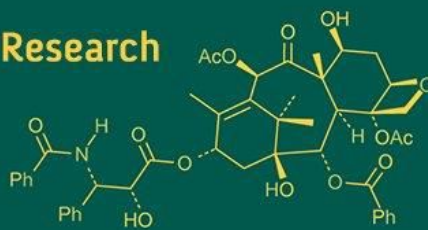


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Efficacy of Entomopathogenic fungi and botanicals against Rugose spiralling whitefly, *Aleurodicus rugioperculatus* martin in coconut under low grade (spirals <10)

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Abstract

The present study evaluated the efficacy of various Entomopathogenic Fungi and Botanicals against the rugose spiralling whitefly (RSW), *Aleurodicus rugioperculatus* Martin in coconut, focusing on different life stages including spirals, nymphs, pupae and adults. Field experiments were conducted at Horticultural Research station, Ambajipeta during 2021-2022 using randomized block design with nine treatments, including entomopathogenic fungi (*Isaria fumosorosea*, *Cladosporium perangustum*, *Fusarium equiseti*, *Metarhizium anisopliae*, *Lecanicillium lecanii*), azadirachtin 10, 000 ppm, jet water spray and untreated control, with five replications. Foliar sprays were applied at 15-day intervals, and observations were recorded at 7-day intervals. The results revealed significant differences among treatments across all evaluation periods (7, 14, 21 and 28 DAS). Among the tested biopesticides, *I. fumosorosea* NBAIR pfu-5 @ 5 ml/L exhibited the highest efficacy in reducing RSW spirals (91.05%), nymphs (82.00%), pupae (76.73%), and adults (91.97%) after 28 DAS, followed closely by azadirachtin 10, 000 ppm @ 1 ml/L, which achieved reductions of 88.02%, 78.71%, 73.29%, and 90.40%, respectively. *C. perangustum* and *F. equiseti* also demonstrated promising suppression of spirals (85.44% and 81.77%) and nymphs (73.38% and 71.20%), while *M. anisopliae* showed comparatively lower efficacy, particularly against pupae and adults. The untreated control consistently recorded the highest populations across all life stages, confirming the effectiveness of biopesticidal interventions.

Keywords: Assessment, rugose spiralling whitefly, biopesticide, *isaria*

Introduction

The coconut palm (*Cocos nucifera* L.), a prominent member of the family Arecaceae (Palmae), is widely recognized for its immense economic, nutritional, medicinal, and industrial value and is aptly referred to as the “Kalpavriksha.” India is one of the leading coconut-producing countries, with cultivation predominantly concentrated in the southern states, where the crop plays a vital role in sustaining rural livelihoods and the national agro-economy (APCC, 2024; CDB, 2024) [4, 8]. However, coconut cultivation is severely constrained by a wide range of insect pests, among which invasive whiteflies have emerged as a major threat in recent years, causing significant yield losses due to sap sucking, honeydew excretion, and subsequent sooty mould development that interferes with photosynthesis (Francis *et al.*, 2016) [14].

The intensification of global agricultural trade has facilitated the accidental introduction and rapid spread of invasive pests such as the rugose spiralling whitefly (*Aleurodicus rugioperculatus*) in coconut ecosystems across India (Ananthakrishnan, 2009; Sundararaj and Selvaraj, 2017; Chalapathirao *et al.*, 2018) [3, 22, 9]. These pests have proliferated rapidly due to their polyphagous nature, cryptic life stages, and favourable climatic conditions, often in the absence of effective native natural enemies (Simala *et al.*, 2015; Srinivasan *et al.*, 2016) [20, 21]. In response, farmers have increasingly resorted to indiscriminate application of chemical pesticides, which has resulted in environmental pollution, destruction of beneficial arthropods, health hazards, pesticide residue problems, and the risk of resistance development and secondary pest outbreaks (Bailey *et al.*, 2010) [5].

