Research Article

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Studies on the predator *Apertochrysa astur* (Banks) (debris carrying green lacewing) on invasive coconut whiteflies

X. Remoniya* and S. Jeyarajan Nelson

Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India

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Abstract

The invasive whitefly species, rugose spiralling whitefly (RSW) and Bondar's nesting whitefly (BNW) (Hemiptera: Aleyrodidae) were reported on coconut in 2016 at Pollachi, Tamil Nadu, India and in 2019 in Kerala, India, respectively. Among the natural enemies of whiteflies, *Apertochrysa astur* (Banks) is the predominant predator observed in the coconut ecosystem. The population effect of RSW and BNW in different host plants, *viz.,* coconut, banana and custard apple, on the growth and development of the *A. astur* were studied. Further, the effects of *A. astur* and yellow sticky traps (YSTs) were evaluated against the invasive whiteflies of coconut. The growth and development of the grubs of *A. astur* were better when fed with the RSW and BNW reared in coconut, followed by custard apple and banana. The weight of the 1st, 2nd and 3rd instar grubs were 0.25 mg, 0.62 mg and 2.46 mg, respectively. The pre-pupal weight was 7.41 mg, and that of the pupa and adult were 8.35 mg and 12.27 mg when fed with RSW. Similarly, when *A. astur* was fed with BNW reared on coconut, the weight of the 1st, 2nd and 3rd instar grub of *A. astur* was 0.22 mg, 0.59 mg and 2.24 mg, respectively. The pre-pupal weight was 7.06 mg, and that of the pupa and adult were 8.22 mg and 12.01 mg, respectively. Among the different treatment dosages of *A. astur* eggs and YSTs evaluated, 3 YST and 10 *A. astur* eggs palm^{-1} were highly effective as they reduced RSW and BNW population by 59.7 per cent and 56.7 per cent per cent, respectively. The grubs of *A. astur* were observed to be extremely efficient in reducing the population of *A. rugioperculatus* and *P. bondari*. The results supported that A. *astur* can be employed as an efficient biological control agent for managing invasive whitefly species in the coconut ecosystem.

Keywords: Coconut, green lacewing, host plants, invasive whiteflies

Introduction

Coconut is an important oilseed crop with a production of 14.63 million metric tons in terms of volume (Statista Research Department, 2022). India ranks third in the list of global coconut-producing nations. An area of 21,50,000 ha contributed to the production of 21,288 million nuts with productivity of 9,901 nuts ha^{-1} (Coconut Development Board, 2022). The coconut inflorescence sap "neera" and recently matured coconut water (MCW), a by-product, are being used as an energy source and also consumed as a drink (Indian Coconut Journal, 2021).

More than 110 exotic insect species had been reported from India, of which whiteflies and mealybugs constitute major invasions. In India, 469 whitefly species belonging to 71 genera are known to feed on many agricultural, horticultural, and forestry crop plants (Sundararaj *et al*., 2021). The first report on the incidence of RSW occurred in 2016 at Pollachi, Coimbatore district, western agro-climatic zone of Tamil Nadu (Sundararaj and Selvaraj, 2017) and that of BNW in 2019 in Kerala (Josephrajkumar *et al*., 2019). These whiteflies suck sap from under the surface of the palm leaves, thereby causing stress to the host plant. Farmers prefer chemical insecticides to manage the whiteflies. However, frequent applications of insecticides result in the problem of resistance, resurgence and residues. Under these circumstances,

* *Corresponding Author: remoniyax@gmail.com*

natural enemies are the best option for managing the whitefly population in the coconut ecosystem.

Lacewings are economically important biocontrol agents which predate on different developmental stages of mealybugs, aphids, thrips, whiteflies and mites under different agro-ecosystems (McEwen *et al*., 2001). Their wide host range, geographical distribution, insecticide resistance, voracious feeding ability and amenability to rearing with the UV sterilized *Corcyra cephalonica* eggs make them a good bio-agent for pest management (Syed *et al*., 2008). The adults are free-living and feed only on nectar, pollen, and honeydew (Coppel and Mertins, 1977). Among the natural enemies of RSW and BNW occurring in coconut, banana and custard apple, *A. astur* is the predominant predator.

