF MANGO MEALY BUG *Drosicha mangiferae* (GREEN) TO STUDY BIOLOGY AND MORPHOMETRY

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ABSTRACT

Sprouted potatoes were used for rearing of mango mealy bug, *Drosicha mangiferae* (Green). Newly emerged 1st instar nymphs were inoculated in the sprouted potatoes and then reared up to adulthood. The duration of each life cycle stages were calculated by keeping close watch on timings of each molting by locating shed exuviae. The total life cycle periods of female and male was different. Females completed the its life span in 121.65±9.32 days whereas in male a little shorter duration of 111.4±11.96 days was required for the completion of life cycle. The life cycle of this mango mealy bug became complicated due to the presence of egg diapause which lasted for almost six months starting from May (last week) to January (1st week) of the next year. Both male and female developed in the same manner till the development of 3rd instar but thereafter due to an intervening pupal stage in the male developmental pattern became different in both sexes. The longevity of female adult was found to be much higher (34.1 & 40 days) than male adults (16.1 &15 days) in two years of study. Till the development of 3rd instar, morphometric measurents of male and female instars were 1st instar, 1.586±0.078 × 0.792±0.031 mm, 2nd instar, 4.82±0.081 × 2.77±0.064 mm, 3rd instar 16.32±0.50×6.82±0.66 mm respectively. Pupa measured 18.2±0.78 x 8.19±0.14 mm. A distinct sexual dimorphism was noticed. The adult females were white and wingless. On the contrary, males were crimson colored having brownish black forewings. Female adults achieved highest mean length × breadth with a measurement of 23.8±1.75×8.4 ± 0.115 mm and males grew upto 10.54±0.36×4.14±0.052 mm. The sex ratio was inclined towards female as 0.475:1 (male: female). This study was undertaken to establish life cycle parameters of the pest which will help pest managers and farmers to formulate control strategies much ahead of the pest attack.

Keywords: *Drosicha mangiferae*; sprouted potato; rearing; egg diapuase; nymphal development; morphometry; sexual dimorphism; sex ratio.

1. INTRODUCTION

Mango is considered king of all fruits. It is appreciated worldwide for its strong aroma, palatability, and high nutritive value as reported elsewhere [1,2]. The total annual production of mango is over 3.95 million tones in India with a share of 11 per cent in the world production as discussed by Sahoo et al. [3]. West Bengal state has 70-80 thousand hectares of mango cultivation field having a share of 44% of the total area that food crop cultivation of the state occupies as elaborated by Bhattacharya [4]. Malda district tops the list within the state with a annual net production of about 270 thousand tons as per Anonymous [5]. Ishaq et al. [6] had observed that several Insect pests attack mango

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plant to inflict considerable damage and also underscore mango production. Amongst all the insect pests,mango mealy bug (*Drosicha mangiferae)* is a notorious pest of India and subcontinent as recoded by Tandon & Verghese [7] and Rao et al. [8]. Huge amount of damage is incurred by this pest to agricultural and horticultural crops as discussed by Arif et al. [9]. Mealy bugs are named so because many of the species secrete 'whitish wax' that prevents water loss from the soft surface. This polyphagous pest infests twigs, inflorescence leaves and causes fruit drop by unremitting sap sucking and it is also responsible for development of black sooty mould due to the secretion of honeydew and can make mango unfit for consumption as discussed by Bhagat [10].

It was reported in West Africa, by Moore [11] that severe mealy bug infestation renders 50-90% mango fruit loss. Karar et al. [12] have observed that mealy bug ranked second pests in consideration to damage to mango after Mango hopper and can cause damage up to 50%. Due to the polyphagous nature, waxy coating on the body surface and prolonged egg incubation in soil, management of this pest becomes very difficult.

There are various reports regarding the existence of this pest elsewhere in India and Pakistan [12,13,14]. But there is not enough reports regarding biology and life cycle study of this dreaded pest. The lack of exploration of biological parameters of this pest may be due to the need of extensive standardization of culture materials and method. As the interference of biotic and abiotic factors with the pest makes it very difficult for keeping tract with the biological activities in the field, a controlled study in laboratory conditions becomes essential. Therefore, the present investigation was undertaken to study the biology, life cycle and morphometric parameters of mango mealy bug, *D. mangiferae* on sprouted potatoes.

