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Research Article

Efficacy of biopesticides under moderate infestation levels of exotic Rugose Spiraling Whitefly (RSW), *Aleurodicus rugioperculatus* Martin in coconut (*Cocos nucifera* L.) plantations

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ABSTRACT: Field evaluation of various biopesticides *viz., Beauveria bassiana, Isaria fumosorosea* NBAIR pfu-5*, Metarhizium anisopliae, Lecanicillium lecanii,* azadirachtin and soapnut powder were carried out against coconut invasive Rugose Spiraling Whitefly (RSW), *Aleurodicus rugioperculetus* Martin at Ramachandrapuram and Ambajipeta (Dr BR Ambedkar Konaseema district, AP) during 2020-21 and 2021-22. Pooled data analysis indicated that azadiracthin 10,000 ppm significantly reduced the nymphal population of RSW to the level of 25.74, 22.14, 17.67 and 15.82 nymphs per leaflet at 7, 14, 21 and 28 days after spray and was found superior among the different treatments tested. Regarding the reduction of the adult population, pest incidence and pest intensity, *I. fumosorosea* NBAIR pfu-5 spray was significantly superior compared to that of other treatments.

KEYWORDS: Bio pesticides, Coconut, Rugose Spiraling Whitefly (RSW), moderate incidence, management

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INTRODUCTION

Coconut (*Cocos nucifera* L.) is one of the most important plantation crops in India and several South East Asian countries. India is the third largest coconut-producing country, after Indonesia and the Philippines, having an area of about 2,150.00 hectares under the crop. The annual production is up to 21,288 million nuts with productivity of 9,901 nuts/ha (APCC, 2019). In India, the four South Indian states namely Kerala, Tamil Nadu, Karnataka and Andhra Pradesh account for around 90 per cent of the coconut production in the country. However, the production and productivity of coconut palms are often limited by the incidence of several pests and diseases (Chowdappa *et al.,* 2018; Neeraja *et al.,* 2020).

Invasive pests inflict billions of dollars in damage and substantial ecological changes in native horticultural ecosystems (Simberloff *et al.,* 2013). Rugose Spiraling Whitefly (RSW), *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae) is a highly polyphagous and exotic pest, recorded for the first time in India in 2016 in Tamil Nadu on coconut plantations (Selvaraj *et al.,* 2016). Later on, the pest was reported from different coconut growing areas of India *viz.,* Kerala, Karnataka, Andhra Pradesh, Assam, Goa, West Bengal, Maharashtra, Telangana, Meghalaya and Gujarat on oil palm, banana, sapota, maize, mango, cashew and many other ornamental plants. The pest is also reported in a serious form on Oil Palm plantations in coastal Andhra Pradesh (Kalidas, 2019).

Bio-pesticides based on plants and pathogenic microorganisms are specific to target insect pests which offer an ecologically sound and effective solution to pest problems (Gupta and Dikshit, 2010). Although chemical pesticides may be effective on crop pests, their long-term usage affects the natural enemy population, resistance development in pests and environmental pollution. The entomopathogenic fungus, *Isaria fumosorosea* was found effective mainly against whiteflies (Luangsa-Ard *et al*., 2005) and the fungus was used as a potential biocontrol agent against RSW under natural field conditions in Florida (USA) (Kumar *et al.,* 2018). To achieve long-term pest suppression of RSW sustainably, bio-

control agents such as entomofungal pathogens and botanical pesticides were tested in the field against the invasive RSW. The benefits of bio-pesticides would reduce the load of synthetic insecticides, delay the build up of resistance in pest populations and provide safer habitat for natural enemies and pollinators (Ali *et al.,* 2015).

MATERIAL AND METHODS

Field efficacy of various bio-pesticides was evaluated against RSW in East Coast Tall (ECT) variety of 7 years age-old palms with moderate RSW incidence (10-20 spirals per leaflet) as per the damage rating scale developed by Srinivasan *et al.,* (2016) during December 2020 to February 2021 and December 2021 to February 2022 at Dr YSR HU - SKPP Polytechnic college, Ramachandrapuram (16°83'72" NL and 82°03'25" EL) and Dr YSR HU - HRS, Ambajipeta (16°59'38" NL and 81°95'36" EL). Evaluation of biopesticides was undertaken at Ramachandrapuram, a horticultural polytechnic college working under the aegis of Dr YSR Horticultural University as the palms were found suitable for carrying out the experimentation with the desired RSW pest load during 2020-21.