Yellow sticky traps (YSTs) are commonly used for monitoring pest populations, including whiteflies, leaf miners, and aphids (Gu *et al*., 2008). Abdel-Megeed *et al*. (1998) also demonstrated that yellow sticky traps could significantly reduce the density of *B. tabaci* in the field for control purposes. The combination of YSTs and parasitoids has proven to be effective in controlling *B. tabaci* in a greenhouse (Shen and Ren, 2003). With this background, we have studied the influence of RSW and BNW in different host plants on the development of *A. astur* and fixed the host plant for mass culturing RSW and BNW to rear *A. astur*. Also, the combination of *A. astur* and YST on the population reduction of *A. rugioperculatus* and *P. bondari* was investigated.

Materials and methods

Influence of RSW and BNW in different host plants on the growth and development of *A. astur*

A laboratory experiment was conducted to study the effect of RSW and BNW in different host plants on the growth and development of *A. astur*. In greenhouse conditions, the culture of RSW was maintained in host plants, *viz*., coconut, banana and custard apple. A newly emerged 1st instar grub of *A. astur* was released individually in each insect-rearing dish of dimension (90 × 40 mm) dish and provided 40 numbers of 2nd instar nymphs of RSW reared on coconut, banana and custard apple daily until their adult stage. The host plants used for culturing RSW were considered treatments and replicated eight times. The weight of the grubs, pre-pupa, pupa and adults of *A. astur* were measured using the weighing balance. Observations on the grub period, pupal period and adult longevity were also recorded. The experimental procedure mentioned above for RSW was followed to assess the effect of BNW reared on different host plants on *A. astur*.

Effect of yellow sticky trap and *A. astur* on coconut trees

A field trial was conducted in the New Area at the Tamil Nadu Agricultural University, Coimbatore, from March to May 2021. Three-year-old coconut palms infested with invasive whitefly species were selected. The treatments fixed were 10 eggs of *A. astur* palm^{-1}, 20 eggs of *A. astur* palm^{-1}, 30 eggs of *A. astur* palm^{-1}, 1 YST palm^{-1}, 2 YST palm^{-1}, 3 YST palm^{-1}, 1 YST+ 30 eggs palm^{-1}, 2 YST+ 20 eggs palm^{-1} and 3 YST+ 10 eggs palm^{-1}. Control was not provided with either YST or eggs of *A. astur.* The YSTs used were 1 × 1 feet in dimension and were smeared with castor oil as adhesive on both sides. These treatments were replicated thrice. A total of 30 trees were utilized for the experiment. The incidence of RSW and BNW was assessed from ten leaflets in three bottom-matured fronds once a week. The per cent reduction of the whitefly population was computed using Abbott's formula (Abbott, 1925).

Statistical analysis

The data collected under laboratory and field experiments in a completely randomized design were analyzed using analysis of variance (ANOVA) using AGRES 3.01 and AGDATA software. Data in the form of numbers were transformed to square root values. The mean values of the treatments were compared using DMRT at a 5 per cent level of significance.

Results and discussion

The quantity and quality of the prey were observed to greatly impact the reproductive potential of the adults (Canard, 2001). The host plants used had a significant effect on the growth and development of *A. astur*. Among them, whiteflies reared on coconut enhanced the growth and development of *A. astur*.

All three instars of the grub were healthier in terms of weight when provided with RSW, and BNW was reared on coconut plants. The weights of the 1st, 2nd and 3rd instars, when fed with RSW reared on coconut, were 0.25 mg, 0.62 mg and 2.46 mg; their developmental period was 3.6, 5.4 and 6.2 days, respectively. The duration of pre-pupa of *A. astur* was recorded as 2.3 days, and their weight was 7.41 mg. The pupa weighed 8.35 mg, and the adult weight was 12.27 mg. The period of pupa stage and adult longevity was 9.2 and 16.9 days, respectively (Table 3). The grub weight was 0.19 mg in 1st instar, 0.57 mg in 2nd instar, 2.13 mg in 3rd instar, 7.14 mg in pre-pupal, 8.08 mg in pupal and 12.02 mg in adult stages when fed with RSW cultured in the custard apple (Table 1). The duration of the 1st, 2nd, 3rd, pre-pupa, pupa and adults were 3.9, 5.8, 6.9, 2.4, 9.3 and 17.1 days, respectively. The growth of the grubs was least when provided with the RSW infested in banana leaves. The weights of the 1st, 2nd and 3rd instars were 0.16 mg, 0.51 mg and 2.04 mg; their duration was 4.2, 6.5, and 7.0 days, respectively. The weight of pre-pupa was 6.83 mg, with a development duration of 2.6 days. The duration of the pupa and adult were 9.8 and 17.8 days, along with their weight of 7.87 mg and 11.83 mg, respectively.

