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# Biology and management of mealybug, *Paracoccus marginatus* Williams and Granara de Willink on *Jatropha curcas* L.

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**Abstract:** Jatropha cultivation is gaining importance as potential source of biofuel. Recently *Paracoccus marginatus* has been found to cause serious damage on Jatropha. Studies on the biology and management of *P. marginatus* at GKVK, Bangalore revealed that the females had three nymphal instars without any pupal stage, while the male had three nymphal instars besides, pre-pupal and pupal stages. The total nymphal period for female ranged from 14 to 21 days, (mean- 17.32±1.6 days) while for male the range was 16 to 23 days, (mean- 18.9±1.3 days). Bisexual and parthenogenetic modes of reproduction were observed. The fecundity of the female mealybug ranged from 248 to 967, with an average of 618.9±19 eggs. Evaluation of insecticides revealed that during first spray and second spray, mean per cent reduction of mealy bug population was highest in profenophos 0.05% (68.05 and 79.35) followed by buprofezin 0.025% (63.61 and 72.69). Least per cent reduction of mealy bug was observed in the NSKE 5% (17.94 and 25.77) treatment.

**Keywords:** Insecticides, Insect pests, Jatropha, Natural enemies, *P. marginatus*

## INTRODUCTION

Biofuels are being promoted as sustainable alternatives to fossil fuels and the potential sources include jatropha, pongamia, mahua, neem, tumba, sal, jajoba and chullu. Among these *Jatropha curcas* L. (Euphorbiaceae) seems to be more promising, since the seeds are very rich in oil (40%), which is used as biofuel (Dehgan, 1984; Pant *et al.*, 2006). Although a native of Mexico and tropical America, it is being naturalized now throughout the world.

There are 22 species of insect and mite pests infesting jatropha of which papaya mealybug *Paracoccus marginatus* Williams and Granara de Willink causes severe damage (Veereshkumar and Ashok kumar, 2013). In India, the mealybug, *P. marginatus* was recorded in 2008 on papaya (*Carica papaya* L), mulberry (*Morus* spp.), jatropha (*Jatropha curcus* L.) and tapioca (*Manihot esculenta* Crantz), besides on some flower crops, vegetables and fruits (Regupathy and Ayyasamy, 2009; 2010; Mahalingam *et al.*, 2010). More recently *P. marginatus* has been found to cause serious damage on jatropha. Initially the mealybugs, congregated on apical shoots and later covered the entire plant; both nymphs and adults are found to suck the sap from leaves, shoots and fruits. The infestation resulted in symptoms like crinkling or twisting of leaves and shoots, bunched and unopened leaves, yellowing of leaves or leaf drop, fruit drop, appearance of honey dew on leaves, sooty mould development, stunted growth, deformation and death of the plants in case of severe infestation (Meyerdirka *et al.*, 2004; Lynne *et al.*, 2005 ; Walker *et al.*, 2008).

Since *P. marginatus* causes serious damage to jatropha, the present investigation was carried out to study the biology and to identify effective means of suppression of this pest on jatropha.

## MATERIALS AND METHODS

Biology of *P. marginatus* was studied in the laboratory during 2011 at Gandhi Krishi Vigyan Kendra (GKVK), Bangalore. The mean maximum and minimum temperatures prevailed during the study were 28.5ºC and 19.1ºC, respectively with mean relative humidity of 88.30 per cent. Terminal shoots of jatropha having cut ends were immersed into 250 ml conical flask containing water to maintain the turgidity, placed in insect rearing cages (35cm x 30cm x 35cm). Individual eggs were placed on the terminal shoots with a fine camel hair brush and totally twenty five replications were maintained. 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.

Efficacy of insecticide molecules and botanicals on *P. marginatus* was studied on jatropha seedlings raised in pots under glass house condition. The seedlings were artificially infested with 50 individuals of *P. marginatus* (2nd and 3rd instar nymphs) each. Three seedlings were maintained per treatment in each replication and the seedlings were kept at safe distances away to avoid drifting of the insecticides, while spraying.

The initial population of *P. marginatus* was recorded. The respective 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 CRD, comprising of ten treatments, with three replications. The treatments were imposed by using a Ganesh hand sprayer. Observations were recorded both before spraying, two, five and ten days after spraying.