The entomofungal pathogens were applied through foliar sprays of talc formulations at the dose of 0.5 per cent from December to February (four rounds) at 15 days intervals (T_1, T_2, T_3 and T_4). Azadiracthin 10,000 ppm (T_5) at the concentration (of 0.1 per cent) and Soapnut powder at 0.3 per cent (T_6) were sprayed similarly. Jet water spray was also given as a treatment. Every treatment is replicated thrice with two palms in each replication. Untreated palms were considered as control treatments. Spray fluid of 5-10 l per palm was used based on the canopy of the palm.

The number of bio-pesticide treatments was eight, which was replicated three times and statistically analysed using a simple Randomised Block Design (RBD). The incidence of RSW was observed at weekly intervals beginning 7 days after the treatments were imposed and lasting up to 28 days.

The data about several RSW nymphs and adults were recorded on four randomly selected infested leaflets per frond per palm from the top, middle and lower whorl representing four directions (total of 4 fronds/palm) was worked out and expressed as a mean number of leaflet/frond/palm (total of 4 leaflets/frond) (16 leaflets/palm) at 1 Day Before Spraying (DBS), 7, 14, 21 and 28 Days After Spraying (DAS). For population count studies, four fronds were selected from four directions and from each frond four leaflets were used randomly. The selected leaflets were marked carefully, sealed in a polythene cover, and brought to the laboratory and the data on the population of RSW nymphs were recorded under Nikon SMZ18 13.5 x stereomicroscope.

Estimation of RSW incidence and intensity (%) were also calculated using the following formulae:

$$\text{RSW Incidence (\%)} = \frac{\textit{Number of fronds infested by RSW}}{\textit{Total number of fronds per palm}} \times 100$$

$$\text{RSW Intensity (\%)} = \frac{\textit{Number of leaflets infested by RSW}}{\textit{Total number of leaflets per leaf}} \times 100$$

Statistical analysis

The statistical analysis of data was done by using OPSTAT software. The data was transformed by arc sine and square root transformations before subjecting to the analysis.

RESULTS AND DISCUSSION

Evaluation of biopesticides *viz., B. bassiana*, *I. fumosorosea* NBAIR pfu-5**,** *M. anisopliae, L. lecanii*, Azadirachtin 10000 ppm, soapnut powder and Jet water spray were carried out against RSW infested coconut palms with moderate incidence during 2020-21 and 2021-22.

Efficacy of biopesticides against incidence and intensity of RSW, *A. rugioperculatus*

The pooled analysis of two years' results revealed that significantly lower incidence and intensity of RSW was observed in all the treatments with bio-pesticides and jet water spray after the second spray onwards, compared to the untreated control palms. However, among the seven treatments tested, *I. fumosorosea* NBAIR pfu-5 spray gave the lowest incidence of RSW (37.98, 33.28 and 29.44 per cent at 14, 21 and 28 DAS) and RSW intensity (45.94, 41.71, 36.58 and 30.93 per cent) compared to the incidence (48.23, 51.35 and 52.96 per cent) and intensity of untreated control palms (50.89, 51.99, 54.86 and 55.73) (Table 3).

Efficacy of biopesticides against nymphs of RSW, *A. rugioperculatus*

The pooled analysis of data indicated that a significant difference was observed among different treatments against RSW nymphs from the 7th day and continued till the 28th day after spraying. Treatment (T_5) Azadirachtin 10000 ppm @ 1 ml/l recorded the least number (25.74, 22.14, 17.67 and 15.82 nymphs) with 27.27 per cent reduction after spraying, 45.86 per cent reduction over control and proved to be superior over remaining treatments. The control treatment (T_8) was recorded with the highest population of 33.47, 35.23, 38.81 and 42.76 nymphs per leaflet (Table 4).

