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RESEARCH ARTICLE

INTERACTIONS AMONG THREE TROPHIC LEVELS: INFLUENCE OF HOST PLANTS ON INTERACTIONS BETWEEN PINK HIBISCUS MEALY BUG, *MACONELLICOCCUS HIRSUTUS* (GREEN) AND ITS PREDATOR, *NEPHUS REGULARIS* SICARD

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ABSTRACT

The insect natural enemy interactions vary with the insect's host plant species and understanding such variation is important to study the preference of natural enemies, which play a major role in biological control programmes. In the present investigation, pink hibiscus mealy bug, *Maconellicoccus hirsutus* – predator interactions were studied on six different hosts *viz*. *Morus alba*, *Psdium guajava, Hibiscus rosasinensis, Abelmoschus esculentus, Gliricidia sepium* and *Mimosa pudica* in different seasons to find out the most favourable host as well as preference of the predator, *Nephus regularis*. The host plants highly influenced the incidence and population build up of *M. hirsutus* and also the third trophic entomophage. *M. hirsutus* preferred *H. rosasinensis* and *A. esculentus*. *M. alba* was the third preferred host. *P. guajava* and *M. pudica* were the least preferred hosts. The highest population of the pest was recorded on *A. esculentus* (28.4no.s/shoot) in winter and by *H. rosasinensis* (16.05 numbers / shoot) followed by *M. alba* (12.33) whereas *M. pudica* (11.00) and *P. guajava* (3.4) in summer. *M. alba* recorded highest population of the predator, *Nephus regularis* recording average number of 1.23 individuals per infested shoot followed by *H. rosasinensis* (1.05) in summer. Though, *A. esculentus* recorded highest *M. hirsutus* population in winter season (28.4 / branch) the predator population was comparatively lower (1.25). From the study it is clearly evident that any biological control measures taken to control *M. hirsutus* in the agricultural fields will be heavily influenced by *H. rosasinensis* and *G. sepium* plantations in the surroundings. Hence while releasing coccinellids for biological control these plants if available in the surroundings also should be considered.

INTRODUCTION

The pink mealy bug *M. hirsutus* was recorded in more than 350 hosts (Ghose, 1971). The mealybug infested garden showed the typical symptoms of curling of apical leaves and stunted growth (Ramesha *et al.,* 2009). The mealy bug population in the field is associated with many species of parasitoids and predators (Kumar *et al.*, 2012). Natural enemies of phytophagous insects grow and develop in multitrophic systems (Price *et al*., 1980). The host plants of insects are not neutral substrates upon which insect and the natural enemies occur. The preys on different host plants are often not of uniform quality (Vet and Dicke, 1992). The herbivore – natural enemy interactions may vary with the herbivore's host plant species and understanding such variation is important to the study of tritrophic interaction (Hare, 2002). The biological parameters in insects which feed on different hosts also vary (Ru and Mitsipa, 2000). *M. hirsutus* infested on *H. rosasinensis* and *H. sabdariffa* produced *A. kamali* with significantly higher fecundity and lower longevity compared to the other host plants (Persad and Khan, 2007). The behaviour and physiology of natural enemies, which determine their fitness, are influenced by both the plant and the phytophagous host in particular, the plant herbivore interactions affect the natural enemies (Tscharntke and Hawkins, 2002). The interactions among the single pests of different crop and interaction among natural enemies need to be understood before recommending a particular natural enemy of a single pest (Hare, 2002). Most of the time the biological control agents released to control a particular pest in the ecosystem is not successful. The different host plants of the pest in the ecosystem will host the pest giving different pest density. Hence in the present investigation, pink hibiscus mealy bug *Maconellicoccus hirsutus* – predator, *N. regularis* interactions were studied in six different hosts *Psidium guajava, Hibiscus rosasinensis, Abelmoschus esculentus, Gliricidia sepium, Mimosa pudica* and *Morus alba* which are available in the same crop environment hosting the same pest. The study is to find out the best preferred host and to find out the preference of the natural enemies.