2. MATERIALS AND METHODS

The present investigation was carried out at laboratory conditions and various experimental mango orchards of kaligram, Malda of West Bengal. Laboratory culture of mango mealy bug, *D. mangiferae* was established on sprouted potatoes as per Gautam [15] with little modifications. Cleaned potato sprouts were used as hosts for rearing *D. mangiferae.* Potato tubers were thoroughly rinsed with sodium hypochlorite and then under tap water and air dried. Potato tubers were then soaked in gibberelic acid 1% for nearly 30 minutes to induce sprouting then dried in air again. After this treatment potatoes were transferred to small bowel containing wet sterilized sand. Thereafter, the bowels were covered with white cotton cloth and kept in dark for rapid sprouting. Each day the sand was sprinkled with water to retain the moisture intact. After 4-5 days when the sprout measured approximately 2-3 cm then were cleaned again and transferred to another bowel lined with moist tissue paper. These potato sprouts were used to inoculate the 1st instar nymphs of mango mealy bug to start fresh culture of it. The time taken in the sprouted potatoes for each developmental stages were recorded and noted separately.

2.1 Mass Culture of Mango Mealy Bug

Mass culture of mealy bug was initiated after collecting the eggs of mealy bug from adjoining soil of mango trees following Bhau et al. [16] during last week of December 2017 and 2018 consecutively Soil sample at almost 20 cm depth was collected of causing minimum interference to the eggs of mealy bug. The soil with eggs was then taken to the laboratory for initiation of mass culture. After that soil was placed in the pots covered with white cotton cloth and tied with the help of rubber band. In order to maintain proper moisture a small quantity of water was sprinkled. Thereafter, day to day observation was done. The time first instar emergence was noted. The newly hatched nymphs were transferred with the help of a camel hair brush on the sprouted potatoes on the first week of January in the next year.

2.1.1 Study of nymphal development

Freshly emerging nymphs were lifted in the first week of January. Thirty such nymphs were individually placed in three separate bowels full of sprouted potatoes each representing a replicate. For maintenance of proper sanitation, the nymphs were dirt-cleaned every 2-3 days time and reared in this manner upto first moulting. Duration of first molting was thoroughly observed and accordingly noted. This duration was considered as the fisrt instar.

Then these 2nd instar freshly emerged nymphs were transferred to another bowel covered with organza for subsequent stage development till adults emergence. After the start of molting, mealy bugs shed their exuviae which was cleaned on daily basis. The time taken between the 1st and second molting was noted and considered as 2nd instar period.

Similarly, the duration between 2nd and 3rd molting was counted as 3rd instar period and accordingly tabulated.

The whole period of molting through which mealy bug nymphs were undergoing were recorded and date of emergence or inoculation of the earlier stage was subtracted to get the mean duration of each developmental stage. Every developmental change was noticed carefully.

Fig. 1. Stages of mealy bug culture in potato sprout, (a) potato sprout in bowel, (b) inoculation of ist instar nymphs (c) moulting of mealy bug nymphs with shed exuviae, (d) & (e) growth of mealy bug nymphs from 2nd instar to last stage

Till the formation of the 3rd instar nymphs male and female were developing in the same manner but later on the process became quite different due to the formation of pupa in males.

2.1.2 Pre -pupal stage

After the emergence of 3rd instar nymphs some of the individuals became very sluggish and were not feeding and then formed pupa. So, the time between 3rd instar emergence and formation of pupa was considered as the pre-pupal period.

2.1.3 Pupal stage

After the completion of pre-pupal period, the male insects started the formation of cocoon and the duration between cocoon formation and adult emergence was noted and considered as pupal period.

2.1.4 Adult stage

The period of survival of adults from the time of their emergence was noted and considered as their period of longevity.

2.1.5 Sex ratio

By counting the number of pupae formed after 3rd instar and the remaining going for further molting, the sex ratio was calculated. The former group denoted as the male and the later one as female. When, the sex ratio was calculated, the mortality of the individuals was also taken into account.

2.1.6 Fecundity analysis

Gravid females with ovisacs were chosen for fecundity study. Ovisacs from the ventral side of the body were dissociated gently with a fine forcep and the dissected. The number of eggs produced per female was considered as fecundity.