Efficacy of biopesticides against adults of RSW, *A. rugi-operculatus*

The pooled analysis of results depicted that; a significant difference was observed among different treatments against RSW adults. *Isaria fumosorosea* NBAIR pfu-5 @ 5 g/l (T_2) recorded the lowest number (19.57, 17.39, 15.84 and 14.81 adults) with a 24.99 per cent reduction after spraying, 29.44 per cent reduction over control and proved to be superior over other treatments. The control palms (T_8) were recorded with the highest population of 22.01, 24.27, 24.44 and 25.08 adults per leaflet (Table 5).

The results suggest that *I. fumosorosea* was more effective in managing the invasive *A. rugioperculatus* adults and reducing pest incidence and intensity in the field than that of *B. bassiana*, *M. anisopliae* or *L. lecanii*. This might be due to the high virulence of *I. fumosorosea* on RSW (Ali *et al.,* 2010). These findings are by those of Boopathi *et al.,* (2013 and 2015) and Chalapathi Rao *et al.,* (2020) who reported that *I. fumosorosea* NBAIR Pfu-5 reduced the early nymphal instars of RSW by 52-68 per cent and 35-40 per cent in Godavari Ganga hybrid and Gauthami Ganga variety of coconut. Selvaraj *et al.,* (2020) identified *I. fumosorosea* NBAIR Pfu-5 as a promising strain and observed an overall reduction of 72.20-73.83 per cent and 74.26-75.83 per cent in the RSW population in Karnataka and Andhra Pradesh with two sprays at 15 days interval in coconut and oil palm. Visalakshi *et al.* (2021) observed a 58.1 to 97.03 per cent reduction in RSW intensity in coconut farms sprayed with *I. fumosorosea* fungus (NBAIR- Pfu-5) @ 2 x 10^8 spores/ ml (5 g/l of water).

Azadirachtin 10,000 ppm was found to be more effective on nymphal stages of RSW, while *I. fumosorosea* NBAIR pfu-5 was more virulent against nymphal stages as indicated in the results of the current study. The higher suppressive effect of azadiracthin on nymphs might be due to the inhibition of the moulting hormone in RSW. Azadirachtin inhibits the activity of ecdysone-20-monooxygenase in the haemolymph, which converts ecdysone to 20-hydroxyecdysone (the active

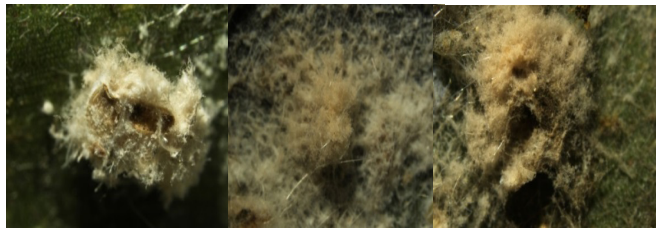

Figure 1. *I. fumosorosea* NBAIR pfu-5 infested RSW nymph and adult.

Table 1. Efficacy of biopesticides against incidence and intensity of RSW, *A. rugioperculatus* under moderate incidence palms (10-20 spirals per leaflet) during 2020-21

