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Initiatives of papain industry by private-public-farmer linkages in classical biocontrol program for papaya mealybug in Tamil Nadu

[1]A. Regupathy and [2]R. Ayyasamy

[1]*Senthil Papain & Food Products (P) Ltd.,* [2]*Department of Entomology, Faculty of Agriculture, Annamalai University, Annamali Nagar-608002, Tamil Nadu , India E-mail: regupathya@yahoo.com*

A B S T R A C T

Papaya cultivation for papain production is taken up by many progressive farmers in Tamil Nadu and facilitated by Senthil Papain and Food Products Ltd (SPFP), Coimbatore since 2004. The onslaught by the new invasive mealybug (PMB)-*Paracoccus marginatus* Williams and Granara de Willink) in 2006 caused major concern in papain production. The need for repeated application of insecticides and dearth of labour for application of insecticides made it difficult for the farmers to maintain the crop and forced many farmers to even abandon papaya crop cultivation altogether. Considering the drastic reduction in the wet latex supply, SPFP has taken up series of initiatives which are summarized in this paper. Initially, a survey made in more than 80 farmers holdings supplying wet latex to the industry to get the first hand information on the extent of mealy bug incidence. Secondly, it facilitated select cluster of papaya growers to meet the concerned authorities and scientists of Tamil Nadu Agricultural University (TNAU), Coimbatore to appraise them of the gravity of the situation and the need for getting effective biocontrol agent [*Acerophagus papayae* (Noyes and Schauff)] through ICAR-NBAII (National Bureau of Agriculturally Important Insects)-TNAU was emphasized as the existing biocontrol agents could not give relief. Later, when the exotic parasitoid was imported by NBAII, Bangalore, the papain industry wholeheartedly supported the training programmes by deploying its field staff in release and multiplication of the parasitoid. For enabling initial multiplication of the released parasitoids, farmers of heavily infested papaya fields were compensated for the yield loss to serve as field-mass-multiplication-strategy. Further, the farmers of neighbouring fields were encouraged and facilitated through thirteen field staff to take the bug infested leaves and fruits from parasite-released fields and dispersed in new fields. The effective mass-spreading of parasitoid was made thorough door-to-door contact and farmers were monitored not to take up spraying. The infested plant parts from infested fields were availed regularly by TNAU to facilitate mass production of parasitoid. This is a successful model of partnership of private sector-public institutions in biocontrol of the PMB biocontrol which has practically impacted through rise in quality and quantity of latex supply and area increase in papaya cultivation.

Keywords: Papaya mealybug, *Acerophagus papayae*, biocontrol, industry-scientists linkage.

Introduction

In Tamil Nadu papaya cultivation has been taken up by progressive farmers in and around Salem, Namakkal, Krishnagiri, Coimbatore Thiruppur, Erode and Dindigal districts for papain production. Papaya cultivation got popularity among the farmers in Tamil Nadu for two main reasons. First, the support extended by papain industry, Senthil Papain & Food Products (P) Ltd., Coimbatore (SPFP) technically and logistically by providing latex collection centres and cold storage facilities considering the export potential of the papain encouraged farmers taking up papaya cultiva-

tion. Secondly, papaya is relatively free from pests and diseases. Before 2006 plant protection measures were seldom taken though occasional and sporadic incidences of insect pests like fruit borer, fruit flies (*Bactrocera cucurbitae* Dov.), ak grasshopper (*Poekilocerus pictus* F.), aphids (*Aphis gossypii* Glov.), red spider mite (*Tetranychus cinnabarinus* Boisd.), stem borer (*Dasyses rugosellus*), grey weevil (*Myllocerus viridanus* Fb.), cotton whitefly (*Bemesia tabaci* Genn.), spiraling whitefly (*Aleurodicus dispersus* Russel) and scale (*Aspidiotus destructor* Sign) were reported (Regupathy *et al*. 2003 NHB; CPTHC 2004).

Change in pest scenario

The recent establishment of the papaya mealybug (PMB), *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae) in Tamil Nadu, India is of serious concern because this is the first reports of its occurrence in Tamil Nadu (Muniappan *et al.* 2008). Within few months of the first discovery of *P. marginatus*, the magnitude of the mealybug problem in papaya, cassava and mulberry was serious. Severe infestation of papaya (Anon 2009; Regupathy & Ayyasamy 2009, 2010a) forced farmers to take up repeated application of insecticides. Some of the farmers could not even maintain the crop after 2006 and has to give up papaya crop altogether. The supply of wet latex was drastically reduced from about 250-300 tones to 20 tones (Regupathy & Ayyasamy 2012).