Observations were made on natural enemies of *P. Marginatus* at fortnight intervals. The percent parasitisation of major parasitoid was recorded and correlated with the weather parameters.

## RESULTS AND DISCUSSION

**Morphometrics and biology of *P. marginatus*:** The morphometric measurements on egg, nymphal instars, pupae and adults (both male and female) of *P. marginatus* on jatropha 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 *P. marginatus* revealed that eggs are greenish yellow and are laid in an egg sac which is 3-4 times the body length and entirely covered with white wax. The incubation period varied from 3 to 9 days in female and 3 to 10 days in male. Similar biology observations were recorded by Miller and Miller (2002), Walker *et al.* (2008), Muniappan *et al.* (2008) and Singh and Beera (2010) who reported that the egg-laying of *P. marginatus* was usually in a small white ovi-sac and egg hatching occurred in about 10 days.

Female had three nymphal instars; the duration of first, second and third nymphal instars being 5.32, 3.48 and 8.52 days, respectively. The total developmental period of female nymphs ranged from 14 to 21 days, with a mean of 17.32 days. The present results are also in conformity with the findings of Muniappan *et al.*

**Table 1.** Morphometric measurements of different life stages of *P. marginatus* on Jatropha (*n=10).

| S. No. | Insect stages | Length(mm) Range | | *Mean ± SD | Width(mm) Range | | Mean ± SD |
|---|---|---|---|---|---|---|---|
| 1 | Egg | 0.32 | 0.37 | 0.35±0.01 | 0.15 | 0.17 | 0.16±0.01 |
| | **Nymphs** | | | | | | |
| 2 | I | 0.39 | 0.42 | 0.41±0.01 | 0.19 | 0.21 | 0.19±0.01 |
| 3 | II | 0.48 | 0.59 | 0.55±0.03 | 0.28 | 0.33 | 0.29±0.01 |
| 4 | III | 0.79 | 0.93 | 0.88±0.04 | 0.52 | 0.61 | 0.57±0.03 |
| 5 | Pupa | 1.52 | 1.88 | 1.78±0.12 | 0.42 | 0.62 | 0.05±0.06 |
| | **Adult** | | | | | | |
| 6 | Female | 2.14 | 2.34 | 2.14±0.06 | 1.12 | 1.29 | 1.21±0.05 |
| 7 | Male | 1.28 | 1.36 | 1.29±0.03 | 0.15 | 0.19 | 0.17±0.01 |

**Table 2.** Life cycle stages of *P. marginatus* on Jatropha (*n=25).

| Stage of Life cycle | Female Duration (in days) Min | Max | *Mean ±SD | Male Duration (in days) Min | Max | Mean ±SD |
|---|---|---|---|---|---|---|
| Incubation period | 3 | 9 | 6.80±2.0 | 3 | 10 | 6.80±2.0 |
| Nymphal instars | | | | | | |
| I | 4 | 6 | 5.32±0.6 | 5 | 7 | 5.8±0.7 |
| II | 3 | 4 | 3.48±0.5 | 4 | 5 | 4.5±0.5 |
| III | 7 | 11 | 8.52±1.3 | 7 | 11 | 8.6±1.5 |
| Total nymphal period | 14 | 21 | 17.32±1.6 | 16 | 23 | 18.9±1.3 |
| Pre pupal period | - | - | - | 2 | 3 | 2.3±0.48 |
| Pupal period | - | - | - | 4 | 5 | 4.7±0.4 |
| Pre-oviposition period | 6 | 9 | 8.28±1.02 | - | - | - |
| Oviposition period | 11 | 15 | 13.48±1.4 | - | - | - |
| Post-oviposition period | 7 | 9 | 7.64±1.0 | - | - | - |
| Adult longevity | 25 | 33 | 29.44±2.2 | 2 | 3 | 2.2±0.4 |
| Fecundity/ female | 248 | 67 | 618.9±19 | - | - | - |
| Total life span | 42 | 63 | 53.56±3.2 | 27 | 44 | 34.5±1.5 |