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MATERIALS AND METHODS

The studies on the influence of different host plants on mealy bug *M. hirsutus* and its predator were conducted at Nagercoil, Kanyakumari district in the southern most side of Tamil Nadu state, India, situated between 77° 05' and 77° 26' of the eastern longitudes and 8° 03' and 8° 35' of the northern latitudes with an altitude of 131m above mean sea level. The details of materials and methodologies are given below: The different hosts of *M. hirsutus* which were commonly available in the farmers garden such as Guava (*P. guajava*), ladies finger (*A. esculentus*), shoe flower (*H. rosasinensis),* Gliricidia (*G. sepium*), sensitive plant (*M. pudica*) and mulberry (*M. alba*) were observed throughout the study. The number of *M. hirsutus* infested plants, healthy plants, number of mealy bug in the infested branch and the natural enemies in the infested branch were recorded in every fortnight for a period of two consecutive years. The above recordings were replicated five times. The recorded values were grouped as per four common season of the area, winter season (December, January and February), summer season (March, April and May), South west monsoon (June, July and August) and North east Monsoon (September, October and November) and tabulated. The following are the calculations implied

Plants infested by the *M. hirsutus* (%) = Number of infested plants / total number of plants x 100

Number of mealy bugs/infested branch = Total number of mealy bugs counted in infested branch / Total No. of infested branch counted

Number of *N. regularis* /infested branch = Total number of *N. regularis* counted in infested branch / Total No. of infested branch counted

data on percentage of mealy bug infestation was subjected to arcsine transformation and population counts were subjected to square root transformation, when any one of the values was zero, 0.5 was added to all the data before transforming the data. Data from laboratory experiments were analyzed by completely randomized block design and field experiments were analyzed by randomized block design. Duncan's multiple range test (DMRT) was used as test for significance.

RESULTS AND DISCUSSION

The results of investigation carried out on different hosts of *M. hirsutus* revealed that the infestation of mealy bug in different hosts and preference of the predator varied significantly. The *M. hirsutus* infestations in six different hosts in four different seasons are tabulated (Table .1). During the winter season the minimum temperature, maximum temperature and humidity recorded were 22 ± 1°C, 29 ± 1°C and 80 ± 10 % respectively. During this season there were significant differences in mealy bug infestation among host plants. The *M. pudica* was not preferred by the mealy bug. The infestation was significantly higher in *H. rosasinensis* followed by *A. esculentus.* The infestation in *G. sepium* was statistically on par with *P. guajava* infestation. In summer the minimum temperature, maximum temperature and humidity recorded were 24 ± 1 °C, 38 ± 1 °C, and 68±2 per cent respectively. During summer season lowest infestation was recorded in *P. guajava*. The *A. esculentus* was the next lowest. 47.75 per cent of the *M. pudica* was infested by mealy bug which was on par with mulberry. The maximum infestation was recorded in *H. rosasinensis* followed by G. *sepium.* In south west monsoon season the minimum temperature, maximum temperature and humidity recorded were 23 ± 5°C, 35 ±3 °C and 75 ±2 per cent respectively. In general the infestation was lesser than in this season, but there were significant differences among host plants. *H. rosasinensis* and *A. esculentus* recorded a significantly higher infestation followed by mulberry. *P. guajava* and *G. sepium* recorded the lowest infestation. There was no infestation of mealy bug in the *M. pudica*. North east monsoon season experienced 33 ± 2 °C of maximum, 23±1°C of minimum temperature, 85 ± 5 per cent of relative humidity. *P. guajava*, *A. esculentus* and the *M. pudica* were not infested by the *M. hirsutus.* The *A. esculentus* plants were least preferred. The significantly higher infestation was recorded in *H. rosasinensis* followed by *M. alba*. Host which was highly infested was considered as highly preferred host. In all the four seasons *H. rosasinensis* and *A. esculentus* were the highly infested hosts, followed by *M. alba* and *A. esculentus. P. guajava* was the least infested host.