2.2 Morpho Measurements

The morphometric measurements of 1st instar were done with the help of Carl Zeiss microscope after standardization with stage micrometer. The length and breadth of eggs and 1st instar mealy bugs, length of antenna and feet were measured using this technique. The rest of the relatively larger instars were measured using both stage and ocular micrometers.

2.2.1 Eggs

Ten eggs were selected randomly from the dissected ovisacs and the length and breadth was measured by using Carl zeiss microscope with image processing software. Each specimen represents one replicate.

2.2.2 1st instar

From the mass culture, ten 1st instar nymphs were selected, killed in 70% alcohol. Length measurement was done by taking the measure from anterior to posterior end while breadth was recorded horizontally from end to end.

2.2.3 Developing stages

From 2nd instar onwards nymphs were taken and killed in 70% alcohol and the length and breadth, antennae and feet length was measured using stage and ocular micrometer.

During this whole life cycle study the maximum temeperature, minimum temperature, maximum and minimum humidity have been noted.

2.3 Statistical Analysis

The data had been subjected to analysis of mean and standard deviations with the help of data analysis pack in Microsoft excel 2007.

3. RESULTS

The duration and biology of various developmental stages are represented in Table 1. It revealed that first instar nymph completed its growth within 43.5±2.87 (39-48) days in 2018. Relatively lesser period was required for the development of 2nd and 3rd instars.2nd instar took 19.5±2.87 (15-24) days for completion of growth and 3rd instar growth was completed within 26.5±2.29(23-30) days. The development up to 3rd instar is same in both male and female but things get different beyond that due to the development of pupa in males.So,the duration of 3rd instar nymph in case male is actually the pre-pupal period which lasted for 17.0±1.41days (15-27). At the completion of prepupal period the male 3rd instar nymphs started forming a cottony cocoon covered pupa that lasted for maximally 18.5±3.45(13-24) days.

The time taken for prepupal, pupal and adult stage did not exhibit any significant difference in their period of developments. There is a significant difference regarding female and male adult longevity. In case of female it was found to be 34±1.41(32-36) and in males it was 16.0±1.41(14-16). The female nymphal development took 121.65±9.32 days for completion whereas for male it took 111.4±11.96 days. This data of male and female total life cycle duration represents a pooled data of two consecutive years.

The activity of mango mealy bug continues up to almost 19-20 th standard meteorological week (SMW).Thereafter, the adult females crawls down from the trees and then entered inside the soil and crevices for egg laying. These eggs remain inside the soil in diapause from last week of may till 1st week of January next year for almost six months. When temperature and humidity became very conducive at about 1SMW, the eggs hatched and started to ascend on the trees and later on settled themselves in the tender twigs and inflorescence. The total developmental from 1st instar to adult was completed within temperature range of 15.85˚C- 34.22˚C .The humidity during that tenure was fluctuating between 45.36-87.35%.

Therefore, a single generation is completed in one year as the period of egg diapauses lasts for six month. In the second year also similar kinds of observations were made and presented in the Table 1. Each life cycle stage was photographed properly and combined to generate the whole life cycle which is presented in Fig. 2.

3.1 Fecundity and Sex Ratio

The mean number of eggs laid per female was recorded as 113±18.66 (range 89-132 days). In the laboratory conditions female mealy bugs continued to lay eggs for 10-14 days. The eggs were initially brick colored but later on the colour converted to reddish brown. Out of total 90(30×3) individuals inoculated 10 individuals died, 80 survived from three replicates and amongst that 80, 33 pupae were noticed and rest were females. The sex ratio was inclined towards female as 0.475:1 (male: female).

3.2 Diapause

Diapause was calculated by noting the behavior of the gravid female disappearing at the end of May and then recording the hatching of eggs collected from the experimental orchard available in the soil around the trees. Hatching started in the first week of January which clearly indicates that insect spend almost 6 months in egg diapause (Table 1) from last of May to January of next year under Malda conditions in the upper Gangetic plain of west Bengal, India.