S. No.	Treatments	Dosage	Before Spraying (B.S)		7 Days after Spraying (7 DAS)		14 Days after Spraying (14 DAS)		21 Days after Spraying (21 DAS)		28 Days after Spraying (28 DAS)	
			Incidence (%)	Intensity (%)	Incidence (%)	Intensity (%)	Incidence (%)	Intensity (%)	Incidence (%)	Intensity (%)	Incidence (%)	Intensity (%)
T_1	*B. bassiana* commercial	5g/L	44.17 (41.59)	47.89 (43.76)	44.00 (41.54)	47.73 (43.68)	39.32 (38.82)	43.05 (40.99)	38.50 (38.34)	42.20 (40.51)	36.33 (37.05)	37.32 (37.64)
T_2	*I. fumosorosea* NBAIR pfu-5	5g/L	47.13 (43.33)	50.86 (45.48)	42.67 (40.73)	46.39 (42.89)	37.40 (37.69)	41.13 (39.88)	33.50 (34.15)	36.38 (35.44)	29.23 (30.79)	30.46 (31.53)
T_3	*M. anisopliae* commercial	5g/L	46.90 (43.20)	50.63 (45.34)	44.67 (41.88)	48.39 (44.06)	43.67 (41.35)	47.39 (43.49)	41.17 (39.89)	44.89 (42.05)	39.75 (39.07)	40.98 (39.79)
T_4	*L. lecanii* commercial	5g/L	48.00 (43.80)	51.73 (45.97)	46.50 (42.98)	50.23 (45.11)	42.50 (40.67)	46.24 (42.82)	40.00 (39.22)	43.67 (41.35)	38.85 (38.54)	40.09 (39.26)
T_5	Azadirachtin 10000 ppm	1ml /L	45.10 (42.17)	48.83 (44.31)	43.33 (41.16)	47.06 (43.29)	39.00 (38.63)	42.75 (40.83)	37.50 (37.75)	41.23 (39.93)	34.85 (36.17)	36.08 (36.91)
T_6	Soapnut powder	3g /L	46.42 (42.93)	50.15 (45.07)	44.33 (41.73)	48.09 (43.87)	40.55 (39.51)	44.32 (41.67)	38.50 (38.34)	41.28 (39.96)	35.00 (36.26)	36.23 (36.99)
T_7	Jet water spray	-	46.28 (42.85)	50.01 (44.99)	45.50 (42.40)	49.24 (44.54)	42.50 (40.67)	46.27 (42.82)	41.50 (40.09)	45.25 (42.26)	39.96 (39.19)	41.19 (39.91)
T_8	Control (No sprayings)	-	47.33 (43.45)	51.06 (45.59)	48.67 (44.22)	52.39 (46.36)	49.00 (44.41)	52.80 (46.55)	53.00 (46.70)	56.49 (48.71)	54.43 (47.53)	58.16 (49.68)
	S.E (m)		1.87	1.86	1.72	1.71	0.17	0.17	0.22	0.27	0.31	0.33
	C.D at 5 %		N.S	N.S	N.S	N.S	0.53	0.53	0.71	0.84	0.97	1.02
	C.V		7.53	7.14	7.08	6.69	0.75	0.71	0.94	1.12	1.37	1.43

*Mean of three replicates; DAS: Days after spraying, Figures in the parenthesis are Angular (or) Arc Sine transformed values.

Table 2. Efficacy of biopesticides against incidence and intensity of RSW, *A. rugioperculatus* under moderate incidence palms (10-20 spirals per leaflet) during 2021-22

S. No.	Treatments	Dosage	Before Spraying (B.S)		7 Days after Spraying (7 DAS)		14 Days after Spraying (14 DAS)		21 Days after Spraying (21 DAS)		28 Days after Spraying (28 DAS)	
			Incidence (%)	Intensity (%)	Incidence (%)	Intensity (%)	Incidence (%)	Intensity (%)	Incidence (%)	Intensity (%)	Incidence (%)	Intensity (%)
T_1	*B. bassiana* commercial	5g/L	44.47 (41.81)	48.19 (43.95)	43.43 (41.21)	47.15 (43.35)	41.44 (40.06)	45.16 (42.21)	40.53 (39.53)	44.25 (41.68)	38.53 (38.35)	40.27 (39.78)
T_2	*I. fumosorosea* NBAIR pfu-5	5g/L	43.58 (41.26)	47.31 (43.43)	41.75 (40.24)	45.47 (42.39)	38.56 (38.37)	42.28 (40.55)	33.05 (33.48)	36.77 (35.67)	29.65 (30.05)	31.39 (32.09)
T_3	*M. anisopliae* commercial	5g/L	45.33 (42.30)	49.06 (44.44)	44.67 (41.92)	48.39 (44.06)	42.68 (40.77)	46.40 (42.92)	41.35 (40.00)	45.08 (42.16)	38.65 (38.42)	40.39 (39.45)
T_4	*L. lecanii* commercial	5g/L	46.10 (42.72)	49.82 (44.87)	44.38 (41.75)	48.09 (43.89)	42.40 (40.59)	46.10 (42.74)	41.02 (39.79)	44.74 (41.96)	38.23 (38.18)	39.97 (39.20)
T_5	Azadirachtin 10000 ppm	1ml /L	44.67 (41.92)	48.39 (44.06)	42.50 (40.67)	46.22 (42.82)	39.50 (38.92)	43.24 (41.09)	38.53 (38.35)	42.25 (40.53)	35.55 (36.59)	37.29 (37.62)
T_6	Soapnut powder	3g /L	43.73 (41.38)	47.57 (43.53)	42.80 (40.84)	46.52 (42.99)	39.75 (39.06)	43.46 (41.23)	38.63 (38.51)	42.52 (40.68)	35.72 (36.74)	37.54 (37.77)
T_7	Jet water spray	-	44.90 (42.06)	48.62 (44.19)	43.00 (40.96)	46.79 (43.10)	41.50 (40.09)	45.23 (42.24)	40.55 (39.54)	44.27 (41.69)	39.75 (39.07)	41.49 (40.09)
T_8	Control (No sprayings)	-	43.84 (41.45)	47.56 (43.59)	45.63 (42.49)	49.37 (44.62)	47.54 (43.56)	51.24 (45.69)	49.55 (44.69)	53.22 (46.83)	51.56 (45.87)	54.29 (47.88)
	S.E (m)		1.55	1.54	0.004	0.004	0.003	0.003	0.01	0.01	0.004	0.004
	C.D at 5 %		N.S	N.S	0.01	0.01	0.01	0.01	0.03	0.03	0.01	0.01
	C.V		6.39	6.05	0.02	0.01	0.02	0.01	0.05	0.05	0.02	0.02