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In this context, biological control using biopesticides offers a promising, environmentally safe alternative to conventional chemical pesticides. Entomopathogenic fungi such as *Beauveria bassiana*, *Metarhizium anisopliae*, *Lecanicillium lecanii*, and *Isaria fumosorosea* have gained considerable attention due to their host specificity, safety to non-target organisms, and compatibility with natural enemies (Ali *et al.*, 2010) [2]. These biopesticides infect insect hosts through cuticular penetration and internal colonization, leading to effective suppression of pest populations without leaving harmful residues or inducing resistance.

Given the increasing incidence of invasive whitefly complexes and the drawbacks associated with chemical-based control measures, systematic evaluation of biopesticides under field conditions is essential. Assessing their efficacy against different life stages of whiteflies and their interaction with natural enemy complexes will aid in identifying sustainable and eco-friendly management strategies (Boopathi *et al.*, 2013; Selvaraj *et al.*, 2020) [6, 18].

Such evaluations are crucial for strengthening integrated pest management (IPM) programmes, reducing chemical dependence, and ensuring long-term sustainability of coconut production systems.

Methods of observation

The field experiment was conducted at Horticultural Research Station (HRS), Ambajipeta during 2021-2022 to evaluate the efficacy of different biopesticides against RSW in coconut. The experiment was laid out in a Randomized Block Design (RBD) with nine treatments and five replications. Coconut palms were planted at a spacing of 7.5 × 7.5 m and the variety 'Gauthami Ganga' was selected for the study.

Among the treatments, six were biopesticides, one botanical (azadiractin 10, 000 ppm), one jet water spray, and an untreated control. The required quantity of spray solution was prepared freshly at the time of application. Jet water spray was applied using a high-jet sprayer (Honda four-stroke petrol sprayer).

Table 1: List of various bio-pesticides evaluated against whitefly complex.

	Treatments	Concentration	Dosage
T ₁	<i>Isaria fumosorosea</i> NBAIR pfu- 5 @ 5 ml/L	1 X 10 ⁸ cfu	5 ml/L
T ₂	Azadiractin	10000 ppm	1 ml/L
T ₃	<i>Cladosporium perangustum</i> (Dr.YSRHU strain 1)	1 X 10 ⁸ cfu	5 ml/L
T ₄	<i>Fusarium equiseti</i> (Dr. YSRHU strain 2)	1 X 10 ⁸ cfu	5 ml/L
T ₅	<i>Lecanicillium lecanii</i>	1 X 10 ⁸ cfu	5 ml/L
T ₆	<i>Beauveria bassiana</i>	1 X 10 ⁸ cfu	5 ml/L
T ₇	<i>Metarhizium anisopliae</i>	1 X 10 ⁸ cfu	5 ml/L
T ₈	Jet water spray	-	-
T ₉	Control (no spraying)	-	-

In the coconut plantation, spray applications were carried out at 15-day intervals. After recording the pre-treatment counts, observations on whitefly populations were made at 7 day intervals following each spray. For population assessment, five coconut palms per treatment were selected randomly. Counts of nymphs, pupae, and adults were recorded from four pest-infested leaflets per leaf, collected from four leaves per palm representing the top, middle, and lower whorls and all four directions, total of 16 leaflets per

palm. The observations were expressed as mean population per leaflet per palm. Nymphs and pupae were counted under a Nikon SMZ18 stereomicroscope, while adult whiteflies were recorded through visual observation. The pest population reduction is obtained by using following formula

$$\text{Pest population reduction \%} = \frac{\text{Pretreatment count} - \text{treatment count}}{\text{Treatment count}} \times 100$$

Table 2: Rating scale for assessing the Rugose spiralling whitefly intensity/ leaflet.

Egg spirals / leaflet	Grade
No egg spirals population	Nil
Fewer than 10 egg spirals per leaflet	Low
Ten to 20 egg spirals per leaflet	Medium
More than 20 egg spirals per leaflet	High

(Selvaraj *et al.*, 2016) [19]

Results and Discussion

Evaluation of biopesticides against RSW (*A. rugioperculatus*) life stages under low grade (> 10 spirals/ leaflet).

The categorization of low, medium and high grade was exclusively based on the number of spirals/ leaflet irrespective of the nymph, pupae and adult stages of whitefly complex.