Table 1. Infestations of M. *hirsutus* in six different hosts in four seasons

Sl. No	Name of Host plant	Plants infested by *M. hirsutus**(%)			
		Winter	Summer	South west monsoon season	North east monsoon season
1	*Psdium guajava*	9.00 (13.44)^{bc}	12.24 (19.47)^{a}	11.67 (16.53)^{b}	0.00 (0.29)^{a}
2	*Abelmoschus esculentus*	35.00 (31.35)^{d}	24.6 (26.17)^{b}	28.67 (32.39)^{e}	0.00 (0.29)^{a}
3	*Hibiscus rosasinensis*	43.46 (41.19)^{e}	64.13 (53.51)^{e}	27.40 (31.22)^{e}	37.4 (37.59)^{c}
4	*Gliricidia sepium*	9.33 (14.58)^{c}	51.25 (45.69)^{d}	12.60 (18.63)^{c}	0.00 (0.29)^{a}
5	*Mimosa pudica*	0.00 (0.29)^{a}	47.75 (43.71)^{c}	0.00 (0.29)^{a}	0.00 (0.29)^{a}
6	*Morus alba*	8.44 (12.20)^{b}	47.13 (43.23)^{c}	18.27 (23.41)^{d}	23.73 (28.39)^{b}

* Mean of 15 replications. Figures in parenthesis are arcsine transformed values.
In a column means followed by same letter are not significantly different (p = 0.05) DMRT

Table 2. *M. hirsutus* population in different hosts in different seasons

Sl. No	Name of Host plant	Number of *M. hirsutus* /infected branch*			
		Winter	Summer	South west monsoon season	North east monsoon season
1	*Psdium guajava*	5.8 (2.21) ^{c}	3.4 (1.95) ^{a}	2.6 (1.62) ^{b}	0.0 (0.71) ^{a}
2	*Abelmoschus esculentus*	28.4 (4.56) ^{e}	5.13 (2.28) ^{b}	8.13 (2.60) ^{d}	0.0 (0.71) ^{a}
3	*Hibiscus rosasinensis*	15.07 (3.77) ^{d}	16.05 (4.07) ^{e}	5.27 (2.23) ^{c}	4.47 (2.11) ^{b}
4	*Gliricidia sepium*	1.6 (1.75) ^{bc}	9.65 (3.07) ^{c}	3.4 (1.87) ^{b}	0.00 (0.71) ^{a}
5	*Mimosa pudica*	0.00 (0.71) ^{a}	11.00 (3.31) ^{cd}	0.0 (0.71) ^{a}	0.0 (0.71) ^{a}
6	*Morus alba*	2.19 (1.48) ^{b}	12.33 (3.55) ^{d}	5.4 (2.43) ^{cd}	6.6 (2.58) ^{c}

* Mean of 15 replications. Figures in parenthesis are square root transformed values.
In a column means followed by same letter are not significantly different (p = 0.05) DMRT

Table 3. Predator *N. regularis* population in the mealy bug infested different hosts during different seasons

Sl. No	Name of Host plant	Number of *N. regularis* in the infested branch*			
		Winter season	Summer season	South west monsoon season	North east monsoon season
1	*Psdium guajava*	0.00 (0.71) ^{d}	0.13 (0.76) ^{b}	0.06 (0.74) ^{b}	0.00 (0.71) ^{b}
2	*Abelmoschus esculentus*	0.26 (0.87) ^{bc}	0.1 (0.75) ^{b}	0.33 (0.83) ^{ab}	0.0 (0.71) ^{b}
3	*Hibiscus rosasinensis*	0.53 (1.03) ^{a}	1.05 (1.18) ^{a}	0.8 (1.30) ^{a}	1.06 (1.34) ^{a}
4	*Gliricidia sepium*	0.06 (0.75) ^{cd}	0.9 (1.13) ^{a}	0.46 (0.97) ^{ab}	0.0 (0.71) ^{b}
5	*Mimosa pudica*	0.00 (0.71) ^{d}	0.1 (0.75) ^{b}	0.0 (0.71) ^{b}	0.00 (0. 71) ^{b}
6	*Morus alba*	0.43 (0.96) ^{ab}	1.23 (1.21) ^{a}	0.4 (0.90) ^{ab}	0.73 (1.13) ^{a}

* Mean of 15 replications. Figures in parenthesis are square root transformed values.
In a column means followed by same letter are not significantly different (p = 0.05) DMRT

The *M. pudica* the common weed plant had maximum infestation only during summer and not preferred during other seasons.