The PMB is to be native to Mexico and/or Central America. It has never gained status as a serious pest there, probably due to the presence of an endemic natural enemy complex. But in places where they got introduced without their native natural enemies, it potentially posed a great threat to numerous agricultural products, if not controlled. The parasitoids *Anagyrus loecki* Noyes*, Pseudleptomastix mexicana* Noyes and Schauff*,* and *Acerophagus papayae* Noyes and Schauff introduced from Puerto Rico and field released in Guam from June to October, 2002 reduced of over 99per cent of PMB in an year and has reduced risk of introduction of this mealybug to neighbouring islands in the Pacific region (Meyerdirk *et al*. 2004). PMB potentially posed a threat to numerous agricultural products in the United States especially in Florida and states such as California, Hawaii, and Texas. Classical biological control was identified as an important component in the management of PMB (Walker *et al.* 2006). Following the successful implementation of a classical biological control programme for the management PMB in Palau, the risk of this mealybug spreading to other islands in the Republic of Palau and to neighboring Micronesian Islands had been considerably reduced (Muniappan *et al*. 2006).

Classical biological control programme in Tamil Nadu

Importing potential biocontrol agent

Thanks to the efforts taken by NBAII through USA consulate at New Delhi (Mark Gilkey)

and Dr Muniappan all the three parasitoids *Acerphagus papayae*, *Anagyrus loecki* and *Psedleptomastix mexicana* from the USDA, APHIS parasitoid rearing facility at Puerto Rico were imported on July, 15, 2010 (Rabindra & Shylesha 2011).

Mass multiplication

The parasitoids reared in quarantine laboratory of NBAII were confirmed for their host specificity and mass multiplied using potato sprouts for inoculative releases. Inoculative releases of the parasites multiplied in National Bureau of Agriculturally Important Insects, Bangalore (NBAII) and Department of Entomology, TNAU were done at the site of severe PMB infestation. The area of release was monitored after every 18 days to see the emergence of *A. papayae* and *A. loecki* and 25 days in case of *P. mexicana as* per the protocol prepared by NBAII, Bangalore. The survey for parasitization was followed up 3 and 6 months after initial release of the parasitoids. Each time, data on the parasitization by the parasitoids, different host plants on which observed and emergence of parasitoids recorded and analysed for assessing the impact of the released parasitoids.

Initiatives of papain industry

Field survey

Immediately on receipt of complaint from the papaya farmers in Coimbatore, Thiruppur, Erode and Dindigul districts that the PMB was affecting papaya on severe scale necessitating repeated application of insecticides and expressed their inability to maintain the crop after 2006 and forced to give up papaya cultivation altogether, a field survey was launched by the authors involving 81 fields of farmers supplying wet latex to SPFP with the logistic support provided by SPFP (Regupathy & Ayyasamy 2010b).

Assessing crop damage

The survey indicated that (Regupathy & Ayyasamy 2010b). Out of 81 fields *P. marginatus* incidence was observed in 76 fields. In fields where the infestation was so severe, the entire plant population was covered with bugs. Bugs after debilitating the papaya plants started moving to hedges and adjacent hosts including banana and neem. The fruit set was affected when male inflorescence was severely infested, reducing pollination. When female flowers were infested heavily, the flowers dried up and the fruit drop was observed. The fields in clusters that are contiguous or in close proximity are affected more or less uniformly. The fields that are secluded or isolated have less chance of infestation. The damage potential on yield was assessed from data collected from the SPFP on wet latex supply received. Data indicated drastic reduction in wet latex supply and reduction in area in papay (Regupathy & Ayyasamy 2012).

Host range

During the present surveillance, high level of infestation of *P. marginatus* was also found on several horticultural crops (bhendi, brinjal, curryleaf, guava, mango, papaya, pomegranate, silk cotton, *Solanum torvum, Solanum nigrum*, star gooseberry and west

indian cherry), mulberry, ornamentals including annuals, biennials and herbaceous perennials, flowering shrubs, foliaged shrubs, flowering trees, *s*elect ornamental foliage trees and weeds, hedge plants, voluntary plants (Regupathy &Ayyasamy 2010b).