Table 1. Various life cycle parameters of mango mealy bug *D. mangiferae*

Life stage	Duration in days		Temperature in degree C^{o}				Relative humidity %			
	Gen 1	Gen 2	Gen 1 (2018)		Gen 2 (2019)		Gen 1		Gen 2	
Eggs	**Diapause from 20th may - 2nd January**	**Diapause from 25th may -7th January**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
I st instar	43.5±2.87(39-48)	42.0±3.16(37-47)	17.62±5.00	15.85±5.26	24.58±3.38	15.19±3.24	81.85±5.82	49.85±4.83	78.34±6.75	48.92±7.65
2 nd instar	19.5±2.87(15-24)	17.8±2.48(15-22)	30.17±1.74	21.96±1.75	31±1.33	15.3±2.11	74.95±5.44	45.66±4.78	75.9±4.60	53.1±4.17
3 rd instar	26.5±2.29(23-30)	25±1.41(23-25)	31.22±4.59	22±2.60	31.43±1.54	21.68±1.81	80.13±4.50	50.86±4.55	83.34±4.49	61.56±3.18
Adult female	34±1.41(32-36)	40.0±2.16(37-43)	33.34±1.57	23.46±1.48	32.44±1.46	23.55±1.75	82.23±4.46	49.16±6.46	86.16±4.00	66.0±4.01
I st instar	43.5±2.87(39-48)	42.0±3.16(37-47)	17.62±5.00	15.85±5.26	24.57±3.38	15.19±3.24	81.85±5.82	49.85±4.83	78.34±6.45	48.92±7.65
2 nd instar	19.5±2.87(15-24)	17.8±2.48(15-22)	30.17±1.74	21.96±1.75	31±1.33	15.3±2.11	79.85±5.49	45.36±4.78	75.9±4.60	53.1±4.17
3 rd instar(pre- pupa)	17.0±1.41(15-27)	16.5±1.29(15-18)	30.44±4.68	21.61±2.70	31±1.47	21.45±1.63	79.88±4.86	57.16±2.98	83.36±5.31	62.09±3.26
Pupa	16.5±1.87(14-19)	18.5±3.45(13-24)	34.22±0.94	23.44±1.50	32.7±1.05	22.4±1.71	78.83±2.14	43.27±4.76	82.6±2.11	61.4±2.36
Adult male	16.0±1.41(14-16)	15±1.58(13-17)	33.57±1.50	23.36±1.49	31.88	23.05	82.68±2.89	51.36±5.63	87.35±2.97	68±3.72