Population of *M. hirsutus* in six different hosts in four seasons

Populations of M. hirsutus in six different hosts in four seasons are tabulated (Table 2). The number of mealy bugs per infected branch during winter season was significantly higher in *A. esculentus* followed by *H. rosasinensis.* The number of mealy bug was lower in *P. guajava*, *M. alba* and *G. sepium.* There was no *M. hirsutus* population in the *M. pudica* plant. The population of mealy bugs per infected branch in summer season was significantly lower in *P. guajava*, followed by *A. esculentus*, *G. sepium* and *M. pudica.* The significantly higher population was recorded in *H. rosasinensis* followed by mulberry per infected branch. The south west monsoon rains reduced the *M. hirsutus* population in all the host plants except *A. esculentus*. Significantly lower population was recorded in *P. guajava* followed by *G. sepium*. Significantly higher population was recorded in *A. esculentus* which was on par with mulberry. There was no incidence of *M. hirsutus* in the *M. pudica*. During north east monsoon season there was no incidence of mealy bug in *P. guajava, A. esculentus*, G. *sepium* and *M. pudica* but significantly higher population is recorded in mulberry followed by *H. rosasinensis* (Fig.1).

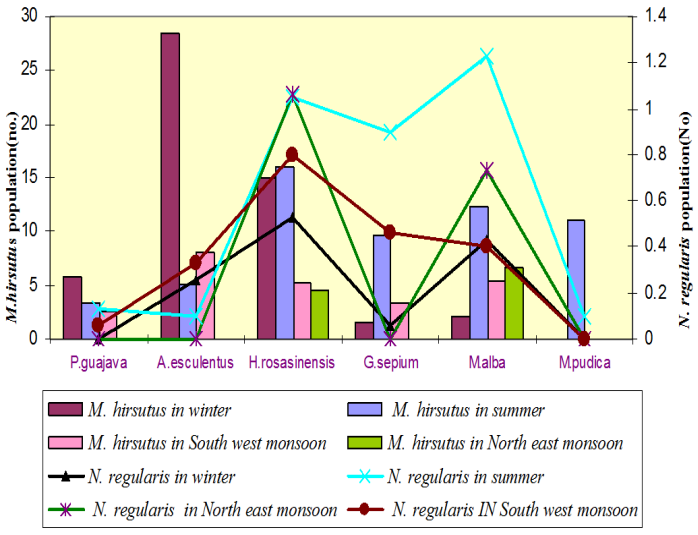

Figure 1. *M. hirsutus* and *N.regularis* population in different hosts

M. hirsutus preference of different host

Even though infestation of the *M. hirsutus* was recorded through out the year, higher infestation was recorded during summer season in all plants. During the summer season the *M. hirsutus* preferred *H. rosasinensis* with significantly higher infestation percentage and higher population of nymphs and adults of *M. hirsutus.* The second highest infestation was

recorded in *G. sepium* plants but only 9.65 number of ***M. hirsutus*** bugs were recorded per infested plant. The next preferred host is *M. alba* where 47.13 per cent of the branches were infested by *M. hirsutus* with 12.33 bugs in them. *M. pudica* plants were preferred only during summer with 11 bugs per infested stem. *A. esculentus* was less preferred, which recorded 24.6 per cent infestation with 5.13 bugs per infested stem. During summer *P. guajava* was the least preferred host with 12.24 per cent infestation and 3.4 bugs per infested stem.

During South West monsoon season highest preference was recorded in *A. esculentus* and *H. rosasinensis* with 8.13 and 5.27 bugs in the infested stem respectively. 18.2 per cent of *M. alba* plants were infested with 5.4 bugs per stem. *M. pudica* plants were not infested. The lowest preference was recorded in *P. guajava* with 11.67 per cent of infestation and 2.6 bugs per infested branch. During South West monsoon season also, *M. hirsutus* preferred *A. esculentus*, *H. rosasinensis,* and *M. alba*. *P. guajava* and *M. pudica* were the least preferred hosts. During north east monsoon season absolutely no infestation was recorded in *P. guajava, A. esculentus, G. sepium,* and *M. pudica* plants.