Stem banding

Some of the farmers even attempted to stem banding by tying black polythene paper around stem above ground level to prevent the migration from infested material (Ayyasamy & Regupathy 2010). But the efficacy was limited.

Insecticides

During the survey taken in farmers holdings, in their anxiety to save the crop the farmers are trying various insecticides like chlorpyriphos, quinalphos, imidacloprid, acepahate, dimethoate in bizarre combinations and at very high doses. The combo may likely to hasten the development for all the chemistries simultaneously. As the effective period of insecticides was up to 7-10 days repeated applications are needed to check the population build up. Systemic poisons are very effective on foliage and flowers. Translocation of the poison to the pericarp of the developed fruits is very limited. Contact poisons are more suitable to check bug infestation on fruits. Moreover the bugs present on the hidden surface of the fruit bunches and on leaf axils poses the problem taking the contact poisons to these hidden targets (Ayyasamy & Regupathy 2010). Hence higher doses of insecticides than that used to other pests may be required when treating for mealy bugs because mealy bugs are protected by thick waxy, cottony sacs, and often are concealed inside damaged leaves, flower racemes and fruit bunches.

Natural enemy complex

Naturally-occurring predators including other lady beetles, lacewings, and hover flies, generally found on other species of mealy bug were seldom found feeding on PMG on papaya (Ayyasamy & Regupathy 2010). Notable numbers of lepidopteran (blue butterfly) predatory larvae, *Spalgis epius* (Westwood) were found feeding on PMB on other hosts like bread fruit, teak, pomegranate, *Tecoma, Thespesia*, *Hibiscus* and *Nerium*, *Thevetia* etc during cooler months only but not on papaya. Release of lab cultured commercially available generalist coccinellid predator, *Cryptolaemus montrouzieri* Mulsant reported to be successful to some extent for the management of other species of mealy bugs feeding on grapes, citrus, mango, guava, coffee, rubber, cocoa and mulberry in Tamil Nadu when done on trial basis did not make any impact on PMB.

Lessons learned

The following lessons were learned during field survey :

The strewn fallen leaves when not removed served as reservoir of bugs for further spread. The adults moved and stationed on the stem near the ground level. Marching of hatched out nymphs could be seen from the egg sacs

of the females harboured near the stem towards the top canopy of the plants preferring flowers / fruits.

The laterals of drip irrigation served as better path than the clods or soil from one plant to other plant.

The fields in clusters that are contiguous or in close proximity are affected more or less uniformly. The fields that are secluded or isolated have less chance of infestation.

Presence of alternative hosts (wide green bridge) of hedge plants, weeds and other crop hosts due to prevailing crop mosaic in small scale farming system enabled reinfestation even insecticide applied fields necessitating repeated applications.

Stem banding with polythene paper has limited efficacy but there is scope for improvement if coated with neem oil.

Repeated applications of insecticides alone and in various combo at an interval 7-10 days eliminated natural enemy complex from papaya field.

Scientists - industry - farmers linkage

Scientists - industry - farmers meet

The information collected from field survey on the extent of infestation of PMB, crop damage, alternative, hosts available for the pest in the vicinity of papaya field, natural enemy complex on papaya and other hosts, frequency of insecticides spray and operational difficulties in spraying encountered by the farmers was passed on to the concerned authorities and scientists in TNAU, Coimbatore and NBAII, Bangalore and ICAR (Table 1). Industry arranged select cluster of papaya growers to meet the concerned authorities and scientists of TNAU on March 12, 2010 at Coimbatore. Farmers appraised the gravity of the situation and the difficulties experienced by the farmers .In the meeting the farmers informed that insecticides need to be repeated at an interval of 7-10 days to keep the pest under check. The repeated application of insecticides escalated cost of production uneconomically. Moreover the operational difficulty experienced by them was on crop like papaya was reasoned out. The shortage of labour thanks to the Mahatma Gandhi Rural Employment Programme was indicated. The farmer himself has to take up spraying and it was difficult single handedly to maintain the field free from bug, by spraying at 7-10 days interval especially on grown up trees. The existing generalist natural enemies available commercially like *Cryptolaemus* cannot be used as potential biocontrol agents. Further repeated application of insecticides eliminated almost entire natural enemy complex in papaya fields. Muniappan (Perscomm) is of the opinion that *Cryptolaemus* is known to feed on *P. marginatus* but none of the coccinellid predators would be able to provide satisfactory control as the exotic parasitoids. The need for getting effective parasitoid agent *A. papayae* / *A. loecki* / *P. mexicana* for the sustainable management of PMB was emphasized. Strong recommendation was put forth by the farmers and SPFP for the import,