Similarly, when *A. astur* was fed with BNW reared in coconut, the weight of the 1st, 2nd and 3rd instar grub was 0.22 mg, 0.59 mg and 2.24 mg with the duration of 3.8, 6.0 and 6.8 days, respectively (Table 2). The pre-pupal weight was 7.06 mg, and their duration was 2.3 days. The weight of the pupa and adult was 8.22 mg and 12.01 mg, and their duration was 9.2 and 17.3 days, respectively.

Table 1. Influence of RSW in different host plants on the growth of *A. astur*

Treatment	Weight in mg (Mean ± S.D)					
	1st instar	**2nd instar**	**3rd instar**	**Pre-pupa**	**Pupa**	**Adult**
RSW in coconut	0.25±0.072 (0.866) a	0.62±0.074 (1.058) a	2.46±0.072 (1.720) a	7.41±0.068 (2.812) a	8.35±0.079 (2.975) a	12.27±0.143 (3.574) a
RSW in banana	0.16±0.058 (0.812) c	0.51±0.085 (1.005) c	2.04±0.110 (1.594) c	6.83±0.083 (2.707) c	7.87±0.095 (2.893) c	11.83±0.084 (3.511) c
RSW in custard apple	0.19±0.065 (0.831) b	0.57±0.087 (1.034) b	2.13±0.091 (1.622) b	7.14±0.088 (2.764) b	8.08±0.080 (2.929) b	12.02±0.085 (3.538) b
SEd	0.0196	0.0201	0.0142	0.0073	0.0539	0.0404
CD (0.50)	0.0408	0.0417	0.0296	0.0151	0.1121	0.0841

*Mean of eight replications; significant at 1%; figures in parentheses are square root transformed values; in a column, means followed by a common letter(s) are not significantly different by DMRT (P = 0.05)

Table 2. Influence of BNW in different host plants on the growth of *A. astur*

Treatment	**Weight in mg (Mean ± S.D)**					
	1st instar	**2nd instar**	**3rd instar**	**Pre- pupa**	**Pupa**	**Adult**
BNW in coconut	0.22±0.024 (0.849) a	0.59±0.048 (1.044) a	2.24±0.044 (1.655) a	7.06±0.089 (2.750) a	8.22±0.059 (2.953) a	12.01±0.091 (3.537) a
BNW in banana	0.12±0.032 (0.787) c	0.46±0.043 (0.980) c	1.83±0.051 (1.526) c	6.54±0.052 (2.653) c	7.51±0.061 (2.830) c	11.48±0.061 (3.461) c
BNW in custard apple	0.16±0.028 (0.812) b	0.52±0.062 (1.010) b	2.01±0.091 (1.584) b	6.89±0.063 (2.718) b	7.88±0.046 (2.895) b	11.97±0.086 (3.531) b
SEd	0.0087	0.0129	0.0103	0.064	0.0048	0.0350
CD (0.50)	0.0182	0.0268	0.0214	0.0134	0.0100	0.0727

*Mean of eight replications; significant at 1%; figures in parentheses are square root transformed values; in a column, means followed by a common letter(s) are not significantly different by DMRT (P = 0.05)

Table 3. Influence of RSW in different host plants on the development of *A. astur*

Treatment	Development period in days (Mean ± S.D)					
	1st instar	2nd instar	3rd instar	Pre-pupa	Pupal period	Adult longevity
RSW in coconut	3.6±0.602 (2.025)	5.4±0.739 (2.429)	6.2±0.555 (2.588)	2.3±0.635 (1.673)	9.2±0.717 (3.114)	16.9±0.748 (4.171)
RSW in banana	4.2±0.634 (2.168)	6.5±0.623 (2.646)	7.4±0.761 (2.811)	2.6±0.555 (1.761)	9.8±0.786 (3.209)	17.8±1.175 (4.278)
RSW in custard apple	3.9±0.944 (2.098)	5.8±0.791 (2.510)	6.9±0.847 (2.720)	2.4±0.532 (1.703)	9.3±0.795 (3.130)	17.1±1.074 (4.195)
SEd	0.0894	0.0720	0.0676	0.0852	0.0610	0.0604
CD (0.50)	0.1859	0.1497	0.1406	1.1772	0.1268	0.1257