**Table 3.** Efficacy of insecticides and botanicals against *P. marginatus* (First spray).

| Treatment | Mean number of mealybugs per plant | | | | | | | Mean % reduction of mealybug population |
|---|---|---|---|---|---|---|---|---|
| | DBS | 2 DAS | % reduction | 5 DAS | % reduction | 10 DAS | % reduction | |
| Dimethoate 30EC (0.06 %) | 46.33 (6.84) | 24.67 $(5.01)^{bc}$ | 46.34 | 23.00 $(4.84)^{c}$ | 48.75 | 23.67 $(4.89)^{c}$ | 47.26 | 47.45 |
| Thiamethoxam 25 WDG (0.0125 %) | 47.33 (6.91) | 22.00 $(4.73)^{bc}$ | 53.15 | 21.00 $(4.64)^{bc}$ | 54.19 | 22.00 $(4.74)^{c}$ | 52.01 | 53.12 |
| Methomyl 40SP (0.04 %) | 47.33 (6.91) | 20.67 $(4.60)^{b}$ | 55.99 | 18.33 $(4.34)^{b}$ | 60.01 | 17.33 $(4.21)^{bc}$ | 62.19 | 59.40 |
| Profenophos 50EC (0.05 %) | 42.33 (6.54) | 15.67 $(4.02)^{a}$ | 62.70 | 13.00 $(3.67)^{a}$ | 68.29 | 11.00 $(3.38)^{a}$ | 73.17 | 68.05 |
| Buprofezin 25 SC (0.025 %) | 39.67 (6.30) | 16.33 $(4.10)^{a}$ | 58.50 | 14.00 $(3.80)^{a}$ | 63.56 | 12.00 $(3.52)^{ab}$ | 68.76 | 63.61 |
| Imidacloprid 200SL (0.10 %) | 41.67 (6.49) | 25.33 $(5.08)^{c}$ | 38.72 | 23.00 $(4.85)^{c}$ | 43.00 | 23.33 $(4.87)^{c}$ | 42.18 | 41.30 |
| Neem oil 300 ppm (0.03 %) | 48.67 (6.98) | 33.67 $(5.84)^{d}$ | 30.27 | 33.00 $(5.79)^{d}$ | 29.99 | 34.67 $(5.93)^{d}$ | 26.45 | 28.90 |
| NSKE 5 % | 44.67 (6.71) | 35.33 $(5.98)^{d}$ | 20.27 | 34.66 $(5.93)^{d}$ | 19.86 | 37.33 $(6.14)^{d}$ | 13.70 | 17.94 |
| FORS (2.00 %) | 46.33 (6.80) | 34.33 $(5.90)^{d}$ | 25.31 | 32.00 $(5.69)^{d}$ | 28.69 | 32.67 $(5.74)^{d}$ | 27.20 | 27.07 |
| Control | 42.33 (6.54) | 42.00 $(6.51)^{e}$ | - | 41.00 $(6.44)^{e}$ | - | 41.00 $(6.44)^{d}$ | - | - |
| ‘F’ test | NS | ** | | ** | | ** | | |
| SE.m (±) | - | 0.15 | - | 0.12 | - | 0.23 | - | - |
| CD @ p = 0.05 | - | 0.44 | - | 0.35 | - | 0.72 | - | - |

DBS: Day before spray; DAS: Days after spray; Means followed by same letter in the column do not differ significantly by DMRT (p = 0.05); Figures in the parentheses are square root transformed values; FORS: Fish oil rosin soap.