*Mean of three replicates; DAS: Days after spraying, Figures in the parenthesis are Angular (or) Arc sine transformed values.

Table 3. Efficacy of biopesticides against incidence and intensity of RSW, *A. rugioperculatus* under moderate incidence palms (10-20 spirals per leaflet) (Pooled data of 2 years)

S. No.	Treatments	Dosage	Before Spraying (B.S)		7 Days after Spraying (7 DAS)		14 Days after Spraying (14 DAS)		21 Days after Spraying (21 DAS)		28 Days after Spraying (28 DAS)	
			Incidence (%)	Intensity (%)	Incidence (%)	Intensity (%)	Incidence (%)	Intensity (%)	Incidence (%)	Intensity (%)	Incidence (%)	Intensity (%)
T_1	*B. bassiana* commercial	5g/L	44.32 (41.71)	48.05 (43.86)	43.72 (41.37)	47.44 (43.51)	40.38 (39.44)	44.11 (41.59)	39.52 (38.93)	43.24 (41.10)	37.43 (37.71)	38.79 (38.51)
T_2	*I. fumosorosea* NBAIR pfu-5	5g/L	45.36 (42.31)	49.09 (44.46)	42.21 (40.49)	45.94 (42.65)	37.98 (38.03)	41.71 (40.21)	33.28 (33.32)	36.58 (35.55)	29.44 (30.92)	30.93 (31.81)
T_3	*M. anisopliae* commercial	5g/L	46.12 (42.75)	49.84 (44.89)	44.67 (41.91)	48.39 (44.06)	43.17 (41.06)	46.90 (43.21)	41.26 (39.95)	44.99 (42.11)	39.20 (38.75)	40.69 (39.62)
T_4	*L. lecanii* commercial	5g/L	47.05 (43.26)	50.78 (45.42)	45.44 (42.36)	49.16 (44.50)	42.50 (40.63)	46.20 (42.78)	40.49 (39.51)	44.18 (41.65)	38.53 (38.36)	40.03 (39.23)
T_5	Azadirachtin 10000 ppm	1ml /L	44.88 (42.04)	48.61 (44.19)	42.92 (40.91)	46.64 (43.06)	39.25 (38.78)	42.98 (40.95)	38.09 (38.05)	41.74 (40.23)	35.20 (36.38)	36.69 (37.26)
T_6	Soapnut powder	3g /L	45.08 (42.16)	48.80 (44.29)	43.57 (41.29)	47.29 (43.43)	40.15 (39.29)	43.85 (41.45)	38.67 (38.42)	41.90 (40.32)	35.49 (36.49)	36.89 (37.38)
T_7	Jet water spray	-	45.59 (42.45)	49.32 (44.59)	44.25 (41.68)	47.98 (43.82)	42.00 (40.38)	45.73 (42.53)	41.03 (39.81)	44.76 (41.98)	39.86 (39.13)	41.34 (39.99)
T_8	Control (No sprayings)	-	45.58 (42.45)	49.34 (44.59)	47.21 (43.35)	50.89 (45.49)	48.23 (43.99)	51.99 (46.12)	51.35 (45.69)	54.86 (47.77)	52.96 (46.69)	55.73 (48.27)
	S.E (m)		1.58	1.57	0.86	0.85	0.09	0.09	0.11	0.14	0.15	0.16
	C.D at 5 %		N.S	N.S	N.S	N.S	0.27	0.27	0.34	0.41	0.47	0.49
	C.V		6.44	6.10	3.56	3.37	0.38	0.36	0.48	0.56	0.69	0.71

