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H Sunil Naik
Department of Entomology, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

KS Jagadeesh
Department of Entomology, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

BS Basavaraju
Department of Entomology, college of agriculture, Hassan, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

Correspondence
H Sunil Naik
Department of Entomology, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

Biology and management of pink mealy bug, *Maconellicoccus hirsutus* (Green) on custard apple (*Anonna squamosa* L.)

H Sunil Naik, KS Jagadeesh and BS Basavaraju

Abstract
Studies on the biology and management of *Maconellicoccus hirsutus* on custard apple was conducted at the Department of Agricultural Entomology and Division of Horticulture, Zonal Agricultural Research Station (ZARS), Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural Sciences, Bengaluru, Karnataka during 2014-15 and 2015-16. The result showed that female had three nymphal instars without any pupal stage, while male had three nymphal instars besides, pre-pupal and pupal stages. The developmental period from immature crawler to adult stage was greater for males (32.5 ± 4.63 days) compared to females (26±2.05 days). Females showed dynamic patterns of fecundity with the ranged from 356 to 444, with an average fecundity of 407.8±23.72 eggs/ovisac. Bisexual and parthenogenetic mode of reproduction was observed in case of *M. hirsutus.* Evaluation of insecticides for the management of *M. hirsutus* under field conditions revealed that the lowest larval population and highest per cent reduction was recorded in profenophos (0.05 %) and methyl parathion (0.05 %).

Keywords: Insecticides, custard apple, insect pests, natural enemies, *M. hirsutus*

1. Introduction

Custard apple, *Annona squamosa* L. (Family, Annonaceae), is a lowland or marginally subtropical crop, growing between latitudes of 23° north and south and native of the Tropical America and West Indies (Pinto *et al*., 2005) [14]. This crop is cultivated throughout the tropics and warmer subtropics for its edible fruit. In India this is an important dryland fruit, grown well in arid zones throughout the plains, at elevations of up to 4,000 ft. and it prefers a tropical climate (Singh, 1992; Pinto *et al*., 2005) [16, 14]. Fruits are considered as delicious and nutritionally valuable dry regions due to its sweet delicate flesh and a fruit contains about 28-55 per cent of edible portion and has got good caloric value (Minh, 2014) [11]. It is having wide application in pharmacological sectors, as an antioxidant, antidiabetics, hepato-protective agent, having cytotoxic activity, gene toxicity, anti-tumour activity, act as an antilice agent and contains various substances like alkaloids, carbohydrates, fixed oils, tannins and phenolic substance and it is known to be salutary for cardiac disease, diabetes hyperthyroidism and (Neha and Dushyant, 2011) [13].

A. squamosa is attacked by a number of pests that feed on its roots, stems, leaves and fruits (Gabriel, 1975) [6]. Butani (1979) [4] recorded about 20 species of insect pests that have been reported to attack the crop in India, of which the mealybug species are the major one causing significant fruit yield loss. Being a polyphagia, in recent years the infestation of pink mealybug, *M. hirsutus* has become very severe on fruits, vegetables, ornamental and other related crops, hence reducing the yield and deteriorating the quality of the crop (Balikai, 2005) [2]. Since *M. hirsutus* causes serious damage to custard apple, the present investigation was carried out to study the biology and to identify effective means of suppression of this pest on custard apple.