mass multiplication and supply of the effective exotic parasitoid as has been done in other countries. TNAU was requested to convey this to NBAII and ICAR. SPFP and farmers associated with SPFP participated in the farmers interaction meeting on management of papaya mealybug through parasitoids held on February 3, 2011 at Sathyamangalm organized jointly TNAU, NBAII and Integrated pest management - Collaborative Research Support Programme (IPM – CRSP0, USA).

Strategy planning

SPFP participated National Consultation Meeting on Strategies for Deployment and Conservation of Imported Parasitoids of Papaya Mealybug on Oct, 10, 2010 held in National Bureau of Agriculturally Important Insects, Bangalore and offered its input and support for implementation of the strategies arrived after elaborate deliberation for implementing classical biological control of papaya mealybug with imported effective parasitoids *A. papayae*, *A. loeck* and *P. mexicana*.

Field production of parasitoids

Training resource persons (Field staff)

To equip with required knowledge and technology, field staff of SPFP were deputed for the training progrmme organized on October 30, 2010 by NBAII on management of PMB and deployment of introduced parasitoids and mass multiplication during February 2011 in the Department of Entomology, TNAU .

Inoculative release of the parasitoids

SPFP got involved and participated in the inaugural meeting of the papaya mealybug parasitoid release programme held at TNAU on October 7, 2010 with the cluster of papaya farmers associated with SPFP. The exotic parasitoids *A. papayae* supplied by NBAII, Bangalore and TNAU were released. Out of 147 releases @ 100 parasitoids / field, parasitoids obtained from NBAII and TNAU were utilized for 7 and 140 field releases respectively (Table 1). Out 140 releases, parasitoids supplied from the mass multiplication facilities in, Department of Entomology, Centre for Plant protection Studies and Agricultural Research Station, Bhavanisagar of TNAU were used for 122 and 28 fields, respectively.

Field production of parasitoids

Considering the quantity of parasitoids required to cover large number fields and the limited production capacities available in NBAII and TNAU, mass multiplication at field level was accomplished by SPFP availing heavily infested fields. Initial releases of the parasitoids obtained from NBAII / TNAU were concentrated in heavily infested papaya fields (Table 2). As the heavily infested papaya fields were non-productive, SPFP adequately compensated for the estimated loss of produce so that the farmers maintained the garden with PMB infestation favouring multiplication of the parasitoids.

Supply of host insects

Availing the heavy infestation in field

supplying latex to SPFP, the bug infested plant parts, leaves and fruits were transported to TNAU for enhancing the host resource for multiplication of parasitoids utilizing the vehicles frequenting to collect wet latex from the farmers at regular intervals. This arrangement enabled TNAU in turn to accomplish enhanced the supply of parasitoids (Table 1) to the farmers associated with SPFP.

Carpet coverage

Though for classical biocontrol programme, carpet coverage is not needed, in the anxiety to revive wet latex production on fast track, steps were taken by SPFP for quick and fast spread of the parasitoids in various clusters of the fields in different areas. Farmers adjacent to fields where mass production of parasitoids has been taken up, were encouraged to carry the parasitzed infested fruits and leaves and fix them in their infested fields (Table 2) facilitating farmers for dissemination from mass field multiplication. SPFP assisted by providing logistic support through their field staff. This enabled quick and vast spread of the parasitoids in the particular clusters. Totally 91 fields were covered by release of parasitoids through infested plant parts (leaves and fruits) from parasitized fields. Each field was implanted with 10-15 infested leaves or/and fruits .

Educating and monitoring of farmers

By routine visit, field staff of SPFP regularly monitored farmers from taking up insecticidal sprays. They also educated farmers on the following

-The need for conservation of the released parasitoids and naturally occurring predators like *Spalgis* and coccinellids by avoiding the use of chemical pesticides.

