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Classical biological control of the papaya Mealybug, *Paracoccus Marginatus* Williams and Granara de Willink, (Hemiptera: Pseudococcidae) in Sericulture

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Abstract : The papaya mealybug (PM), *Paracoccus marginatus* Williams and Granara de Willink, (Hemiptera: Pseudococcidae), is a major pest of mulberry plants in south India. Apart from common predators, several parasitoids viz. *Acerophagus papayae* (Noyes and Schauff), *Anagyrus loecki* (Noyes and Menezes), *Anagyrus californicus* Compere, and *Pseudaphycus* sp. have been reported to be highly potential. Recently another parasitoids identified as *Pseudleptomastix mexicana* (Noyes and Schauff) has been reported to be highly effective at field level. All four species of parasitoids prefers to attack second and third instars of *P. marginatus*. However, *Acerophagus* sp. emerged as the dominant parasitoid species. The parasitoids *Anagyrus loecki* Noyes, *Pseudleptomastix mexicana* Noyes and Schauff, and *Acerophagus papayae* Noyes and Schauff (Hymenoptera: Encyrtidae) were imported from Puerto Rico and field released in Tamil Nadu. *Anagyrus loecki* and *A. papayae* appear to be promising biological control agents of PM in Tamil Nadu. The reduction of the papaya mealybug population density levels below detectable levels was observed in a six-month period following the introduction of these exotic parasitoids. Following the successful implementation of a classical biological control program, the risk of this mealybug spreading to other neighboring states has been considerably reduced.

Biological potential, reproductive strategy, host searching ability and sex ratio of the parasitoids have been reported. Biological suppression methods involving augmentation, conservation and utilization of natural enemies are the most important aspect and the pest population is maintained at lower level by the action of parasitoids in its natural habitat. Augmentation involves actions to increase the populations of beneficial effects of parasitoids. Augmentation through inoculative or inundative releases of parasitoid is the most direct way of increasing the numbers of these beneficial. However our limited mass rearing capability is a serious impediment to the effective implementation of augmentation programme. Suitable strategy has been evolved for mass rearing of the parasitoids. Efficient and economical mechanized rearing systems are key requirements to wide spread use of this approach to biological control. Cost efficient and effective utilization of augmentation techniques is possible and has been implemented successfully to contain the bug population. All these aspects have been discussed in detail.

Key words:Papaya mealybug, *Paracoccus marginatus*, Hemiptera, Pseudococcidae, *Anagyrus loecki, Pseudleptomastix mexicana, Acerophagus papayae*, Encyrtidae, biological control.

INTRODUCTION

The papaya mealybug (PM), *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae) is native to Mexico and/or Central America (Miller et al. 1999)[1]. It was first described in 1992 (Williams & Granara de Willink 1992,[2]) and re-described by Miller & Miller (2002),[3]. In April 2003, G.W. Watson,[4] Natural History Museum, London, England (Currently, California Department of Food and Agriculture, Sacramento) confirmed the identity of PM following a

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March 2003 report of heavy infestations of mealybugs on papaya *Carica papaya* L. (Caricaceae) on the island of Koror and in the southern state of Airai on the island of Babeldaob of the Republic of Palau (Anonymous 2003),[5]. Papaya mealybug has a wide host range of over 60 species of plants (Kauffman et al., 2001 a &b)[6,7]. Its distribution and damage symptoms have been reviewed by Meyerdirk et al. (2004)[8]. The establishment of PM in Guam in 2002 and Palau in 2003 was flagged as a serious concern for the neighboring islands in the Pacific (Meyerdirk et al. 2004)[8,9]. This concern has been justified by its recent establishment on Maui in the Hawaiian Islands (Heu & Fukada 2004)[10]. Since the establishment of PM in Palau, home gardeners have been washing mealybugs from papaya trees with water using hoses and farmers have been using insecticides to control PM without much success.

Recent findings on the basic biology of insect parasitoids are providing new ideas that may help to increase the role of parasitoids in pest management in sericulture. Potential new approaches include behavioral manipulation with semiochemicals and artificial culture techniques that may allow economical mass production of parasitoids for release (DeBach and Hagen, 1964,[11] Lewis and Nordlund, 1985,[12]).The papaya mealybug (PM), *Paracoccus marginatus* Williams and Granara de Willink, (Hemiptera: Pseudococcidae), a serious pest of mulberry in south India is native to Mexico and /or Central America (Singh and Saratchandra 2010;[13] 2011,[14]) . Papaya mealybugs potentially poses a serious threat to mulberry crops as well as other crops, if not controlled. It was first described by Williams and Granara de Willink in 1992[2] and re-described by Miller & Miller in 2002[3] and since then causing serious damage to various economically important plants (Williams and Granara de Willink 1992;[2] Watson and Chandler 1999)[4]. The invasion due to this pest was first noticed in 2006 in Tamil Nadu and subsequently spread rapidly to several other part in India (Quadri et al. 2010)[15]. The papaya mealybug is a polyphagous pest and has been recorded on more than 55 host plants in more than 25 genera. Presently this invasive pest has spread to other crops in the region like, Okra, Cotton, Teak, Mulberry and Sunflower. Economically important host plants of the papaya mealybug include papaya, hibiscus, avocado, citrus, cotton, tomato, eggplant, peppers, beans and peas, sweet potato, mango, cherry, and pomegranate.