2. Material and Methods

Biology of *M. hirsutus* was studied in the laboratory during 2015 at Gandhi Krishi Vigyan Kendra (GKVK) campus, University of Agricultural Sciences, Bengaluru. The mean maximum and minimum temperatures prevailed during the study were 25.9°C and 18.7°C, respectively, with a mean relative humidity of 71.2 per cent. Custard apple shoots with fruits having cut ends were immersed into 250 ml conical flask containing water to maintain the turgidity and freshness for longer time, placed in insect rearing cages (35cm x 30cm x 35cm). Individual eggs of *M. hirsutus* were placed on the custard apple fruits by using a fine camel hair brush and totally twenty five replications were maintained and the culture thus maintained in the laboratory was used as a source to study the biology of *M. hirsutus*. Observations were made twice in a day, on the incubation period, moulting period (to estimate the duration of each instar), total number of instars, pre pupa and pupa, pre oviposition, oviposition and post oviposition period, fecundity and adult longevity. Few individuals of each nymphal instar were collected and preserved in separate vials containing 70 per cent ethyl alcohol for making morphometric measurements of their body length and breadth and also to study other morphological features. The measurements were made by using ocular micrometer after standardizing it with a stage micrometer at 40x magnification. Similarly the length and breadth of adult male female was also measured, in order to know the influence of host plants on the growth parameters of the insect.

The field investigation was conducted to evaluate the bio-efficacy of two commercial entomopathogenic fungal formulation, one commercial neem formulation and four chemical insecticides against *M.hirsutus* on custard apple and spray solution at the required concentration was prepared and 1 ml of sticker was added to each litre of the suspension. The experiment was laid out in a randomized complete block design (RCBD), comprising of nine treatments and three replications and each replication comprised of four plants. In each plant six fruits were labelled appropriately for taking pre and post-spray observations on the pest. The treatments were imposed by using a knapsack sprayer. The initial population of *M. hirsutus* was recorded. The respective Observations were recorded before spraying, two, five and ten days after spraying. Observations were made on natural enemies of *M. hirsutus* at weekly intervals. The per cent parasitisation /predation of major natural enemies was recorded and correlated with the weather parameters. The data on the number of mealy bugs per fruit and the per cent reduction in pest population was subjected to square root and angular transformations, respectively. The transformed data was subjected to statistical analysis under RCBD.

3. Results and Discussion

3.1. Morphometrics and biology of *M. hirsutus*: The morphometric measurements on egg, nymphal instars, pupae and adults (both male and female) of *M.hirsutus* on custard apple are shown in Table 1. The growth parameters on developmental periods of egg, nymphal instars, pupae, adult (both male and female), pre-oviposition, oviposition, fecundity and post-oviposition period are shown in Table 2.

Studies on the biology of *M. hirsutus* revealed that the eggs of *M. hirsutus* were smooth, translucent and yellowish to pale orange in colour, laid in egg sac which is three to four times the body length and entirely covered with white wax. The ovisac was observed on the ventral side of the adult female; the incubation period varied from 3 to 8 days with a mean of 5.80±1.31days. Similar biology observations were recorded by Katke *et al*. (2009) [8], Mani (1986) [10] and Shelke (2001) [16].

The female had three nymphal instars, the mean duration of the first, second and third nymphal instars of female were 4.9±0.87, 9.50±0.84 and 11.60±2.01 days, respectively. The total developmental period of female nymphs ranged from 21 to 28 days, with a mean of 26±2.05 days. The results of the present study are also confirmative with the findings Sahito *et al.* (2012) [15] and Katke *et al.* (2009) [8], who reported that the total nymphal period of female was 24.8±1.17 and 23.6±1.02 days in winter and summer, respectively.

The male mealybug had three nymphal instars, besides the pre-pupal and pupal stages. Mean duration of first, second and third instar nymph was 5.5±1.58, 10.4±0.5 and 9.3±1.25 days, respectively. At the end of third nymphal instar, the male nymph produced puparia over their bodies. The pre pupal period ranged from 2 to 4 days, with a mean of 2.7±0.8 days; pupal duration ranged from 4 to 6 days, with an average of 5.1±.73 days. The total developmental period of male nymphs ranged from 26 to 36 days, with a mean of 32.8±2.68 days. The longer nymphal duration of males as compared to that of the females was due to additional pre-pupal and pupal stages. The present findings are supported by the results published by Sahito *et al.* (2012) [15]. Contrary to the present findings Katke *et al.* (2009) [8] reported that the total nymphal duration of male in winter and summer was 23.3±1.07 and 21.6±0.89 days, respectively. The slight variation in the nymphal developmental time could be due to the differences in climatic conditions, particularly temperature and relative humidity.