-Redistribution of the natural enemies / released parasitoids to new areas of infested by

PMB infested weeds like parthenium, *Plumeria alba*, *Acalypha indica*, hedge plants and other hosts like - teak, mulberry, silk cotton, notchi (*Vitex negundo*), guava, mango, pomegranate maintained in their homestead can be very valuable reservoirs of parasitoids and hence should not be destroyed or sprayed with chemical pesticides.

Impact assessment

With the help of field staff and the logistic support by SPFP, the survey for parasitization was followed up after 3 and 6 months after initial release of the parasitoids. Each time data on the parasitization by the parasitoids, different host plants on which observed and emergence of parasitoids recorded as per the protocol prepared by NBAII, Bangalore. Added information on the impact of withdrawal of pesticide application against papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink on the biodiversity of natural enemy complex in small scale papaya farming system in Tamil Nadu were gathered (Regupathy & Ayyasamy 2011). The impact of parasitoid was observed in low incidence and reduced intensity of the mealybug. The mealybug

incidence was as low as 7-33 per cent with very low intensity in parasitoid released fields when compared to cent per cent incidence with very high intensity in abandoned fields. Farmers got normal yield without any loss in income. Farmers were inclined to extend the papaya cultivation and prepared to give up insecticide applications. The drudgery of taking insecticide application on tall papaya tree was done away with. There by the chances of developing resistance to insecticides due to repeated application is avoided and impact of insecticides on environment is reduced. This facilitated revival and conservation of natural enemy complex and biodiversity in papaya farming system. The wet latex production was restored and the papain industry is sustained.

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Table 1.
Industry-scientists- farmers' linkage

	SPFP (Industry)	**TNAU (Scientists)**	**NBAII (Scientists)**	**Papaya Farmers**
Assessing the bug intensity, and yield loss on papaya and the green bridge in Tamil Nadu	Lead			
Assessing the potential of existing natural enemy complex in papaya field in Tamil Nadu	Lead			
Review of insecticide efficacy on papaya in Tamil Nadu	Lead			
Facilitating industry-farmers- scientists linkage	Lead	Support	Support	Support
Import of parasitoids		Support	Lead	
Mass multiplication of potential biocontrol agent	Support	Support	Lead	
Training field staff	Support	Support	Lead	
Field- mass multiplication	Lead	Support		Support
Carpet coverage	Lead			Support
Field demonstration strategy	Support	Lead		Support
Monitoring farmers from applying insecticides in parasitoid released fields	Lead			Support
Impact assessment of parasitoid release on PMB	Lead			
Total activities	Lead 7 Support 5	Lead 1 Support 5	L3 S1 Lead 3 Support 1	Support 5

Table 2.
Releases of papaya mealybug parasitoid , *Acerophagus papayae* released in different farm holdings in Tamil Nadu during 2010-2011

Cluster	**Holdings**	**Area in acres**		**Source of released parasitoids**		
		Range	**Total**	**NBAII**	**TNAU**	**Infested leaves/fruits**
Chandrapuram Coimbatore district	7	1-6	15.5		8/12/10(1)* 7/1/11(1) * 17/1/11 (2*), 22/3/11(1) *, 3/4/11, (1) *, 13/4/11(1) *, 10/5/11(1) * 7/7/11(1) * 17/7/11(2*), 11/8/11(1) * 15/8/11(1) *	5/1/11 (7)