As per the rating scale given by Selvaraj *et al.* (2016) [19], the RSW spirals under field conditions were less than 10 numbers (grade - low incidence) were used for the study. The data on efficiency of biopesticides in reducing the pest population viz., egg spirals, nymphs, pupae and adults are furnished in the below heads.

Table 3: Evaluation of various biopesticides against RSW spirals under low grade (<10 spirals/ leaflet).

Treatment	PTC	7 DAS	14 DAS	21 DAS	28 DAS	Reduction % Over PTC
<i>I. fumosorosea</i> NBAIR pfu- 5 @ 5 ml/L	8.35 (3.04)	3.61 (2.14)	2.63 (1.89)	1.06 (1.43)	0.73 (1.31)	91.05
Azadiractin 10000 ppm @ 1ml/L	7.42 (2.88)	3.47 (2.10)	2.62 (1.89)	1.19 (1.47)	0.86 (1.36)	88.02
<i>C. perangustum</i> @ 5 ml/L (Dr. YSRHU strain1)	6.54 (2.73)	3.23 (2.04)	2.57 (1.88)	1.27 (1.50)	0.96 (1.39)	85.44
<i>F. equiseti</i> @ 5 ml/L (Dr. YSRHU strain2)	8.41 (3.05)	4.41 (2.31)	3.66 (2.15)	1.94 (1.71)	1.53 (1.58)	81.77
<i>L. lecanii</i> Commercial @ 5 ml/L	7.52 (2.90)	4.29 (2.29)	3.66 (2.15)	2.11 (1.76)	1.72 (1.64)	77.17
<i>B. bassiana</i> Commercial @ 5 ml/L	8.10 (3.00)	4.94 (2.42)	4.37 (2.30)	2.60 (1.89)	2.21 (1.78)	72.74
<i>M. anisopliae</i> Commercial @ 5 ml/L	6.25 (2.68)	4.04 (2.23)	3.67 (2.15)	2.31 (1.81)	2.05 (1.74)	67.31
Water spray	6.79 (2.77)	6.25 (2.67)	6.15 (2.66)	5.60 (2.55)	5.45 (2.52)	12.30
Control (untreated)	7.37 (2.87)	10.56 (3.38)	13.78 (3.82)	17.24 (4.24)	20.15 (0.29)	-
SE (m) ±	-	0.04	0.06	0.08	0.09	-
C.D at 5%	NS	0.11	0.17	0.25	0.10	-

*values in the table are mean/ leaflet; DAS: Days after spraying, PTC: Pre-treatment data, Figures in the parenthesis are $\sqrt{x} + 0.5$ transformed values.

Table 4: Evaluation of various biopesticides on RSW nymphs under low grade.

Treatment	PTC	7 DAS	14 DAS	21 DAS	28 DAS	Reduction % Over PTC
<i>I. fumosorosea</i> NBAIR pfu- 5 @ 5 ml/L	34.12 (5.89)	17.87 (4.31)	14.99 (3.97)	7.06 (2.82)	6.21 (2.67)	82.00
Azadiractin 10000 ppm @ 1ml/L	33.50 (5.83)	18.38 (4.37)	15.79 (4.05)	7.99 (2.98)	7.13 (2.83)	78.71
<i>C. perangustum</i> @ 5 ml/L (Dr. YSRHU strain1)	32.47 (5.71)	18.51 (4.39)	16.44 (4.15)	9.16 (3.17)	8.42 (3.05)	73.38
<i>F. equiseti</i> @ 5 ml/L (Dr. YSRHU strain2)	33.76 (5.86)	20.26 (4.58)	18.53 (4.39)	10.87 (3.42)	10.20 (3.33)	71.2
<i>L. lecanii</i> Commercial @ 5 ml/L	34.57 (5.92)	22.88 (4.85)	21.40 (4.70)	13.12 (3.73)	12.47 (3.65)	63.93
<i>B. bassiana</i> Commercial @ 5 ml/L	35.11 (5.93)	24.56 (5.02)	23.40 (4.91)	15.30 (4.01)	14.83 (3.95)	57.72
<i>M. anisopliae</i> Commercial @ 5 ml/L	33.25 (5.81)	24.37 (5.00)	23.54 (4.92)	16.47 (4.15)	16.11 (4.11)	51.54
Water spray	35.50 (6.00)	34.07 (5.88)	33.31 (5.82)	31.32 (5.65)	30.37 (5.56)	11.47
Control (untreated)	34.42 (5.66)	37.78 (6.19)	42.26 (6.53)	46.02 (6.81)	50.67 (7.14)	-
SE (m) ±	-	0.056	0.07	0.11	0.12	-
C.D at 5%	NS	0.169	0.21	0.33	0.37	-