In the present study, pre-oviposition and oviposition periods varied from 5 to 9 and 10 to 15 days, with a mean of 7.20±1.22 and 12.60±1.7 days respectively. Fecundity of female mealybug ranged from 356 to 444, with a mean of 407.80±23.72 eggs/ovisac. These results are more or less similar with findings of the Mani (1986) [10], who reported the average fecundity of 510.52±30.24 and 432.18±21.68 eggs by female of *M. hirsutus* on pumpkin and grapevine, respectively.

The developmental period of the adult female varied from 49 to 58 days, with an average of 53.5±2.01 days; while, the male developmental period varied between 31 to 40 days with a mean of 36.7±2.71 days. Similar observations were also reported by Sahito *et al*. (2012) [15]. On the contrary Katke *et al.* (2009) [8], reported that the total life cycle duration accounted for 32.8±1.72 and 45.9±1.92 days for male and female, respectively during winter season on pumpkin.

3.2. Efficacy of selected insecticides and botanicals against *M. hirsutus*: The studies on efficacy of insecticides revealed that the pre-treatment population of the mealybug ranged from 31.11 to 53.89 before imposition of the treatment (table 3). After imposition of the spray, the lowest mealybug population was recorded in profenophos (0.05) at two, five and ten days after spraying (DAS) was 12.28, 6.54 and 2.53, respectively, which was lowest and significantly superior over rest of the treatments. The highest mealybug population was observed in control. The reduction of mealybug population to the insecticidal treatment in the decreasing order of their efficacy were profenophos > methyl parathion > dichlorvos > methyl parathion dust > imidacloprid > *Verticillium lecanii*> *Beauveria bassiana* > neemark (Fig.1and 2).

The perusal of literature revealed that there is little work on the efficacy of insecticides against *M.hirsutus* under field conditions. However, the efforts have been made to compare these results with earlier work on other crops. The present findings are in line with those Bhosle *et al.* (2009) [3], who reported that the yield of seed cotton was significantly highest in acephate 70 SP (22.2 q/ha) and profenophos 50 EC (22.2 q/ha) which were at par with each other. Balikai (2002 and 2005) [1, 2], reported that buprofezin 25 SC @ 1125 ml/ha, along with fish oil rosin soap (meenark) at 3125 g /ha was effective for the management of the grape vine mealybug, *M.*

hirsutus. Muthukrishnan *et al.* (2005) [12], who reported that buprofezin 25 SC@1125 ml/ha sprayed thrice at 15 days interval reduced the congregation of *M. hirsustus* on grape and increased the yield. However, methyl parathion is on the list of insecticides which are being phased out. Therefore, caution has to be exercised, with the use of methyl parathion, particularly in the context of custard apple pest management**.**

Natural enemy complex of *M. hirsutus*: During the field investigation there were six species of natural enemies were recorded on the *M. hirsutus*. It includes five predators *viz.*, *Spalgis epius* (Westwood) (Lycaenidae: Lepidoptera), *Cryptolaemus montrouzieri* Mulsant, *Brumoides suturalis* (Fabricius), *Chilocorus nigritus* (F.) and *Scymnus coccivora* (Ayyar) and one parasitoid *Anagyrus kamali* Moursi (Encyrtidae: Hymenoptera). Among these, *S. epius* was found to be very effective and successful in reducing the *M. hirsutus* population under field condition. The population of *S.epius* was significant and positively correlated with *M. hirsutus* population (0.84**). Besides the same was positively correlated with morning RH (0.38**) and evening RH (0.40**), whereas it was, negatively correlated with maximum temperature (-0. 24), sunshine hours (-0.30) and rainfall (-0.04) (Table 4). Another predatory beetle *Cryptolaemus montrouzieri* activity was also showing significant positive correlation with *M.hirsutus* population (0.80**). Whereas, all the remaining weather parameters were not showing any significant correlation. Vinod kumar *et al*. (2007) [19], reported that *S. epius* had a significantly positive correlation with the mealybug population in coffee orchard, indicating that their population was density dependent. In contradictory the findings of Mani (1986) [10], who reported positive and significant correlation of maximum temperature with mealybug population on grapevine, while the relative humidity showed negative correlation. Similar studies were made by Dhawan *et al.* (2009) [5], Kumar *et al.* (2002) [9] and Hanchinal *et al.* (2010) [7] positive and significant correlation of maximum temperature with *M. hirsutus*, while the relative humidity showed negative correlation.