**Table 4.** Efficacy of insecticides and botanicals against *P. marginatus* (Second spray).

| Treatment | Mean number of mealybugs per plant | | | | | | | Mean % reduction of mealybug population |
|---|---|---|---|---|---|---|---|---|
| | DBS | 2 DAS | % reduction | 5 DAS | % reduction | 10 DAS | % reduction | |
| Dimethoate 30EC (0.06 %) | 33.00 (5.77) | 20.67 $(4.60)^{c}$ | 36.46 | 16.00 $(4.05)^{cd}$ | 50.45 | 6.67 $(6.67)^{c}$ | 79.20 | 55.37 |
| Thiamethoxam 25 WDG (0.0125 %) | 33.00 (5.76) | 19.33 $(4.44)^{c}$ | 40.56 | 14.33 $(3.84)^{cd}$ | 55.61 | 4.33 $(4.33)^{bc}$ | 86.48 | 60.88 |
| Methomyl 40SP (0.04 %) | 34.33 (5.88) | 16.33 $(4.10)^{bc}$ | 51.73 | 11.33 $(3.43)^{bc}$ | 66.26 | 4.00 $(4.00)^{bc}$ | 88.00 | 68.67 |
| Profenophos 50EC (0.05 %) | 30.66 (5.54) | 12.00 $(3.51)^{a}$ | 60.30 | 5.33 $(1.33)^{a}$ | 82.23 | 1.33 $(1.33)^{a}$ | 95.52 | 79.35 |
| Buprofezin 25 SC (0.025 %) | 30.66 (5.58) | 14.33 $(3.85)^{ab}$ | 52.58 | 8.00 $(2.90)^{ab}$ | 73.34 | 2.33 $(2.33)^{ab}$ | 92.17 | 72.69 |
| Imidacloprid 200SL (0.10 %) | 39.33 (6.20) | 27.00 $(5.24)^{d}$ | 30.35 | 18.00 $(4.27)^{d}$ | 53.23 | 11.33 $(11.33)^{d}$ | 70.33 | 51.30 |
| Neem oil 300 ppm (0.03 %) | 37.33 (6.14) | 27.33 $(5.27)^{d}$ | 25.72 | 26.33 $(5.17)^{d}$ | 27.91 | 24.00 $(24.00)^{e}$ | 33.81 | 29.14 |
| NSKE 5 % | 39.00 (6.23) | 30.00 $(5.52)^{d}$ | 21.95 | 28.33 $(5.36)^{d}$ | 25.75 | 26.67 $(26.67)^{e}$ | 29.60 | 25.77 |
| FORS (2.00 %) | 38.00 (6.20) | 28.67 $(5.38)^{d}$ | 23.46 | 26.00 $(5.13)^{d}$ | 30.07 | 22.67 $(22.67)^{e}$ | 38.58 | 30.70 |
| Control | 46.33 (6.84) | 45.67 $(6.79)^{e}$ | - | 45.33 $(6.77)^{e}$ | - | 45.00 $(45.00)^{f}$ | - | - |
| 'F' test | NS | ** | | ** | | ** | | |
| SE.m (±) | - | 0.19 | - | 0.24 | - | 0.20 | - | - |
| CD (p = 0.05) | - | 0.57 | - | 0.73 | - | 0.63 | - | - |

DBS: Day before spray; DAS: Days after spray; Means followed by same letter in the column do not differ significantly by DMRT (p = 0.05); Figures in the parentheses are square root transformed values; FORS: Fish oil rosin soap.