RSW Spirals

The overall results revealed that, significant difference was observed among different treatments of bio pesticides against spirals and webs at 7, 14, 21 and 28 days after spraying (DAS). The treatment *I. fumosorosea* NBAIR pfu- 5 @ 5 ml/L recorded highest spiral reduction of 91.05% and was found to be superior followed by Azadiractin 10, 000 ppm @ 1 ml/ L with reduction of 88.02% after 28 DAS. Among the other entomopathogenic fungi, evaluated *C. perangustum* and *F. equiseti* were found to be promising with reduction of 85.44% and 81.77% after 28 DAS (Table 3).

RSW Nymphs.

I. fumosorosea NBAIR pfu-5 @ 5 ml/L was found to be effective in reducing the nymphal population of RSW with 82.00% reduction after 28 DAS followed by Azadiractin 10, 000 ppm @ 1 ml/L with reduction of 78.71%. Among the other entomopathogenic fungi evaluated, *C. perangustum* was found to be promising in reducing the nymphs with reduction 73.38% after 28 DAS. *F. equiseti* was found to be promising in reducing nymphs of RSW with reduction 71.20% after 28 DAS. However, the control treatment recorded highest population of nymphs of both RSW with 50.67/leaflet (Table 4).

Table 5: Evaluation of different biopesticides on RSW pupae under low grade.

Treatment	PTC	7 DAS	14 DAS	21 DAS	28 DAS	Reduction% Over PTC
<i>I. fumosorosea</i> NBAIR pfu- 5 @ 5 ml/L	24.50 (5.02)	14.55 (3.92)	12.23 (3.61)	6.89 (2.79)	5.70 (2.57)	76.73
<i>Azadiractin</i> 10000 ppm @ 1ml/L	25.35 (5.10)	15.54 (4.04)	13.61 (3.80)	8.14 (3.00)	6.90 (2.79)	73.29
<i>C. perangustum</i> @ 5 ml/L (Dr. YSRHU strain1)	26.12 (5.17)	16.95 (4.12)	15.19 (4.00)	9.43 (3.21)	8.16 (3.01)	68.75
<i>F. equiseti</i> @ 5 ml/L (Dr. YSRHU strain2)	25.53 (5.12)	17.15 (4.23)	15.60 (4.05)	10.22 (3.33)	9.01 (3.14)	64.72
<i>L. lecanii</i> Commercial @ 5 ml/L	26.58 (5.22)	18.74 (4.14)	17.25 (4.24)	11.90 (3.57)	10.75 (3.41)	59.58
<i>B. bassiana</i> Commercial @ 5 ml/L	25.85 (5.15)	19.10 (4.45)	17.90 (4.26)	12.82 (3.69)	11.80 (3.55)	54.38
<i>M. anisopliae</i> Commercial @ 5 ml/L	24.63 (5.03)	18.82 (4.42)	17.91 (4.32)	13.57 (3.79)	12.74 (3.68)	48.26
Water spray	26.52 (5.21)	25.38 (5.10)	25.09 (5.07)	23.74 (6.34)	23.27 (4.89)	12.24
Control (untreated)	26.60 (5.22)	32.14 (5.72)	35.55 (6.01)	39.78 (6.34)	43.62 (6.63)	-
SE (m) ±	-	0.048	0.06	0.09	0.10	-
C.D at 5%	NS	0.14	0.18	0.28	0.32	-

Table 6: Evaluation of different biopesticides on RSW adults under low grade.