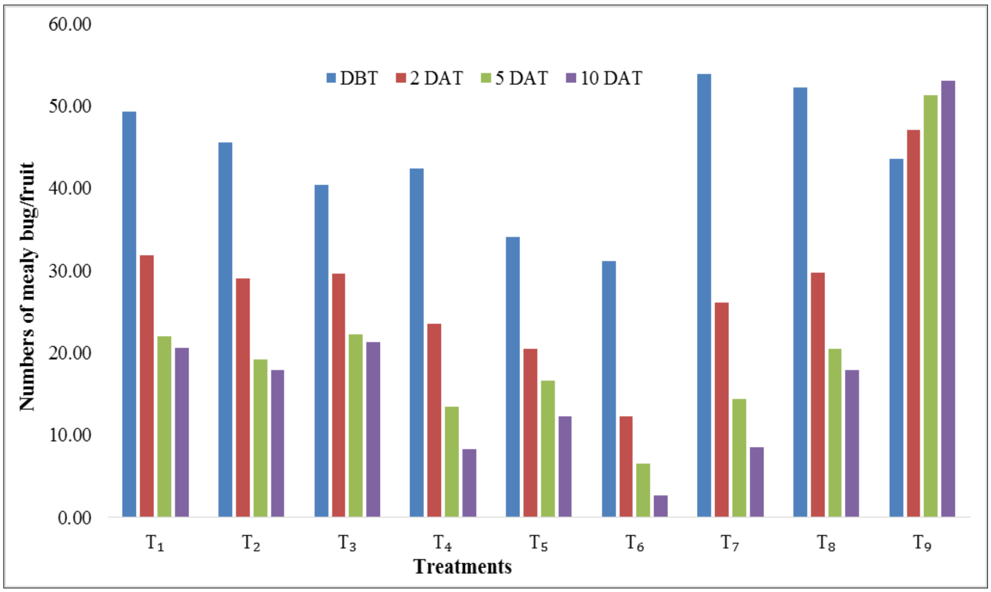

Fig 1: Effect of different insecticides on mealy bug numbers per fruit
(T_1-Verticillium; T_2-Beauveria; T_3-Neemark; T_4-Dichlorvos; T_5-Imidacloprid; T_6-Profenophos; T_7-Methyl parathion; T_8-Methyl parathion dust; T_9-water spray)