**Table 5.** Incidence of *P. marinatus* and its parasitoid, *A. papayae* in relation to weather parameters.

| Period | Mean no. of mealybug population/10cm top shoot | *A. papayae* | | RF (mm) | Sun shine hours | Temp. ($^0$C) | | RH (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean no. of mummified mealybugs | % Parasitization | | | Min. | Max. | Morning | Evening |
| JUNE I | 4.20 | 0.23 | 5.48 | 0.40 | 5.44 | 19.46 | 28.76 | 92.60 | 50.46 |
| JUNE II | 0.16 | 0.00 | 0.00 | 2.10 | 6.83 | 19.48 | 29.41 | 94.33 | 46.86 |
| JULY I | 0.00 | 0.00 | 0.00 | 3.90 | 4.89 | 19.21 | 27.82 | 93.66 | 53.26 |
| JULY II | 0.00 | 0.00 | 0.00 | 1.97 | 5.08 | 19.34 | 27.66 | 94.53 | 53.73 |
| AUG I | 0.00 | 0.00 | 0.00 | 3.73 | 3.83 | 18.66 | 27.16 | 94.33 | 52.86 |
| AUG II | 0.00 | 0.00 | 0.00 | 12.30 | 2.84 | 19.31 | 27.45 | 94.56 | 56.68 |
| SEPT I | 0.00 | 0.00 | 0.00 | 2.01 | 4.74 | 19.18 | 27.05 | 94.20 | 52.73 |
| SEPT II | 0.00 | 0.00 | 0.00 | 1.96 | 7.00 | 18.69 | 28.25 | 93.46 | 49.53 |
| OCT I | 0.00 | 0.00 | 0.00 | 4.89 | 5.00 | 18.61 | 28.58 | 93.80 | 50.73 |
| OCT II | 0.00 | 0.00 | 0.00 | 2.94 | 6.28 | 19.80 | 28.72 | 93.13 | 51.73 |
| NOV I | 0.00 | 0.00 | 0.00 | 2.53 | 6.72 | 16.58 | 26.76 | 89.26 | 53.73 |
| NOV II | 0.30 | 0.00 | 0.00 | 0.33 | 5.85 | 15.37 | 26.54 | 89.00 | 51.93 |
| DEC I | 2.60 | 0.00 | 0.00 | 0.00 | 6.85 | 16.34 | 27.01 | 90.33 | 53.26 |
| DEC II | 4.30 | 0.00 | 0.00 | 0.00 | 7.69 | 12.56 | 26.97 | 92.00 | 51.00 |
| JAN I | 3.20 | 0.00 | 0.00 | 0.34 | 4.02 | 16.12 | 28.30 | 89.92 | 47.79 |
| JAN II | 5.70 | 0.17 | 2.98 | 0.00 | 4.70 | 12.20 | 27.30 | 89.00 | 48.00 |
| FEB I | 7.20 | 2.10 | 29.17 | 0.00 | 8.82 | 15.39 | 29.61 | 88.67 | 36.73 |
| FEB II | 8.10 | 3.42 | 42.22 | 0.00 | 9.76 | 14.71 | 31.46 | 83.07 | 35.29 |
| MAR I | 8.90 | 3.78 | 42.47 | 0.00 | 8.73 | 18.79 | 32.92 | 82.40 | 32.20 |
| MAR II | 11.75 | 4.13 | 35.15 | 0.03 | 9.07 | 18.71 | 34.40 | 82.69 | 31.44 |
| APR I | 15.21 | 5.21 | 34.25 | 0.00 | 8.43 | 20.73 | 34.65 | 81.93 | 31.80 |
| APR II | 13.56 | 4.78 | 35.25 | 0.57 | 7.99 | 21.59 | 34.50 | 81.20 | 33.27 |
| MAY I | 10.54 | 2.32 | 22.01 | 5.40 | 7.66 | 20.51 | 32.49 | 86.60 | 39.00 |
| MAY II | 5.20 | 1.56 | 30.00 | 0.16 | 7.29 | 21.91 | 33.56 | 89.67 | 59.13 |

RF:Total rainfall (mm); Temp: Temperature (˚C); Min: Minimum; Max: Maximum; RH- Relative humidity (%)