But 37.4 per cent of H. *rosasinensis* and 23.73 per cent of *M. alba* plants were infested by *M. hirsutus* with 4.47 and 6.6 bugs per infested stem. The heavy monsoon rains washed away the *M. hirsutus* from *P. guajava, A. esculentus, G. sepium,* and *M. pudica* plants. The bushy top appearance of the curled leaves of *H. rosasinensis* and *M. alba* could protect few bugs which latter multiplied in these hosts. During winter season except *M. pudica* all the hosts were preferred by the *M. hirsutus,* but the infestation rate and population of *M. hirsutus* were lower. *A. esculentus* and *H. rosasinensis* were highly preferred. Several researchers have reported on variation in biological parameters in herbivores on different hosts. Biology, survival percentage; female sex ratio and fecundity of *M. hirsutus* differed significantly when fed on different hosts (Persad and Khan, 2007).

The *M. hirsutus* infestation was seen through out the year in *M. alba* and *H. rosasinensis*. When the hosts were not intercepted by rains the ***M. hirsutus*** preferred *H. rosasinensis* and *A. esculentus, M. alba* was the third preferred host. *P. guajava* and *M. pudica* were the least preferred hosts. This is in confirmation with the findings which reported *H. rosasinensis* was the most preferred host of *M. hirsutus* (Goolsby *et al*., 2002)**.**

Population of predator *N. regularis* in the *M. hirsutus* infested branches in different hosts.

The populations of predator, *N. regularis* in the *M. hirsutus* infested branches in six different hosts are tabulated (Table .3). In the winter season significantly higher *N. regularis* population was recorded in *H. rosasinensis* which was on par with mulberry followed by *A. esculentus.* No predator was recorded in *P. guajava*. In summer, higher *N. regularis* population was recorded in mulberry and *H. rosasinensis* followed by *G. sepium.* Even though the *M. hirsutus* population was higher in *M. pudica* the predatory population was only 0.1 per infected branch. In south west monsoon season significantly higher *N. regularis* population was recorded in *H. rosasinensis* which was on par with *G. sepium* and mulberry. Significantly lower population was recorded in *P. guajava*. No predator was recorded in *M. pudica* as there was no *M. hirsutus* infestation. In north east monsoon season significantly higher *N. regularis* population was recorded in *H. rosasinensis* and mulberry. No predator was recorded in other host plants (Fig.1).

Preference of the predator *N. regularis*

The predator was recorded in all host plants during summer season. *M. alba* recorded highest population of *N. regularis* 1.23 no. per infested branch followed by 1.05 no. per infested branch in *H. rosasinensis* in summer. Even though *A. esculentus* recorded highest *M. hirsutus* population the predator population was lower. This may be due to the fact that the walking speed and host searching parameters of the predators were influenced by the size of the predator and the type of trichomes present in the plants which could affect the level of mealy bug control (Heidari, 1999). *P. guajava* was not preferred by predators. The *M. pudica* which recorded 47.75 per cent infestation with 11 *M .hirsutus* bugs per infested branch was not preferred by the predator. The predators preferred *H. rosasinensis*, M. *alba* and *G. sepium* plants than *A. esculentus* and *P. guajava.* This may be due the facts that during host's selection the predator use a variety of cues to assess the quality of the hosts such as shape, surface structure, internal and external chemical substances such as waxy secretions and honeydew (Godfray, 1994). The quality and quantity of these substances vary according to the species, variety, resistance level of the plant and influence of the host discrimination by natural enemies (Powell, 1992 ; Ru and Souissi, 1998). The predatory population was more in *H. rosasinensis* and *M .alba*. Lesser predatory populations were recorded in other hosts. The abundance of host plants coupled with their overlapping growing periods was be the main reason for the high pest densities of *Mussidia nigrivenella* (Lepidoptera; Pyralidae) in the field (Setamou, *et al*.,2000). Same condition of abundance of host plants and overlapping growing periods helped the pest *M. hirsutus* through out the year.

Conclusion

The host plants highly influenced the *M. hirsutus* infestation and population build up as well as the third trophic natural enemy. From the these results it is clearly evident that any biological control measures taken to control *M. hirsutus* in the agricultural fields will be heavily influenced by *H. rosasinensis* and *G. sepium* plantations in the surroundings. Hence while releasing coccinellids for biological control of *M hirsutus,* the pest population in different host plants available in the surroundings also should be considered to make the bio control successful.

To have a natural avoidance of the pest in *M. alba* plantations the host plants such as *A. esculentus* which was highly preferred by *M. hirsutus* but not by natural enemies can be avoided in the pest endemic areas or after harvest the plants should be carefully removed and composted.

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