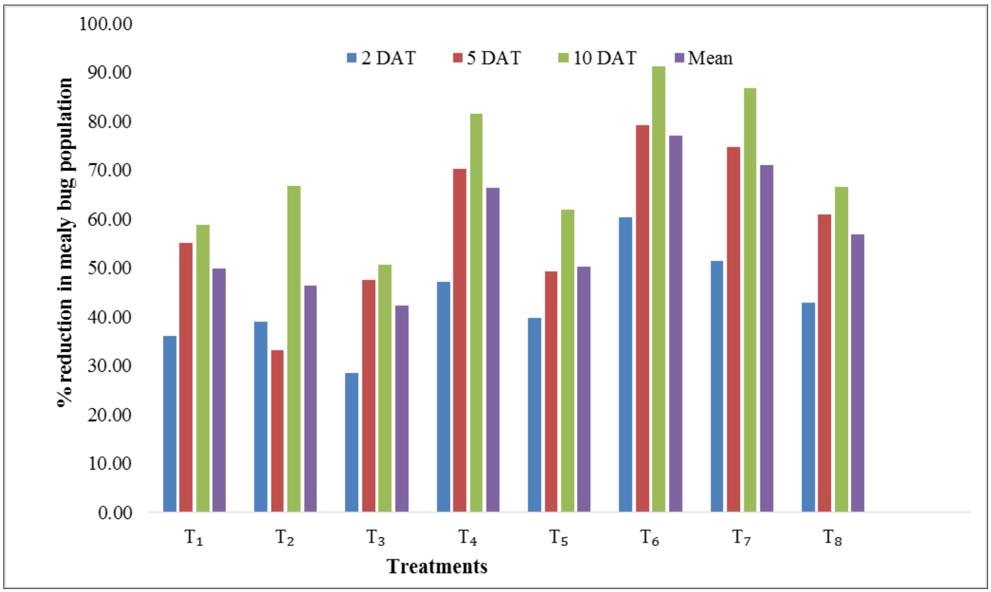

Fig. 2: Per cent reduction in mealy bug population due to insecticidal treatment
(T_1-Verticillium; T_2-Beauveria; T_3-Neemark; T_4-Dichlorvos; T_5-Imidacloprid; T_6-Profenophos; T_7-Methyl parathion; T_8-Methyl parathion dust)

Table 1: Morphometric measurements of different life stages of *M.hirsutus* on custard apple (*n=10).

Sl. No.	Insect stages	Length(mm)			Width(mm)		
		Range		Mean ± SD	Range		Mean ± SD
1	Egg	0.46	0.52	0.50±0.04	0.19	0.24	0.21±0.03
Nymphs							
2	I instar	0.43	0.47	0.42±0.03	0.21	0.24	0.21±0.06
3	II instar	0.67	0.84	0.76±0.08	0.30	0.33	0.29±0.02
4	III instar	1.61	2.13	1.88±0.07	0.66	0.74	0.68±0.10
5	Pupa	1.62	1.98	1.84±0.12	0.68	0.82	0.75±0.06
Adult							
6	Female	3.24	3.94	3.54±0.46	1.52	1.79	1.71±0.25
7	Male	1.30	1.38	1.29±0.07	0.17	0.21	0.18±0.04

Table 2: Life cycle stages of *M.hirsutus* on custard apple (*n=25).

Stages of Life cycle	Female (Duration in days)			Male (Duration in days)		
	Min	Max	Mean ±SD	Min	Max	Mean ±SD
Incubation period	3	8	5.80±1.31	3	8	5.80±1.31
Nymphal instars						
I	4	6	4.90±0.87	4	8	5.50±1.58
II	8	11	9.50±0.84	8	13	10.30±1.56
III	7	14	11.60±2.01	7	11	8.99±0.99
Total nymphal period	22	28	26.00±2.05	20	26	24.7±3.1
Pre-oviposition period	5	9	7.20±1.22	-	-	-
Oviposition period	10	15	12.60±1.7	-	-	-
No. of eggs/ovisacs	356	444	407.80±23.72	-	-	-
Pre-pupal period	-	-	-	2	4	2.7±0.80
Pupal period	-	-	-	4	6	5.1±0.73
Adult longevity	25	31	27.30±1.70	3	5	3.9±0.73
Total life span	49	57	53.5±2.01	32	40	36.7±2.71

Table 3: Efficacy of insecticides against *M. hirsutus* on custard apple under field conditions
Note: DBS-Day before spray; DAS-Day after spray.