*Mean of eight replications; significant at 1%; figures in parentheses are square root transformed values; in a column, means followed by a common letter(s) are not significantly different by DMRT (P = 0.05)

The weight of grubs was 0.16 mg in 1st instar, 0.52 mg in 2nd instar, 2.01 mg in 3rd instar, 6.89 mg in pre-pupal, 7.88 mg in pupal and 11.97 mg in the adult stage when fed with BNW reared on custard apple. Their duration was 4.3, 6.4, 7.1, 2.5, 9.5 and 17.7 days, respectively. The growth of the grubs was least when provided with the BNW infested in banana leaves; the duration of the 1st, 2nd and 3rd instars was 4.8, 6.9 and 7.7 days and weighed 0.12 mg, 0.46 mg and 1.83 mg, respectively. The weight of the pre-pupa was 6.54 mg, and their duration was 2.6 days. The weights of the pupa and adult were 7.51 mg and 11.48 mg, and the duration was 9.9 and 18.4 days (Table 4.), respectively. The findings showed that the grubs favoured the RSW life stages over those of the BNW when reared on different host plants. The duration of development and weight of the *A. astur* grubs varied significantly among the three host plants, coconut, banana, and custard apple. Coconut was found to be an appropriate host since it had the lowest developmental time and the heaviest grub weight. Similar results were also reported on another species of green lacewing when *C. rufilabris* fed on *Bemisia argentifolii* reared on cucumber and melon had the quickest development, much longevity and heavy in weight than when it was reared on poinsettia and bean (Legaspi *et al*., 1994). Moreover, Giles *et al*. (2009) also reported that the grubs of *C. rufilabris* when supplied with pea aphids reared on alfalfa, had faster developmental rates than with the pea aphids reared on faba bean.

Almost all whiteflies of economic importance can be monitored using yellow sticky traps (Yano, 1987). The population of RSW and BNW were

Table 4. Influence of BNW in different host plants on the development of *A. astur*

Treatment	Development period in days (Mean ± S.D)					
	1st instar	2nd instar	3rd instar	Pre-pupa	Pupal period	Adult longevity
BNW in coconut	3.8±0.743 (2.074)	6.0±0.778 (2.550)	6.8±0.875 (2.702)	2.3±0.660 (1.673)	9.2±0.410 (3.114)	17.3±0.641 (4.219)
BNW in banana	4.8±0.920 (2.302)	6.9±0.843 (2.720)	7.7±1.115 (2.864)	2.6±0.670 (1.761)	9.9±0.699 (3.225)	18.4±0.902 (4.347)
BNW in custard apple	4.3±0.688 (2.191)	6.4±0.902 (2.627)	7.1±0.944 (2.757)	2.5±0.737 (1.732)	9.5±0.760 (3.162)	17.7±0.595 (4.266)
SEd	0.0932	0.0809	0.0889	0.1074	0.0511	0.0423
CD (0.50)	0.1937	0.1682	0.1848	0.2233	0.1062	0.0879

*Mean of eight replications; significant at 1%; figures in parentheses are square root transformed values; in a column, means followed by a common letter(s) are not significantly different by DMRT (P = 0.05)

Table 5. Influence of *A. astur* and yellow sticky trap on Rugose spiralling whitefly population