-Figures in the column denoting means and standard deviations

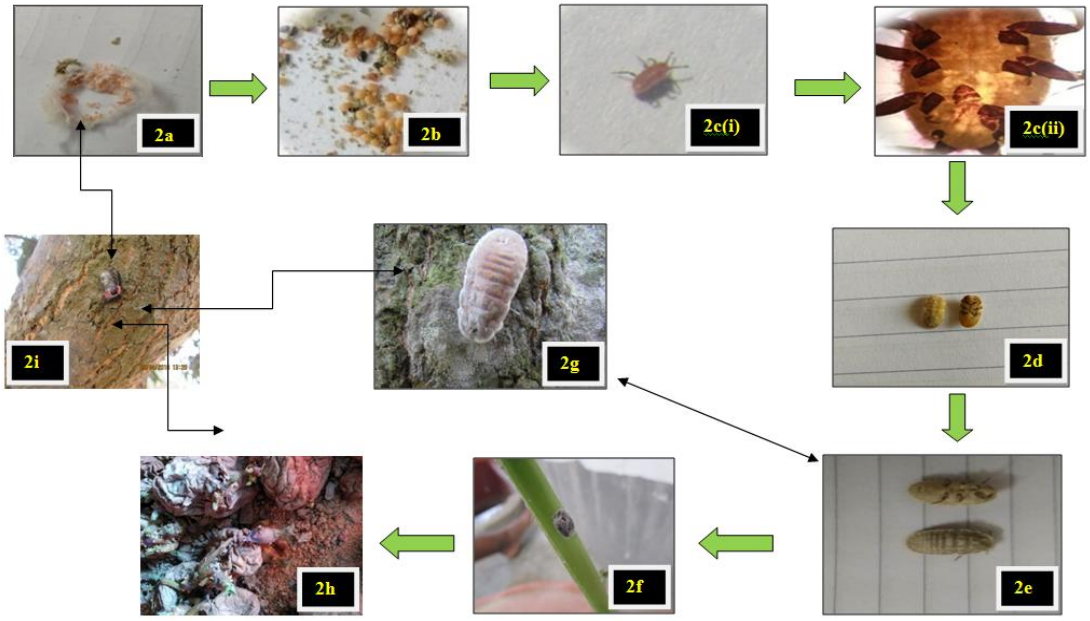

Fig. 2. Life cycle of mango mealy bug, *Drosicha mangiferae* (a) Gravid female with egg sacs, (b) Eggs, c(i)1st instar nymph, c(ii) microscopic image of 1st instar nymph, (d) 2nd instar nymph, (e) 3rd instar nymph, (f) Male pupa (g) Female adult, (h) Male adult, (i) Copulating male and female

Table 2. Mean morphometric measurements of various life cycle stages of mango mealy bug, *D. mangiferae*

Sex	Developmental stage		Length × Breadth (mm)	Antenna length (mm)	Feet length (mm)
Female	Egg		0.7±0.31×0.4±0.2		
	Instars	1st	1.586±0.078×0.792±0.031	0.679±0.011	0.566±0.018
		2nd	4.82±0.081×2.77±0.064	0.686±0.012	1.258±0.0074
		3rd	16.32±0.50×6.82±0.66	0.761±0.009	6.82±0.6696
	Adult		23.8±1.75×8.4±0.115	6.891±0.007	1.835±0.0195
Male	Instars	1st	1.586±0.078×0.792±0.031	0.679±0.011	0.566±0.018
		2nd	4.82±0.081×2.77±0.064	0.686±0.012	1.258±0.0074
		3rd *	16.32±0.50×6.82±0.66	0.761±0.009	6.82±0.6696
		Pupa	18.2±0.78×8.19±0.14	-	-
		Adult	10.54±0.36×4.14±0.052	2.42±0.066	2.64±0.052

**3rd instar male is prepupa. -Figures in the column denoting mean and standard deviations*

4. MORPHOMETRY OF DEVELOPMENTAL STAGES OF *D. mangiferae*

The various measurements like length, breadth of eggs, nymphs, adults (Both male and female),antenna and feet are given in the Table 2.

4.1 Eggs

The average length × breadth of an egg was noted and computed as 0.7±0.31×0.4±0.2 mm.

4.2 Nymphs

Freshly emerged first instar nymphs were oblong in shape and light brown in color with three pairs of legs and a pair of six segmented .The The mean body length × breadth of first instar nymph was 1.586± 0.078×0.792±0.0311 mm. The antenna and feet measured 0.679 ± 0.011mm and 0.566 ± 0.018 mm respectively. Whereas, the morphological features of 2nd instar is same except the secretion of waxy powder just after molting on the dorsal side of the body. The mean length × breadth was found to be 4.82±0.081× 2.77±0.064 mm. Antenna and feet accordingly grew longer and they were measured to be 0.686±0.012 and 1.258±0.0074mm.Size increased enormously when 2nd instar molts to become 3rd. Wax secretion amount also increased manifold. The mean length × breadth of third instar female and male nymph were measured to be 16.32±0.50 x 6.82±0.66. Similarly, antennae and

feet became longer and achieved length of 0.761±0.009 & 6.82±0.6696 mm. When pupation completed, the male pupa measured 18.2±0.78× 8.19±0.14 mm.

4.3 Adults

A unique sexual dimorphism in mango mealy bug adults was noticed. Males were crimson colored having brownish black forewings. On the contrary, the females were white and wingless. Adults eventually achieved highest mean length × breadth with a measurement of 23.8±1.75×8.4±0.115 mm in females and males 10.54±0.36×4.14±0.052 mm. Antennae and feet also grew much longer achieving a length of 6.891±0.007 & 1.835±0.0195 mm in females and 2.42±0.066 & 2.64±0.052 mm males.

5. DISCUSSION

In the present study, mango mealy bug *D. mangiferae* completed only one generation in one year. The whole process of development took place in a period of 140-150 days (from 1 SMW-20 SMW) with an intervening egg diapause for almost 6 to 7 months separating the two consecutive generations. With the advent of conducive weather factors in January, eggs started to hatch. This observation was in close conformity with previously published reports [12,16,17,18,19,20,21,22]. The marginal variations that were noticed may be due to heterogeneity of agro climatic conditions.