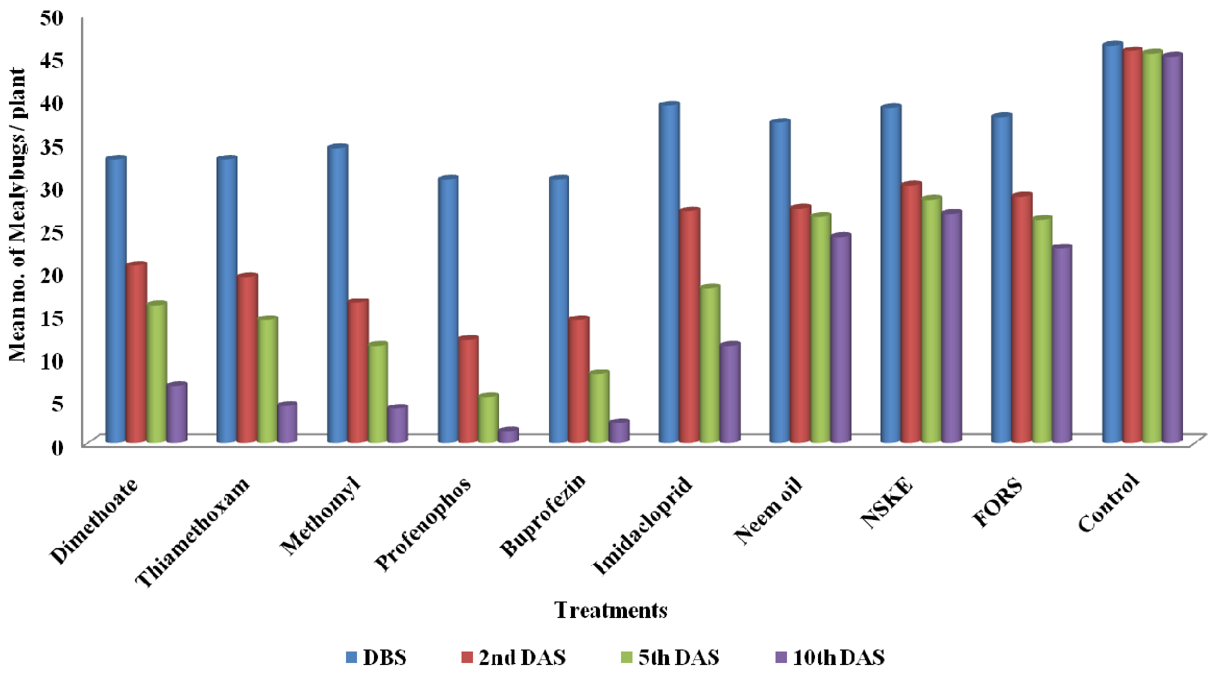


**Fig. 1.** *Efficacy of new insecticides and botanicals against P. marginatus under glass house condition.*

(2008), as they reported three nymphal instars, more or less same duration and no pupal stage in the wingless *P. marginatus* female.

Male mealybug had three nymphal instars besides pre-pupa and pupa; the mean duration of first, second and third instar was 5.8, 4.5 and 8.6 days, respectively. At the end of third nymphal instar, males produced puparia over their bodies. Pre-pupal period ranged from 2 to 3 days, with an average of 2.3 days; pupal duration ranged from 4 to 5 days, with an average of 4.7 days. The total developmental period of male nymphs ranged from 16 to 23 days, with a mean of 18.9 days. Longer nymphal duration of males compared to females was due to additional pre pupal and pupal stages. The present results are comparable to the findings of Walker *et al*. (2008), who reported three nymphal instars besides pupa and a winged adult stage in *P. marginatus*. But, the present results are contrary to the findings of Muniappan *et al.* (2008), as they had reported that the winged *P. marginatus* male has two nymphal stages, a pre-pupa and a pupal stage. The slight variation in the nymphal developmental time may be due to the differences in climatic conditions, particularly with respect to temperature and relative humidity. Amarasekare *et al.* (2008), who investigated the effect of temperature on the development of *P. marginatus* was able to complete its development between 18$^{o}$C to 35$^{0}$C and required 303.00 DD and 294.10 DD to complete development of the male and the female, respectively.

In the present study, pre-oviposition, oviposition and post-oviposition periods varied from 6 to 9, 11 to 15 and 7 to 9 days, with an average of 8.28±1.02 days, 13.48±1.4 days and 7.64±1.0 days, respectively. The present findings are similar to the findings of Muniappan *et al.* (2008) and Singh and Beera (2010) who reported that egg-laying of *P. marginatus* usually occurs over the period of one to two weeks; fecundity of female mealybug ranged from 248 to 967, with an average of 618.9±19. The fecundity of *P. marginatus* was similar to the observations made by Walker *et al.* (2008) and Singh and Beera (2010), who reported that females of *P. marginatus* usually lay 100 to 600 eggs in an ovisac, in a span of one to two weeks.

The developmental period of the adult female varied from 43 to 62 days, with an average of 53.56±3.2 days; while, male development varied between 27 to 44 days with an average of 34.5±1.5. Similar observations were recorded by McKenzie (1967), Walker *et al.* (2008) and Singh and Beera (2010), as they reported that the total life cycle/developmental period was 1-2 months depending on the season.