Treatment	Number of RSW population (10 leaflets/frond/palm)									
	Pre-treatment count	7th Day	14th Day	21st Day	28th Day	35th Day	42nd Day	49th Day	56th Day	Per cent reduction over control
10 *A. astur* eggs palm^{-1}	88.00 (3.742)^{c}	85.00 (3.606)^{g}	62.00 (3.240)^{c}	71.00 (3.742)^{b}	50.00 (3.316)^{c}	48.00 (3.606)^{e}	50.00 (3.535)^{e}	32.00 (3.082)^{e}	20.00 (2.738)^{e}	8.9
20 *A. astur* eggs palm^{-1}	72.00 (4.122)^{e}	77.00 (2.646)^{c}	63.00 (3.082)^{d}	62.00 (3.873)^{d}	51.00 (3.742)^{c}	33.00 (3.162)^{c}	44.00 (3.240)^{d}	31.00 (2.915)^{d}	19.00 (2.550)^{d}	18.3
30 *A. astur* eggs palm^{-1}	74.00 (3.605)^{b}	69.00 (2.236)^{b}	62.00 (2.915)^{b}	58.00 (3.605)^{c}	47.00 (3.464)^{b}	35.00 (3.162)^{d}	30.00 (3.391)^{c}	27.00 (2.732)^{c}	17.00 (2.121)^{b}	24.8
1 YST palm^{-1}	53.00 (4.796)^{h}	50.00 (3.316)^{f}	47.00 (3.535)^{e}	41.00 (4.243)^{e}	38.00 (4.000)^{d}	33.00 (3.742)^{f}	28.00 (3.674)^{g}	22.00 (3.391)^{f}	18.00 (3.082)^{f}	39.7
2 YST palm^{-1}	69.00 (4.359)^{e}	62.00 (2.646)^{c}	50.00 (2.739)^{b}	41.00 (3.606)^{c}	32.00 (3.464)^{b}	24.00 (3.162)^{b}	21.00 (3.082)^{b}	11.00 (2.550)^{b}	7.00 (2.345)^{c}	46.0
3 YST palm^{-1}	62.00 (3.163)^{a}	59.00 (2.000)^{a}	41.00 (2.345)^{a}	39.00 (2.828)^{a}	31.00 (2.449)^{a}	21.00 (2.236)^{a}	20.00 (2.345)^{a}	9.00 (2.121)^{a}	7.00 (1.871)^{a}	50.5
1 YST + 30 *A. astur* eggs palm^{-1}	55.00 (4.899)^{i}	50.00 (2.828)^{d}	41.00 (3.240)^{g}	35.00 (4.582)^{g}	27.00 (4.472)^{e}	22.00 (4.123)^{g}	14.00 (3.937)^{e}	12.00 (3.082)^{e}	9.00 (2.738)^{e}	54.2
2 YST + 20 *A. astur* eggs palm^{-1}	51.00 (5.196)^{j}	48.00 (3.000)^{e}	40.00 (3.391)^{f}	32.00 (4.472)^{f}	23.00 (4.123)^{c}	20.00 (3.605)^{c}	17.00 (3.240)^{f}	13.00 (2.738)^{c}	10.00 (2.345)^{c}	55.8
3 YST + 10 *A. astur* eggs palm^{-1}	58.00 (4.472)^{g}	51.00 (2.645)^{c}	39.00 (2.915)^{d}	31.00 (3.873)^{d}	22.00 (3.742)^{b}	17.00 (3.162)^{b}	11.00 (3.082)^{c}	9.00 (4.183)^{g}	5.00 (2.738)^{e}	59.7
Control	84.00 (4.000)^{d}	81.00 (3.000)^{e}	78.00 (4.527)^{h}	71.00 (4.690)^{h}	67.00 (4.899)^{f}	53.00 (5.196)^{h}	48.00 (5.049)^{h}	32.00 (2.915)^{d}	29.00 (3.936)^{g}	-
Sed	0.041	0.026	0.044	0.037	0.032	0.037	0.039	0.026	0.032	-
CD(0.05)	0.087	0.054	0.092	0.078	0.068	0.078	0.081	0.054	0.068	-

*Mean of three replications; significant at 1%; figures in parentheses are square root transformed values; in a column, means followed by a common letter(s) are not significantly different by DMRT (P = 0.05)

Table 6. Influence of *A. astur* and Yellow Sticky Trap on Bondar's Nesting Whitefly population