The time taken for completion of the whole nymphal period in the current study was found to be in close agreement with the report of Bhau et al. [16] who have shown that within 125±10.17 and 110.5±10.01 days female and male mealy bug finishes their life cycle in the agro-ecological conditions of Jammu, India.

Female adult had a much greater longevity than adult male. Regarding the survival duration of the adult female and male, this present observation is contradicted by the findings of Chandra et al. [19] who have reported that males and females lived for 4-6 and 18-51 days respectively. The difference of abiotic factors i.e temperature, humidity during the period of study or food source are supposed to be the causal agents of these anomalies and it can be concluded so because it is very well established fact that ecological zone and associated weather conditions as well as host plant can have a profound effect on life cycle parameters as elucidated by Amarasekare et al. [23] and Venilla et al. [24].

According to the current study 1st instar took maximum amount of time to mature compared to 2nd and 3rd instars. From pupa to adult i.e. pre-pupa, pupa and adults period of development are not differing from each other significantly. All these findings regarding the the time spent in various instars is supported by the findings of Chandra et al. [25] and Bhau et al. [16]. Fecundity expressed as number of eggs produced by female and fecundity of the female in present study was very much similar the reports of Bhau et al. [16] who have reported that females produce 122.2±22.70 eggs (range 85-133).

Sex ratio was female biased similar to the findings of Mani Chellappan et al. [26] who have reported that in potato sprouts sex ratio of mealy bug gets more female biased.

Current findings corresponding to the mealy bug egg shape & size were perfectly in sync with the studies of Singh et al. [27] who have reported the length and breadth to be 0.79 - 1.30×0.435 - 0.830 mm and in close conformity with Rahman & Latif [28] who had reported the length × breadth of the eggs to be & 0.9 - 1.1 0.65 to 0.75 mm respectively.

The length width of the freshly emerged 1st instar nymphs was very much similar to the findings of Singh et al. [29] and Rahman & Latif [28]. As per this current study the length of the 2nd instar is fitting closely with that of Bessan [30] who had reported body length of 2nd instar nymph to be 4 mm.

The mean length and width of the 3rd instar was recorded in current study was much higher than the earlier reports by Bhau et al. [16] Rahman & Latif [28] & Singh et al. [27] about 3rd instar mango mealy bug size. They have reported maximum length 3rd instar to be 7.7 mm and breadth to be 3.72 and 3.70 mm respectively. The mean size of the female adult was found to be 23.8 mm in the present study. Even individual female adults collected from field had the approximately the same sizes as the present laboratory study. Therefore, it can be inferred that the size of the 3rd instar and female adult was bigger compared to other studies of mango mealy bug [16,28]. The reason for this difference can be host plant type on which it is reared [31] One study undertaken by Tanga et al. [32] revealed that mealy bugs reared on different host plants significantly differ from each other in size. Body size is influenced, among other factors, by differential nutritional quality of the host plant species, chemical constituents as well as physical differences in the plant structures as these factors affect development, reproduction, behavior and survival of herbivorous insects as discussed elsewhere [33,34].

Throughout the period of development of mango mealy bug agro-ecological conditions play important role as reported elsewhere [35,36,37]. During this laboratory rearing study also it was noticed that temperature played important role to influence the life cycle parameters. With the rise of temperature atJanuary crawlers (maximum average temperature 17.62±5.00C°, 24.58±3.38C° and the average minimum temperature 15.85±5.26C°, 15.19± 3.24 C°) i.e the 1st instars started to hatch. 1st and 2nd molting were induced by further augmentation of temperature. Maintenance of this optimum temperature is indispensible as any kind of alteration will deviate brain hormone titer and subsequently molting hormone level in haemolymph as discused elsewhere [38,39].

6. CONCLUSION

Mango is one of the most important crop of Malda district of West Bengal state in India. Huge amount of revenue is generated in this region from mango and mango processed product. But each year farmers have to tolerate huge magnitude of crop loss due to variety of insect pest attack and amongst all, mealy bug is one such dreaded pest. The information generated by this life cycle study will be helpful to predict the time of attack, identify the most vulnerable stage and formulate control strategies for combating this notorious pest. Inegrated pest management plan like timing of foliar or soil pesticide spray, ploughing of orchard, plastic and grease banding of trunks, water spray etc can be constructed beforehand that can give farmers a chance for targeted suppression of mango mealy bug in the region of Malda and can also be tried elsewhere in India .