*Mean of three replicates; DAS: Days after spraying, Figures in the parenthesis are Angular (or) Arc Sine transformed values.

Table 4. Efficacy of biopesticides against nymphs of RSW, *A. rugioperculatus* under moderate incidence palms (10-20 spirals per leaflet)

S. No.	Treatments	Pre-Count*	Post-Count*															Per cent Reduction (%)			Per cent Reduction over control (%)		
			7 DAS			14 DAS			21 DAS			28 DAS											
		2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results
T_1	*B. bassiana* commercial	21.44 (4.74)	22.73 (4.87)	22.08 (4.80)	19.91 (4.57)	21.20 (4.71)	20.56 (4.64)	19.59 (4.54)	20.88 (4.68)	20.24 (4.61)	18.93 (4.46)	20.22 (4.61)	19.58 (4.54)	18.44 (4.41)	19.73 (4.55)	19.08 (4.48)	10.35	9.77	10.01	17.48	16.59	17.04
T_2	*I. fumosoro-sea* NBAIR pfu-5	21.92 (4.79)	23.14 (4.91)	22.53 (4.84)	18.96 (4.47)	20.18 (4.59)	19.57 (4.54)	16.78 (4.20)	18.01 (4.34)	17.39 (4.29)	15.23 (4.02)	16.45 (4.14)	15.84 (4.10)	14.20 (3.97)	15.42 (4.02)	14.81 (3.98)	25.68	24.29	24.99	30.06	29.75	29.44
T_3	*M. anisopliae* commercial	21.79 (4.77)	22.08 (4.80)	21.91 (4.78)	21.08 (4.69)	22.37 (4.83)	21.73 (4.77)	20.22 (4.61)	20.51 (4.64)	20.37 (4.62)	19.83 (4.56)	21.12 (4.70)	20.48 (4.63)	18.46 (4.41)	19.75 (4.56)	19.11 (4.48)	8.72	6.29	6.75	14.59	15.86	14.69
T_4	*L. lecanii* commercial	20.66 (4.65)	22.40 (4.83)	21.53 (4.75)	19.74 (4.55)	20.65 (4.65)	20.19 (4.60)	18.13 (4.37)	20.03 (4.59)	19.08 (4.48)	17.42 (4.29)	18.65 (4.43)	18.04 (4.36)	16.25 (4.15)	18.20 (4.38)	17.23 (4.27)	13.41	13.48	13.42	23.19	21.87	22.17
T_5	Azadirachtin 10000 ppm	20.77 (4.66)	23.21 (4.92)	21.99 (4.79)	19.23 (4.49)	21.03 (4.69)	20.13 (4.59)	17.89 (4.35)	18.42 (4.41)	18.16 (4.38)	15.78 (4.09)	17.73 (4.33)	16.75 (4.21)	13.54 (3.81)	16.04 (4.13)	14.79 (3.97)	20.03	21.07	20.60	28.68	25.58	27.09
T_6	Soapnut powder	21.11 (4.69)	21.95 (4.79)	21.53 (4.75)	19.36 (4.51)	20.25 (4.61)	19.81 (4.56)	18.55 (4.42)	19.84 (4.57)	19.19 (4.49)	17.36 (4.29)	18.52 (4.42)	17.94 (4.35)	16.91 (4.23)	16.54 (4.19)	16.73 (4.21)	14.49	14.39	14.45	22.50	23.59	23.08
T_7	Jet water spray	21.99 (4.79)	23.28 (4.93)	22.64 (4.86)	20.53 (4.64)	21.82 (4.78)	21.18 (4.71)	19.50 (4.53)	20.79 (4.67)	20.15 (4.59)	19.10 (4.48)	20.39 (4.63)	19.75 (4.56)	18.13 (4.37)	19.47 (4.52)	18.79 (4.45)	12.19	11.43	11.79	17.09	16.14	16.62
T_8	Control (No sprayings)	20.84 (4.67)	22.13 (4.81)	21.49 (4.74)	21.37 (4.73)	22.65 (4.86)	22.01 (4.79)	23.62 (4.96)	24.91 (5.08)	24.27 (5.02)	23.74 (4.98)	25.08 (5.11)	24.44 (5.04)	24.43 (5.04)	25.72 (5.17)	25.08 (5.11)	-	-	-	-	-	-
	S.E (m)	0.09	0.09	0.07	0.03	0.04	0.03	0.07	0.06	0.07	0.04	0.03	0.03	0.06	0.04	0.05	-	-	-	-	-	-
	C.D at 5 %	N.S	N.S	N.S	0.11	0.12	0.08	0.21	0.19	0.19	0.11	0.10	0.09	0.17	0.12	0.14	-	-	-	-	-	-
	C.V	3.55	3.35	2.69	1.29	1.45	0.92	2.62	2.40	2.45	1.38	1.29	1.23	2.26	1.49	1.78	-	-	-	-	-	-