Treatment	Number of BNW population (10 leaflets $frond^{-1}$ $palm^{-1}$)									
	Pre-treatment count	**7^{th} Day**	**14^{th} Day**	**21^{st} Day**	**28^{th} Day**	**35^{th} Day**	**42^{nd} Day**	**49^{th} Day**	**56^{th} Day**	**Per cent Reduction over Control**
10 *A. astur* eggs $palm^{-1}$	51.00	43.00	40.00	42.00	40.00	37.00	26.00	21.00	16.00	
	(6.16)^{c}	(6.12)^{b}	(5.95)^{c}	(5.87)^{c}	(5.61)^{d}	(5.52)^{e}	(4.95)^{f}	(4.41)^{e}	(3.53)^{e}	6.7
20 *A. astur* eggs $palm^{-1}$	68.00	62.00	43.00	44.00	36.00	24.00	20.00	11.00	6.00	
	(6.48)^{d}	(6.59)^{d}	(6.36)^{e}	(6.51)^{e}	(6.36)^{f}	(6.12)^{g}	(5.43)^{h}	(4.63)^{g}	(4.06)^{h}	13.3
30 *A. astur* eggs $palm^{-1}$	49.00	46.00	42.00	39.00	35.00	29.00	24.00	14.00	7.00	
	(5.56)^{a}	(5.87)^{a}	(5.95)^{c}	(5.43)^{ab}	(5.33)^{c}	(4.74)^{c}	(4.41)^{d}	(3.80)^{c}	(3.53)^{e}	16.9
1 YST $tree^{-1}$	43.00	39.00	31.00	28.00	22.00	18.00	16.00	20.00	5.00	
	(7.28)^{g}	(7.10)^{f}	(6.89)^{g}	(6.51)^{e}	(6.04)^{e}	(5.70)^{f}	(5.33)^{g}	(4.52)^{f}	(3.93)^{g}	37.0
2 YST $tree^{-1}$	39.00	30.00	30.00	28.00	25.00	20.00	14.00	10.00	7.00	
	(6.48)^{d}	(6.12)^{b}	(5.70)^{b}	(5.43)^{ab}	(4.52)^{b}	(4.18)^{b}	(3.93)^{b}	(3.39)^{b}	(2.91)^{b}	42.3
3 YST $tree^{-1}$	35.00	29.00	25.00	22.00	20.00	19.00	17.00	11.00	9.00	
	(6.24)^{c}	(6.04)^{b}	(5.52)^{a}	(5.33)^{a}	(4.18)^{a}	(3.80)^{a}	(3.53)^{a}	(3.24)^{a}	(2.73)^{a}	46.5
1 YST + 30 *A. astur* eggs $palm^{-1}$	38.00	33.00	27.00	23.00	20.00	13.00	11.00	8.00	6.00	
	(6.92)^{e}	(6.81)^{e}	(6.51)^{f}	(6.28)^{d}	(5.95)^{e}	(5.43)^{e}	(4.95)^{f}	(3.80)^{c}	(3.08)^{c}	50.4
2 YST + 20 *A. astur* eggs $palm^{-1}$	37.00	31.00	26.00	22.00	19.00	12.00	10.00	7.00	5.00	
	(8.04)^{h}	(7.90)^{g}	(6.59)^{f}	(6.67)^{f}	(6.04)^{e}	(4.95)^{d}	(4.52)^{e}	(4.18)^{d}	(3.39)^{d}	53.5
3 YST + 10 *A. astur* eggs $palm^{-1}$	42.00	35.00	31.00	17.00	13.00	11.00	7.00	6.00	3.00	
	(7.14)^{f}	(6.74)^{de}	(6.20)^{d}	(5.52)^{b}	(4.63)^{b}	(4.18)^{b}	(4.06)^{c}	(3.80)^{c}	(2.91)^{b}	56.7
Control	53.00	50.00	47.00	42.00	30.00	32.00	28.00	31.00	24.00	
	(6.00)^{b}	(6.28)^{c}	(6.36)^{e}	(6.20)^{d}	(6.04)^{e}	(6.04)^{g}	(4.41)^{d}	(4.52)^{f}	(3.67)^{f}	-
Sed	0.062	0.072	0.048	0.057	0.064	0.064	0.044	0.032	0.030	-
CD (0.05)	0.130	0.151	0.100	0.120	0.134	0.134	0.092	0.068	0.062	-