**Efficacy of insecticide molecules and botanicals against *P. marginatus*:** The studies on efficacy of insecticides *revealed* that the pre-treatment population of the mealybug ranged from 39.67 to 48.67 during 1$^{st}$ spray and 30.66 to 39.33 during 2$^{nd}$ spray (Table 3 and 4).

During 1$^{st}$ spray, the lowest mealybug population was recorded in profenophos at two, five and ten DAS was 15.67, 13.00 and11.00, respectively followed by buprofezin at two (16.33), five (14.00) and ten (12.00) DAS. The highest mealybug population was observed in control. The mortality of mealybug to the insecticides in the decreasing order, according to their efficacy were profenophos > buprofezin > methomyl > thiamethoxam > dimethoate > imidacloprid > neem oil > FORS and NSKE 5%. During 2$^{nd}$ spray, the lowest

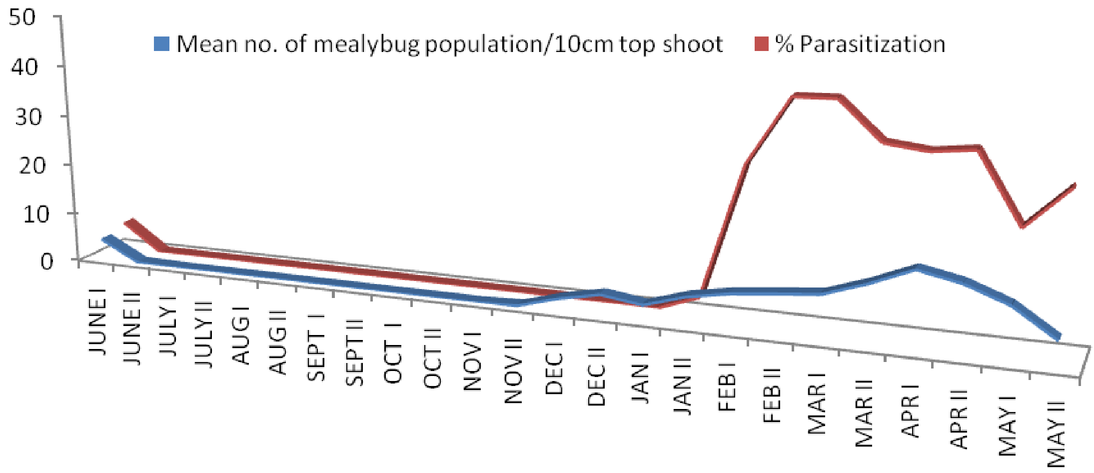


**Fig. 2.** *Population of P. marginatus and its per cent parasitization.*

mealybug population was recorded in profenophos at two, five and ten DAS with the mean value of 12.00, 5.33 and 1.33, respectively followed by buprofezin at two (14.33), five (8.00) and ten (2.33) DAS. The highest mealybug population was observed in control. The mortality of mealybug to the insecticides in the decreasing order, according to their efficacy were profenophos > buprofezin > methomyl > thiamethoxam > dimethoate > imidacloprid > neem oil > FORS and NSKE 5% (Fig. 1).

The perusal of literature revealed that there is little work on the efficacy of insecticides against *P. marginatus* under glass house conditions. However, the efforts have been made to compare these results with earlier work on other crops. Mahalingam *et al.* (2010) reported the effectiveness of profenophos @ 2 ml/liter on stumps immediately after pruning followed by second spray, 15 days after pruning along with stickers in controling of *P. marginatus*. Agarwal *et al.* (2009) reported three days after second spray, profenophos 50 EC recorded 93.73 per cent mortality over control and was on par with spirotetramate 12% + imidacloprid 36% 480 SC (36+108 g a.i./ha) (85.09% mortality) and thiodicarb 75 WP 750 g a.i./ha (84.48% mortality) on cotton. Bhosle *et al.* (2009), have reported 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 gave good control of mealybugs. Balikai (2002, 2005) reported 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) had reported that buprofezin 25 SC@1125 ml/ha sprayed thrice at 15 days interval reduced the congregation of *M. hirsutus* on grape and increased the yield.