*Mean of three replicates; DAS: Days after spraying, Figures in the parenthesis are √x + 0.5 transformed values

Table 5. Efficacy of biopesticides against adults of RSW, *A. rugioperculatus* under moderate incidence palms (10-20 spirals per leaflet)

S. No.	Treatments	Pre-Count*	Post-Count*															Per cent Reduction (%)			Per cent Reduction over control (%)		
			7 DAS			14 DAS			21 DAS			28 DAS											
		2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results	2020-21	2021-22	Pooled results
T_1	*B. bassiana* commercial	27.68 (5.35)	28.39 (5.42)	28.04 (5.39)	25.46 (5.14)	26.17 (5.21)	25.82 (5.18)	24.60 (5.06)	25.31 (5.13)	24.96 (5.09)	22.60 (4.86)	23.31 (4.93)	22.96 (4.89)	18.00 (4.36)	18.71 (4.44)	18.36 (4.39)	18.09	17.65	17.87	40.11	37.29	38.70
T_2	*I. fumosorosea* NBAIR pfu-5	30.06 (5.56)	30.77 (5.63)	30.42 (5.59)	27.43 (5.33)	28.14 (5.39)	27.79 (5.36)	23.67 (4.97)	24.38 (5.04)	24.03 (5.00)	19.73 (4.55)	20.44 (4.63)	20.09 (4.59)	16.00 (4.12)	17.23 (4.28)	16.62 (4.20)	27.78	26.71	27.25	43.66	40.51	42.09
T_3	*M. anisopliae* commercial	27.33 (5.32)	28.04 (5.39)	27.69 (5.35)	26.09 (5.27)	27.61 (5.34)	27.26 (5.31)	25.33 (5.13)	26.04 (5.20)	25.68 (5.17)	23.35 (4.94)	24.06 (5.01)	23.71 (4.97)	19.35 (4.51)	20.06 (4.59)	19.71 (4.55)	13.90	12.83	13.00	37.83	34.42	35.88
T_4	*L. lecanii* commercial	30.52 (5.61)	31.23 (5.67)	30.88 (5.64)	28.47 (5.43)	29.18 (5.49)	28.83 (5.46)	26.43 (5.24)	27.14 (5.31)	26.79 (5.27)	22.46 (4.84)	23.17 (4.92)	22.82 (4.88)	19.78 (4.56)	20.49 (4.63)	20.14 (4.59)	20.41	19.98	20.17	35.81	32.97	34.39
T_5	**Azadirachtin 10000 ppm**	27.26 (5.31)	27.97 (5.38)	27.62 (5.35)	25.38 (5.14)	26.09 (5.21)	25.74 (5.17)	21.79 (4.77)	22.49 (4.85)	22.14 (4.81)	17.32 (4.28)	18.03 (4.36)	17.67 (4.32)	15.46 (4.06)	16.17 (4.14)	15.82 (4.10)	27.79	26.83	27.27	47.19	44.51	45.86
T_6	Soapnut powder	30.08 (5.58)	30.79 (5.64)	30.44 (5.61)	27.42 (5.33)	28.13 (5.39)	27.78 (5.36)	24.45 (5.05)	25.16 (5.12)	24.81 (5.08)	18.32 (4.39)	19.03 (4.48)	18.68 (4.44)	16.94 (4.24)	17.65 (4.32)	17.29 (4.28)	27.02	25.95	26.36	42.01	39.37	41.07
T_7	Jet water spray	29.63 (5.53)	30.34 (5.59)	29.98 (5.57)	27.39 (5.32)	28.10 (5.39)	27.75 (5.36)	25.83 (5.18)	26.54 (5.25)	26.18 (5.21)	23.10 (4.91)	23.81 (4.98)	23.46 (4.95)	21.21 (4.71)	21.92 (4.78)	21.57 (4.74)	17.71	17.30	17.48	35.59	32.69	34.15
T_8	Control (No sprayings)	30.10 (5.58)	30.81 (5.64)	30.46 (5.61)	33.11 (5.84)	33.84 (5.90)	33.47 (5.87)	37.48 (6.19)	33.00 (5.83)	35.23 (6.02)	38.45 (6.28)	39.16 (6.34)	38.81 (6.31)	42.40 (6.59)	43.11 (6.64)	42.76 (6.62)	-	-	-	-	-	-
	S.E (m)	0.13	0.13	0.13	0.10	0.09	0.09	0.07	0.05	0.06	0.04	0.04	0.04	0.08	0.08	0.08	-	-	-	-	-	-
	C.D at 5 %	N.S	N.S	N.S	0.31	0.30	0.30	0.22	0.14	0.18	0.11	0.11	0.11	0.25	0.25	0.25	-	-	-	-	-	-
	C.V	4.12	4.02	4.07	3.25	3.17	3.19	2.38	1.49	1.90	1.25	1.24	1.24	3.08	2.97	3.03	-	-	-	-	-	-