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Cluster	Holdings	Area in acres		Source of released parasitoids		
		Range	Total	NBAII	TNAU	Infested leaves/fruits
Mettukadai Thiruppur district	6	1-4	21		3/2//11(3) * , 10/2/11(2) *, 11/2/11(2) *, 17/2/11(1) *, 5/3/11(1) *, 1/4/11(2) *, 18/5/11(1) *, 2/6/11(1) *, 10/6/11(1) *, 30/6/11(1) *, 8/7/11(1) *, 15/7/11(2) *, 16/9/11(2) *, 29/9/11(2) *, 11/10/11(1) *,	
Suriyanallur Thiruppur district	3	2-6	10			
Dharapuram Thiruppur district	2	2-4.5	6.5			
Nathakadaiyoor Thiruppur district	1	21	21			
Udumalai Thiruppur district	2	2.5-4.5	7			
Sennampatti Erode district	7	1-3	11		3/2/11 (3) *	12/3/11(4)
A.G.pudur Erode district	24	1-5	49	23/10/10 (1) 31/10/10 (1)	3/11/10(1) *, 8/11/10 (2) *, 10/11/10 (2) *, 13/11/10(1) *, 6/12/10(1) *, 10/12/10(1) *, 12/12/10(1) *, 16/12/10(1) *, 17/12/10(1) *, 20/12/10(1) *, 21/12/10(1) *, 14/1/11(1) *, 17/1/11(1) *,11/3/11(1) *, 12/6/11(1) **, 10/7/11(1) **, 14/7/11(1) **, 18/7/11(1) ** 17/8/11(1) **, 20/9/11(1) **	3/12/10 (14) 16/12/10(1) 18/3/11(4)
Bhasuvapalayam Erode district	12	1-4	19	1/11/10 (1)	20/11/10(1) *, 23/11/10(1) *, 9/12/10(1) *,15/12/10(1), 20/12/10(1*), 24/12/10(1) *, 27/12/10(1) *, 23/6/11(1) *, 24/6/11(1) **, 11/7/11(1) **, 23/6/11(1)**, 18/8/11(1) **, 27/8/11(1) **	10/1/11 (1) 17/1/11 (7) 18/1/11 (1) 20/1/11 (1)
Sathyamangalam Erode district	10	1-4	24	1/11/10 (1)	15/12/10(1) *, 20/12/10(1) * 21/12/10(1) *, 25/12/10(1) * 11/1/11(1) *' 19/1/11(1) * 10/7/11(1) **.,15/8/11(1) ** 16/9/11(1) **,	15/2/11(9)
C.K.Pudur Erode district	11	1-3	16.5		15/1/11(1) *, 21/1/11(1) *, 24/1/11(1) *, 4/2/11(1) *, 16/2/11(1) *, 15/6/11(1) ** 21/7/11(1) **	22/2/11(11)
Bhaguthampalayam Erode district	6	1-3	8		12/11/10(1), 18/2/11(1) 21/7/11(1) **' 19/8/11(1) **	17/1/11(5)

Contd..

Cluster	Holdings	Area in acres		Source of released parasitoids		
		Range	Total	NBAII	TNAU	Infested leaves/fruits
Vettuvanputhur Erode district	6	1.5-2	9		12/2/11 (1) * 23/2/11(1) * 10/3/11(1) *, 17/3/11(1) *	
Rajan nagar Erode district	18	1-3	31	7/10/10 (1)	5/11/10(1) *, 14/11/10(1) * 20/11/10(1) *, 24/12/10(1) * 19/2/11(1) *, 17/3/11(1) * 12/4/11(1) *, 20/4/11(1) ** 21/4/11(1*), 12/6/11(1) ** 29/7/11(1) **, 16/8/11(1) ** 24/8/11(1) **' 12/9/11(1) ** 24/9/11(1) **	17/1/11(5) 20/4/11(8) 23/3/11(6)
Puliampatti Erode district	10	1-2	16.5	1/11/10 (2)	22/11/10(1) * 24/10/10(1) ** 26/11/10(1) * 2711/10(1) * 21/7/11(1) ** 17/9/11(1) **	5/1/11(7)
Oddanchatram Dindugal district	12	0.5-7	34		3/2/11(17) *, 11/2/ 11(2) * 9/5/ 11(2) *, 3/5/ 11(1) * 26/5/ 11(1) *, 30/5/ 11(2) * 7/6/ 11(1) *, 14/6/ 11(1) * 16/6/ 11(3) *' 10/8/ 11(2) * 22/8/ 11(1) *' 16/9/ 11(1) *	
Narikalpatti Dindugal district	5	2-3	12			
Ulagampatti Dindugal district	6	1-3	14			
Satharapatti Dindugal district	6	1-7	23			
Esanatham Dindugal district	1	10	10			
Cumbum Dindugal district	1	13	13			
Eruthala parai Dindugal district	4	2-3	10			
Total releases				7	122+ 28 **	91

In () number of field releases on that date; Parasitoids supplied by Department of Entomology, Centre for Plant Protection Studies (*) and Agricultural Research Station, Bhavanisagar (**), Tamil Nadu Agricultural University