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COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Litz RE. The mango: Botany, production and uses, CAB International, University Press,Cambridge; 1997.
2. Sathe TV, Shendge N, Khairmode PV, Kambale C, Patil SS, Desai AS. Incidence and damage of mealy bug *Droschia mangiferae* Green (Hemiptera: Coccidae) on mango *Mangifera indica* L. from Kolhapur District, INDIA. International Journal of Science, Environment and Technology. 2014;3(3):905-909.
3. Sahoo SK, Jha S. Bio-ecology of mango fruit borer, (*Autocharis = Noorda*) *albizonalis* Hampson (Pyralidae Lepidoptera) - A recent threat to mango growers in West Bengal, India. Acta Horticulture. 2009;(820):1345-1425.
4. Bhattacharyya M. Impact of ecological factors on the infestation of mango red banded caterpillar. Journal of Entomology and Zoology Studies. 2014;2(4):68-71.
5. Anonymous. Report of joint inspection team, Major Horticultural Crops in Malda District, West Bengal; 2017.
6. Ishaq M, Usman M, Asif M, Khan LA. Integrated pest management of mango against mealy bug and fruit fly. Journal of Agriculture and Biological Science. 2004;6: 452-454.
7. Tandon PL, Verghese A. World list of insect, mite and other pests of mango. Technical Document No. 5, IIHR, Banglore; 1985.
8. Rao CN, Shivankar VJ, Shyam S. Citrus mealy bug (*Planococcus citri* Risso) management - A review. Agricultural Review. 2006;27(2):142-146.
9. Arif MI, Rafiq M, Ghaffar A. Host plants of cotton mealy bug (*Phenacoccus solenopsis*): A new menace to cotton agro-ecosystem of Punjab, Pakistan. International Journal Agriculture and Biology. 2002;11(2): 163-67.
10. Bhagat KC. Mango mealy bug, *Drosicha mangiferae* (Green) (Margarodidae: Hemiptera) on Ashwagandha - a medicinal plant. Insect Environment. 2004;10 (1):14.
11. Moore D. Biological control of *Rastrococcus invadens.* Review article. Biocontrol News and Information. 2004;25:17-27.
12. Karar H, Arif J, Hameed A, Ali A, Hussain M, Shah FH, Ahmad S. Effect of cardinal directions and weather factors on population dynamics of mango mealy bug, *Drosicha mangiferae* (Green) (Margarodidae: Homoptera) on Chaunsa cultivar of mango, Pakistan Journal of Zoology. 2013;45(6):1541-1547.
13. Atwal AS. Insect pests of mango and their control. Punjab Hort. J. India.1963;3:238–245.