drastically reduced when the yellow sticky trap and eggs of *A. astur* were used together. The highest per cent reduction of the RSW population was observed to be 59.7 per cent when three YST and 10 eggs palm^{-1} were used in the palms. On the other hand, when two YST and 20 eggs palm^{-1} were used, 55.8 per cent of the whitefly population was reduced. The population was reduced to 54.2 per cent when one YST and 30 eggs palm^{-1} were used. The YSTs, when used @ three, two and one palm^{-1}, resulted in the reduction of the whitefly population to the tune of 50.5, 46.0 and 39.7 per cent, respectively (Table 5). Similarly, the eggs of *A. astur,* when stapled in the underside of the coconut leaflet @ 10 eggs, 20 eggs and 30 eggs palm^{-1}, 8.9, 18.8 and 24.8 per cent of the RSW population were reduced within a period of eight weeks, respectively. Similar to our observations, Elango *et al*. (2021) had reported that the maximum number of whitefly adults was attracted when traps were smeared with castor oil @ 270.59 adults trap^{-1} week^{-1} in coconut. Similarly, Premalatha and Rajangam (2011) reported that using YST had reduced *Trialeurodes vaporariorum* in gerbera.

The highest per cent reduction of BNW was observed to be 59.7 per cent when three YSTs and 10 eggs palm^{-1} were used. On the other hand, when 2 YST and 20 eggs palm^{-1} were used, 53.5 per cent of the whitefly population was reduced. The YSTs, when used @ three, two and one palm^{-1}, the whitefly population reduced to the tune of 46.5, 42.3 and 37.0 per cent, respectively (Table 6.). The BNW population was reduced to 6.7, 13.3 and 16.9 per cent when 10 eggs, 20 eggs and 30 eggs palm^{-1} were used. Duelli (2001) and Nordlund *et al*. (2001) reported that when the mated female adults of the chrysopids were released into the field, they dispersed and left the target site. To overcome this issue, the eggs of *A. astur* were stapled in the under-surface of the infected coconut leaflets. The grub stages of *A. astur* were found efficient in the field conditions which was previously reported by (Rao *et al*., 2020) that in four years old hybrid Godavari Ganga plantation, the RSW population was reduced to 3 spirals per leaflet in the palms after 20 days when 500 eggs of *Dichochrysa astur* were clipped in five palms.

Results from the field trials could also be compared with the reports on the effect of *Chrysoperla* spp. on aphids and whiteflies. Alghamdi *et al.* (2018) observed that, after the second release of five grubs of *C. carnea* per plant, there was a 90 and 97 per cent reduction of aphid and whitefly populations in squash and a cent per cent reduction in sweet pepper plants. Similarly, El-Arnaouty *et al*. (2000) obtained the best results when second-instar grubs of *C. carnea* were released on green pepper plants under greenhouse conditions against *M. persicae*.

Conclusion

Invasive whiteflies reared on coconut significantly influenced the growth and development of *A. astur* when compared to the whiteflies reared on other host plants like banana and custard apple. The data obtained from the field trials showed that the YSTs and releases of *A. astur* successfully suppressed the invasive whitefly populations in coconut fields. Control of two whitefly species under investigation differed according to the number of eggs released and the number of yellow sticky traps used. Therefore, the predatory green lacewing, *A. astur*, and YST can be exploited as an efficient strategy for managing invading whiteflies in the coconut ecosystem.

References

Abbott, W.S. 1925. A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology* **18**: 265-267.

Abdel-Megeed, M.I., Hegazy, G.M., Hegab, M.F. and Kamel, M.H. 1998. Non-traditional approaches for controlling the cotton whitefly, *Bemisia tabaci* Genn infesting tomato plants. *Annals of Agricultural Science* **1**: 177-189.

Alghamdi, A., Al-Otaibi, S. and Sayed, S. M. 2018. Field evaluation of indigenous predacious insect, *Chrysoperla carnea* (Steph.) (Neuroptera: Chrysopidae), fitness in controlling aphids and whiteflies in two vegetable crops. *Egyptian Journal of Biological Pest Control* **28**: 20.

Canard, M. 2001. Natural food and feeding habits of lacewings. In: *Lacewings in the Crop Environment*. (Eds) McEwen, P.K., New, T.R. and Whittington, A.E. Cambridge Unversity Press, Cambridge, pp. 116-129.

Coconut Development Board. 2022. All India final estimates of area and production of coconut. CDB - Statistics (Accessed on 18th may, 2022).

Coppel, H.C. and Mertins, J.W. 1977. *Biological Insect Pest*

Suppression. Springer, Berlin. pp. 98-110.

Duelli, P. 2001. Lacewings in field crops In*: Lacewings in the Crop Environment,* (Eds) McEwen, P.K., New, T.R. and Whittington, A.E. Cambridge university Press, Cambridge, pp. 158-171.