**Natural enemy complex of *P. marginatus*:** There are ten natural enemies were recorded on the mealybug. They were 3 parasitoids *viz*., *Acerophagus papayae* Noyes and Schauff, *Anagyrus loecki* Noyes, *Pseudleptomastix mexicana* Noyes and Schauff and 7 predators *viz*., *Spalgis epius* (Westwood), *Cryptolaemus montrouzieri* Mulsant, *Brumoides suturalis* (Fabricius), *Cheilomenes sexmaculata* (Fabricius), *Scymnus coccivora* Ayyar, *Chilocorus* sp. and *Chrysoperla zastrowi* Sillemi (Esben-Petersen). Among these, *A. papayae* found to be more effective in controlling the mealybug population.

The population of the encyrtid parasitoid, *A. papayae* was significant and positively correlated with *P. marginatus* population (Table 5 and Fig. 2). Peak mealybug infestation was noticed during second fortnight of January to first fortnight of June (4.2 to 15.21/ 10cm top shoot). The peak infestation may be due to higher temperature that prevailed during this period, which probably helped fast multiplication of the mealybug. Further, positively correlated with maximum temperature (r = 0. 91) and sunshine hours (r = 0. 74). Whereas, significantly negatively correlated with morning (r = -0. 90) and evening (r = -0.85) relative humidity (Table 6). However, gradually decreases as the season advanced and there was no incidence during July to November. This could be due to higher rainfall during *kharif* and low temperature during *rabi* which might have caused low rate of reproduction of the mealy bug. This closely agrees with the findings of Mani (1986), 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), Kumar *et al.* (2002) and Hanchinal *et al.* (2010) positive and significant correlation of maximum temperature with *Maconellicoccus hirsutus*, while the relative humidity showed negative correlation.

Maximum per cent parasitization was noticed during mid February to first fortnight of March (42.47 %). The present results are in accordance and conformity with the observations made by Noyes and Schauff (2003), Kauffman *et al.* (2001), Meyerdirk *et al.* (2004) and Muniappan *et al.* (2006), who had reported that *A. papayae*, *A. loecki*, *Pseudaphycus* sp. and *P. mexicana* and predator, *C. montrouzieri* Mulsant as

**Table 6.** Correlation between mealy bug population and its parasitoid, *Acerophagus papayae* with weather parameters.

| Parameters | X1 | X2 | X3 | X4 | X5 | X6 | X7 |
|---|---|---|---|---|---|---|---|
| Parasitoid population | 0.928** | 0.916** | 0.294 | -0.914** | -0.888** | -0.318 | 0.741** |
| Mealy bug population | 1 | 0.861** | 0.139 | -0.902** | -0.858** | -0.391 | 0.693** |

X1= Mealy bug population; X2= Maximum Temperature; X3=Minimum Temperature; X4=Morning Relative humidity; X5=Evening Relative humidity; X6=Rainfall; X7=Sunshine hours; *Correlation is significant at $P \leq 0.05$ ; ** Correlation is significant at $P \leq 0.01$

effective in controlling of mealybug. Kaushalya *et al.* (2009), had reported that *A. papayae* recorded a higher per cent parasitism than *A. loecki* in both the open-sleeve cage (31.0% v/s 2.3%) and the no-cage treatments (21.4% v/s 1.6%) and caused the maximum mortality of *P. marginatus.* Mahalingam *et al.* (2010) found *Spalgis epeus* to be quite active and keeping the population under check in certain areas. Thangamalar *et al.* (2010) observed that *S. epeus* larvae devoured about 42 to 53 (48.15±4.08) ovisacs and 196 to 222 (210.99 ± 10. 77) nymphs and adults of *P. marginatus*.

## Conclusion

Accurate knowledge of the insects present in an area is essential as a basis for development of integrated pest management. Thus, the present study on biology is helpful to determine the weak links in its growth stages and paved the way for its effective suppression. In addition to general examination, to detect their speed, special attention should be focused on areas where mealybugs are likely to hide, such as shoot tips, leaf bases and on the fruits. Commodities for export should preferably be grown in pest-free areas. Pre-entry quarantine inspection and treatment should be prerequisites for export. Monitoring and timely control measures can also help to reduce the pest impact to increase bio-fuel production while, biological control avenues may be fully explored.

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