14. Kumar A, Pandey SK, Kumar R. Population dynamics of mango mealy bug, *Drosicha mangiferae* Green from Jhansi, Uttar Pradesh Biol. Fr. 2009;1(2):77-79.
15. Gautam RD. Biological pest suppression. Westville Publishing House, New Delhi; 2008.
16. Bhau B, Ushankar U, Abrol U. Studies on host range and biology of mango mealy bug (*Drosicha mangiferae*) in Jammu Region. International Journal of Current Microbiology and Applied Sciences. 2017; 6(9):230-240.
17. Ashfaq M, Khan RA, Khan MA, Rasheed F, Hafeez S. Complete control of mango mealy bug using funnel type slippery trap. Pakistan Entomology. 2005;27(1):45-48.
18. Atwal AS. Insect pests of mango and their control. Punjab Horticulture Journal. 1969;3 (2-1):235-58.
19. Chandra A, Singh KM, Bhatti DPS. Egg laying behaviour of gravidfemales of mango mealy bug, *Drosicha mangiferae* Green is influenced by soil moisture regimes. Indian J Entomol. 1989;51:101-104.
20. Singh R, Prasad CS, Kumar D, Kumar H, Kumari N. Study on biology of mango mealy bug, *Drosicha mangiferae* (Green), (Tephritidae:Diptera). South Asian J. Food Technol. Environ. 2015;1(2):170-174.
21. Srivastava RP. Mango insect pests and their management. In: Mango cultivation. International Book Distribution Co. Lucknow; 2000.
22. Tandon PL, Lal B. Comparative efficacy of synthetic garlic oil with some modern insecticides against *Drosicha mangiferae* Green. Progressive Horticulture. 1979;12(3): 62-65.
23. Amarasekare KG, Mannion CM, Osborne LS, Epsky ND. Life history of *Paracoccus marginatus* (Hemiptera: Pseudococcidae) on four host plant species under laboratory conditions. Enviromental Entomolology. 2008; 37:630-635.
24. Vennila S, Deshmukh AJ, Pinjarkar D, Agarwal M, Ramamurthy VV, Joshi S, Kranthi KR, Bambawale OM. Biology of the mealybug *Phenacoccus solenopsis* on cotton in the laboratory. Journal of Insect Science. 2010;10: 115.
25. Chandra A, Bhati DPS, Singh KM. Bionomics of mango mealy bug *Drosicha mangiferae* Green. Bulletin of Entomology.1987 28 (2): 145-52.
26. Mani Chellappan, Lawrence L, Ranjith MT. Biology and morphometry of *Paracoccus* marginatus Williams and Granara de Willink (Hemiptera: Pseudococcidae). Entomon. 2013; 38(2):97- 110.
27. Singh R, Prasad CS, Kumar D, Kumar H, Kumari N. Study on biology of mango mealy bug, *Drosicha mangiferae* Green, Tephritidae: Diptera. South Asian J. Food Technol. Environ. 2015;1(2):170-174.
28. Rahman KA, Latif M. Description, bionomics and control of giant mealy bug *Drosicha stebbingi* Green (Homoptera: Coccoidae). Bull Entomol Res.1944;35:197-209.
29. Singh A. Probable agricultural biodiversity heritage sites in India: XIII. Lower Gangetic Plain or Delta Region. Asian Agricultural-History. 2012;16(3):237-260.
30. Beesan CF. The ecology and control of the forest insects of India and the neighboring countries. The Vasant Press, Dehradun, India; 1941.
31. Chrysantus MT, Ekesi S, Govender P, Mohamed AS. Effect of six host plant species on the life-history and population growth parameters of *Rastrococcus iceryoides*. (Hemiptera: Pseudococcidae). Florida Entomologist. 2013;96(3): 1030-1041.
32. Tanga MC. Bio-ecology of the mango mealybug, *Rastrococcus iceryoides* Green (Hemiptera: Pseudococcidae) and its associated natural enemies in Kenyaand Tanzania. PhD Thesis, University of Pretoria, Pretoria 0002, South Africa. 2012.
33. Bethke JA, Redak RA, Schuch UK. Melon aphid performance on chrysanthemum as mediated by cultivar and deferential levels of fertilizationand irrigation. Entomol. Exp. Appl. 1998.88: 41-47.
34. Slansky JE, Rodriguez JG. Nutritional ecology of insects, mites, spiders and related invertebrates: An overview Slansky Jr, Rodriguez JG [eds.], John Wiley & Sons, New York, USA;1987.
35. Chakraborty K, Sarkar A, Nandi PS. Incidence of mango mealy bug *Drosicha maangiferae* (Coccidae: Hemiptera) in the agro-climatic conditions of the upper gangetic plain of West Bengal. India. I.J.S.N. 2015;6(4):568-575.
36. Das T, Chakraborty K. Seasonal occurrence and record of alternative host plant of mango mealy bug, *Drosicha mangiferae* in relative to climatic parameters at Malda, West Bengal.

The Pharma Innovation Journal. 2018;7(9):55-61.

37. Nandi PS, Chakraborty K. Effect of temperature ramping on the mortality of mango mealybug, *Droschia mangiferae* under laboratory conditions. J. Entomol. Zool. Stud. 2015;3(3):469-474.

38. Okasha AYK. Effects of high temperature in *Rhodnius prolixus (Stal.)*. Nature, Lond. 1964; 204,1221-22.

39. Wigglesworth VB. The action of growth hormones in insects. In The Biological Action of Growth Substances. Symp. Soc. Exp. Biol. XI. 1957;204-27.