ECOLOGY and BIOLOGY

Papaya mealybug infestations are typically observed as clusters of cotton-like masses on the above-ground portion of plants. The adult female is yellow and is covered with a white waxy coating. Adult females are approximately 2.2 mm long and 1.4 mm wide. A series of short waxy caudal filaments less than 1/4 the length of the body exist around the margin. Eggs are greenish yellow and are laid in an egg sac that is three to four times the body length and entirely covered with white wax. The ovisac is developed ventrally on the adult female. Adult males tend to be colored pink, especially during the pre-pupal and pupal stages, but appear yellow in the first and second instars. Adult males are approximately 1.0 mm long, with an elongate oval body that is widest at the thorax (0.3 mm). Adult males have ten-segmented antennae, a distinct aedeagus, lateral pore clusters, a heavily sclerotized thorax and head, and well-developed wings. The papaya mealybug can easily be distinguished from pink mealybug *Maconellicoccus marginatus* (Green), because papaya mealybug females have eight antennal segments, in contrast to nine in the latter species (Miller and Miller, 2000,[16] Miller and Miller 2002)[3].

Papaya mealybugs have piercing-sucking mouthparts and feed by inserting their mouthparts into plant tissue and sucking out sap. Mealybugs are most active in warm, dry weather. Females have no wings, and move by crawling short distances or by being blown in air currents. Females usually lay 100 to 600 eggs in an ovisac, although some species of mealybugs give birth to live young. Egg-laying usually occurs over the period of one to two weeks. Egg hatch occurs in about 10 days, and nymphs, or crawlers, begin to actively search for feeding sites. Female crawlers have four instars, with a generation taking approximately one month to complete, depending on the temperature. Males have five instars, the fourth of which is produced in a cocoon and referred to as the pupa. The fifth instar of the male is the only winged form of the species capable of flight. Adult females attract the males with sex pheromones.

The papaya mealybug feeds on the sap of plants by inserting its stylets into the epidermis of the leaf, as well as into the fruit and stem. In doing so, it injects a toxic substance into the leaves. The result is chlorosis, plant stunting, leaf deformation, early leaf and fruit drop, a heavy buildup of honeydew, and death.

BIOLOGICAL CONTROL

Biological control was identified as a key component in a management strategy for the papaya mealybug (Kauffman et al. 2001a & b, Meyerdirk and Kauffman, 2001)[6,7,8,9]. Several potential predators and parasitoids were identified. Natural enemies of the papaya mealybug include the commercially available mealybug destroyer lady beetles (*Cryptolaemus montrouzieri*), lacewings, and hover flies, all which are generalist predators that have a potential impact on mealybug populations (Singh and Saratchandara 2010)[10]. In addition to predators, several parasitoids were recorded as potential biological control agents. The most important among them are: *Acerophagus papayae* (Noyes and Schauff, 2003)[17], *Anagyrus loecki* (Noyes and Hayat, 1994)[18], *Anagyrus californicus* Compere, and *Pseudaphycus* sp. Recently another parasitoids identified as *Pseudleptomastix mexicana* (Noyes and Schauff, 2003)[17] has been reported to be highly effective at field level. All four species of parasitoids prefers to attack second and third instars of *P. marginatus*. However, *Acerophagus* sp. emerged as the dominant parasitoid species. Few other parasitoids are also being collected and released in the affected areas along with measures to conserve and enhance their activity. Attempts have also been made to import potential parasitoids from United States of America for evaluation and large scale release in mulberry and other crops of the affected areas in India. Proven integrated methods adopted in effectively containing sugarcane woolly aphid and Cotton mealy bug is being replicated in mulberry also to minimize pest population (McKenzie 1967;[19] USDA, 1999,2000,[20,21,] Meyerdirk et al.)[8].

Biological suppression methods involving augmentation, conservation and utilization of natural enemies are the most important aspect and the pest population is maintained at lower level by the action of parasitoids in its natural habitat. Augmentation involves actions to increase the populations of beneficial effects of parasitoids. Augmentation through inoculative or inundative releases of parasitoid is the most direct way of increasing the numbers of these beneficial.

Augmentation involves actions to increase the populations of beneficial effects of parasitoids, predators or pathogens (Nordlund, 1984;[22] Ridgway and Vinson, 1977,[23]).There are two basic approaches to augmentation, environmental manipulation and periodic releases (Greany et al. 1983)[24]. Periodic releases can be inoculative or inundative. Inoculative releases are releases of relatively small number of biological control agents, often on seasonal basis. The control in inoculative release programs is expected to come primarily from the progeny of these agents being released. Inundative releases are releases of relatively large numbers of biological control agents, and the control is expected to come from the released agents, not necessarily from their progeny (DeBach and Hagen, 1964)[11]. Inundative releases programs usually involve the number of releases during the season, while inoculative release programs may involve only one release. It is possible by sustained release of laboratory-reared parasitoids.

Our ability to use periodic releases of the parasitoid to control mealybug , is to rear, transport and effectively release large number of high quality biological control agents. Periodic release requires continuous release program and thus, has commercial potential and fit IPM programs well. The growing number of commercial suppliers of biocontrol agents is evidence of this potential (Martinez et al. [25]; Rigway et al., 1977)[26]. Adoption of biological control has had positive economic impact (Rigway and Vinson, 1977)[26]. It must be pointed out that biological control particularly augmentation and conservation does not operate in vacuum. Biological control is the most successful as part of an integrated program involving host resistance and cultural control technology. The efficacy of such natural enemies may be sometimes enhanced through various method of augmentation, or direct manipulation of their populations, such as periodic colonization, genetic improvement, or the use of semio chemicals that affect their performance. Another possible approach is through conservation, or manipulation of the environment, either by adding of asking requisites or by mitigation of various detrimental factors.

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