*Mean of three replicates; DAS: Days after spraying, Figures in the parenthesis are √x + 0.5 transformed values

form of the moulting hormone), and thus acts as a growth regulator, antifeedant and insect repellent against insects of various genera, including those that feed on plant fluids (Copping and Duke, 2007). The significance of Azadirachtin (a limonoid triterpenoid molecule) in inhibiting insect growth and development has been discovered in the digestive, endocrine and reproductive systems of insects. On several phytophagous insects, it has a severe antifeedant effect. The results are in line with the findings of Chandrika *et al.,* (2017), Elango and Nelson (2020), Alagar *et al.,* (2021) and Krishnarao and Chalapathi Rao (2019) who reported that Azadirachtin 10,000 ppm (1 ml) and detergent powder (10 g) resulted in a low RSW adult intensity (9.43±2.18).

The powdered soapnut, which contains active ingredients like triterpenoid saponins (I) and sesquiterpene glucoside (II) was found to have higher ovicidal, larvicidal and pupicidal effects in the current study, resulting in mortality of all *A. rugioperculatus* developmental stages. The findings were supported by Koodalingam *et al.,* (2009), who explained the superiority of soapnut powder against stages of the *A. aegypti* mosquito.

In comparison to *B. bassiana* and *M. anisopliae*, *I. fumosorosea* and *L. lecanii* demonstrated promising levels of virulence against *A. rugioperculatus* life stages in all applications and seasons. Dipcolonic acid, hydroxycarboxylic acid and cyclosporine are produced by *L. lecanii* and cause an elevation in the pH of the haemolymph, clotting and stopping the circulation of the haemolymph in the insect. Boopathi *et al.,* (2013) also obtained similar results against *A. dispersus*. Elango and Nelson (2020) reported that *L. lecanii* (NBAIR VL-15 strain) @ 1 x 10^8 conidia/ml exhibited up to 50 per cent RSW mortality.

CONCLUSION

Thus, considering all aspects in the present study, azadiracthin 10,000 ppm significantly reduced the nymphal population of RSW and was found superior among the different treatments tested. Regarding the reduction of the adult population, pest incidence and pest intensity, *I. fumosorosea* NBAIR pfu-5 spray was significantly superior compared to that of other treatments. Further investigations on the combined use of Azadirachtin and *I. fumosorosea* may be helpful for the effective management of coconut RSW.

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