Elango, K., Nelson, S.J. and Kumar, P.D. 2021. Yellow sticky trap for monitoring rugose spiralling whitefly *Aleurodicus rugioperculatus* Martin. *Indian Journal of Entomology* **83**: 1-12.

El-Arnaouty, S.A., Gaber, N. and Tawfik, M.F.S. 2000. Biological control of the green peach aphid *Myzus persicae* by *Chrysoperla carnea* (Neuroptera: Chrysopidae). *Egyptian Journal of Biological Pest Control* **10**(12): 109-116.

Giles, K.L., Madden, R.D., Payton, M.E. and Dillwith, J.W. 2009. Survival and development of *Chrysoperla rufilabris* (Neuroptera: Chrysopidae) supplied with pea aphids (Homoptera: Aphididae) reared on alfalfa and faba bean. *Population Ecology* **29**(2): 304-311.

Gu, X.S., Bu, W.J., Xu, W.H., Bai, Y.C., Liu, B.M. and Liu, T.X. 2008. Population suppression of *Bemisia tabaci* (Hemiptera: Aleyrodidae) using yellow sticky traps and *Eretmocerus nr. rajasthanicus* (Hymenoptera: Aphelinidae) on tomato plants in greenhouses. *Insect Science* **15**: 263-270.

Indian Coconut Journal (2021) Coco chemicals - potential value-added products from CNO. *Coconut Journal*. pdf. (Accessed on 18th may, 2022)

Josephrajkumar, A., Mohan, C. and Babu, M. 2019. First record of the invasive Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi on coconut from India. *Phytoparasitica* **47**: 333-339.

Legaspi, J.C., Carruthers, R.I. and Nordlund, D.A. 1994. Life history of *Chrysoperla rufilabris* (Neuroptera: Chrysopidae) provided whitefly *Bemisia tabaci* (Homoptera: Aleyrodidae) and other food. *Biological Control* **4**: 178-184.

McEwen, P.K., New, T.R. and Whittington, A. 2001. Lacewings in the crop environment. Cambridge University Press, Cambridge, United Kingdom, 157 p.

Nordlund, D.A., Cohen, A.C. and Smith, R.A. 2001. Mass rearing, release techniques and augmentation In: *Lacewings in the Crop Environment.* (Eds.) McEwen, P.K., New, T.R. and Whittington, A.E. Cambridge University Press, Cambridge, pp. 800-819.

Premalatha, K. and Rajangam, J. 2011. Efficacy of yellow sticky traps against greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) (Aleyrodidae: Hemiptera) in gerbera. *Journal of Biopesticides* **4**(2): 208-210.

Rao, C.N.B.V., Ramani, B.S., Roshan, R.D. and Bhagavan, B.V.K. 2020. Biocontrol management options for invasive whiteflies on coconut. *Indian Coconut Journal* **17**: 22.

Shen, B.B. and Ren, S.X. 2003. Yellow card traps and its effects on populations of *Bemisia tabaci*. *Journal of South China Agricultural University* **24**(4): 40-43.

Statista Research Department (2022) Production volume of coconuts across India from financial year 2014 to 2020, with an estimate for 2021. India: production volume of coconuts 2021 | Statista. (Accessed on 18th May, 2022).

Sundararaj, R. and Selvaraj, K. 2017. Invasion of rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae): a potential threat to coconut in India. *Phytoparasitica* **45**(1): 71-74.

Sundararaj, R., Krishnan, S. and Sumalatha, B.V. 2021. Invasion and expansion of exotic whiteflies (Hemiptera: Aleyrodidae) in India and their economic importance. *Phytoparasitica* **49**(5): 851-863.

Syed, A.N., Ashfaq, M. and Ahmad, S. 2008. Comparative effect of various diets on development of *Chrysoperla carnea* (Neuroptera: Chrysopidae). *International Journal of Agricultural Biology* **10**: 728-730.

Yano, Eizi. 1987. Control of the greenhouse whitefly, *Trialeurodes vaporariorum* Westwood (Homoptera: Aleyrodidae) by the integrated use of yellow sticky traps and the parasite *Encarsia formosa* Gahan (Hymenoptra: Aphelinidae). *Applied Entomology and Zoology* **22**(2): 159-165.