Treatment and doses	Mean number of mealy bugs per fruit				% reduction in mealy bug population			Mean % reduction of mealy bug population
	DBS	2 DAS	5 DAS	10 DAS	2 DAS	5 DAS	10 DAS	
Verticillium lecanii (1.15% WP) 5g/lit	49.28 (7.05)	31.38 (5.69^{bcd})	22.00 (4.73^{b})	20.63 (4.59^{c})	36.00 (36.87^{abc})	55.05 (47.90^{b})	58.78 (50.06^{ab})	49.94 (44.97^{abc})
Beauveria bassiana (1.15 % WP) 5g/lit	45.56 (6.69)	29.00 (5.33^{bcd})	19.22 (4.31^{b})	17.86 (4.15^{bc})	39.02 (38.66^{abc})	33.26 (35.22^{a})	66.69 (54.75^{b})	46.32 (42.89^{ab})
Neemark 1000ppm 1.00%	40.39 (6.36)	29.67 (5.45^{bcd})	22.22 (4.70^{b})	21.27 (4.60^{c})	28.43 (32.22^{a})	47.59 (43.62^{ab})	50.62 (45.36^{a})	42.21 (40.52^{a})
Dichlorvos 76 WSC 0.15%	42.39 (6.48)	23.56 (4.84^{abc})	13.41 (3.64^{ab})	8.33 (2.92^{ab})	47.20 (43.39^{bcd})	70.31 (56.98^{cd})	81.47 (64.50^{c})	66.32 (54.53^{d})
Imidacloprid 17.8SL 0.017%	34.11 (5.82)	20.50 (4.58^{ab})	16.58 (4.13^{b})	12.25 (3.56^{bc})	39.69 (35.05^{ab})	49.34 (44.62^{b})	61.83 (51.84^{ab})	50.29 (45.17^{bc})
Profenophos 50 EC 0.05%	31.11 (5.59)	12.28 (3.56^{a})	6.54 (2.64^{a})	2.63 (1.76^{a})	60.40 (51.00^{c})	79.28 (62.92^{d})	91.27 (72.81^{c})	76.98 (61.33^{e})
Methyl parathion 50 EC 0.05%	53.89 (7.33)	26.05 (5.08^{bcd})	14.44 (3.80^{ab})	8.50 (2.83^{ab})	51.48 (45.85^{cd})	74.76 (59.84^{cd})	86.82 (69.71^{c})	71.02 (57.43^{de})
Water spray+ Methyl parathion dust 2 DP	52.22 (7.25)	29.68 (5.49^{bcd})	20.43 (4.57^{b})	17.90 (4.29^{c})	43.89 (41.49^{bc})	61.40 (51.59^{bc})	66.14 (54.42^{ab})	57.14 (49.10^{a})
Untreated control	40.28 (6.59)	40.13 (6.29^{cd})	40.00 (6.30^{c})	41.11 (6.44^{d})	-	-	-	-
'F' test	(NS)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
SE.m (±)	-	(0.45)	(0.43)	(0.44)	(3.07)	(2.86)	(2.84)	(1.55)
CD @ p = 0.05	-	(1.34)	(1.32)	(1.33)	(9.22)	(8.59)	(8.52)	(4.63)

Table 4: Correlation between *M.hirsutus* and its natural enemy with weather parameter

Parameters	Y	X1	X2	X3	X4	X5	X6
Y= *M. hirsutus*	1	0.32^{*}	0.45^{**}	-0.33	-0.33	-0.23	0.36
A= *Spalgis epius*	0.84^{**}	-0.24	0.16	0.38^{**}	0.40^{**}	-0.30^{**}	-0.04
B= *Cryptolaemus*	0.80^{**}	-0.08	0.11	0.14	0.17	-0.14	-0.08

Note: X1-Maximum temperature; X2-Minimum temperature; X3-Morning RH; X4-Evening RH; X5-Sunshine hour X6-Rainfall.

Conclusion

The present study on biology is helpful to determine the weak links in its growth stages and paved the way for its effective suppression. Due to the mealy/ waxy coated body the chemical means of managing mealybug in field is quite difficult, so encouraging the natural enemies and biopestiicde application is recommended. Monitoring and timely control measures can also help to reduce the pest impact to increase production while, biological control avenues may be fully explored.

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