Treatment	PTC	7 DAS	14 DAS	21 DAS	28 DAS	Reduction% Over PTC
<i>I. fumosorosea</i> NBAIR pfu- 5 @ 5 ml/L	13.46 (3.78)	6.24 (2.67)	4.04 (2.23)	1.77 (1.65)	1.08 (1.44)	91.97
<i>Azadiractin</i> 10000 ppm @ 1ml/L	15.42 (4.02)	7.64 (2.92)	5.05 (2.44)	2.33 (1.81)	1.48 (1.52)	90.40
<i>C. perangustum</i> @ 5 ml/L (Dr. YSRHU strain1)	12.46 (3.64)	6.50 (2.72)	4.48 (2.33)	2.21 (1.78)	1.47 (1.56)	88.28
<i>F. equiseti</i> @ 5 ml/L (Dr. YSRHU strain2)	15.63 (4.05)	8.72 (3.10)	6.15 (2.66)	3.22 (2.04)	2.23 (1.79)	85.74
<i>L. lecanii</i> Commercial @ 5 ml/L	13.94 (3.84)	8.15 (3.01)	5.97 (2.62)	3.34 (2.07)	2.39 (1.83)	82.92
<i>B. bassiana</i> Commercial @ 5 ml/L	15.23 (4.00)	9.55 (3.23)	7.43 (2.89)	4.43 (2.32)	3.32 (2.07)	78.23
<i>M. anisopliae</i> Commercial @ 5 ml/L	13.48 (3.78)	9.03 (3.15)	7.28 (2.86)	4.64 (2.36)	3.69 (2.15)	72.67
Water spray	13.47 (3.78)	12.87 (3.70)	12.62 (3.67)	11.96 (3.58)	11.67 (3.54)	12.43
Control (untreated)	14.23 (3.88)	20.15 (4.57)	26.79 (5.24)	35.15 (5.54)	42.10 (6.82)	-
SE (m) ±	-	0.05	0.082	0.11	0.15	-
C.D at 5%	NS	0.15	0.24	0.33	0.46	-

*values in the table are mean/ leaflet; DAS: Days after spraying, PTC: Pre-treatment data, Figures in the parenthesis are $\sqrt{x} + 0.5$ transformed values.

RSW Pupae

The overall results revealed that there was existence of significant difference among different treatments against RSW. Least number of pupae were recorded in treatment *I. fumosorosea* NBAIR pfu-5 @ 5 ml/L with 76.73% reduction over PTC RSW pupae after spraying and proved to be superior compared to that of other treatments followed by *Azadiractin* 10, 000 ppm @ 1 ml/L with 73.29% reduction. The control treatment was recorded with highest population of 43.62 pupae/ leaflet after 28 DAS. *M. anisopliae* @ 5 ml/L was found to be least effective in reducing the pupal population of RSW as per the data presented in (Table 5).

RSW Adults

The overall results during the experiment indicated that, significant difference was observed among different

treatments against adults of RSW. *I. fumosorosea* NBAIR pfu-5 @ 5 ml/L recorded lowest number with 91.97% reduction of RSW after spraying and found to be promising followed by *Azadiractin* 10, 000 ppm @ 1 ml/L (T_2) with reduction of 90.40%. Among the treated biopesticides *M. anisopliae* had least effect on adult population with 72.67% reduction of RSW adults after 28 days. The control (untreated) was recorded with highest population of both RSW adults with 42.10 after 28 days (Table 6).

The present investigation clearly demonstrated that foliar application of entomopathogenic fungi (EPF) substantially reduced the population of spirals, webbing, nymphs, pupae, and adults of both rugose spiralling whitefly (RSW). During the infection process, EPF secrete a complex of extracellular enzymes such as proteases, chitinases, and lipases, which facilitate degradation of the insect cuticle and enhance adhesion, germination, and penetration of fungal conidia

into the host body. Among the evaluated treatments, *Isaria fumosorosea* proved to be the most effective in suppressing all life stages of *Aleurodicus rugioperculatus*, including spirals, nymphs, pupae, and adults. Its performance was markedly superior to that of *Beauveria bassiana*, *Metarhizium anisopliae*, *Cladosporium perangustum*, *Fusarium equiseti*, and *Lecanicillium lecanii*, resulting in a significant reduction in pest incidence and intensity in coconut plantations.

The higher efficacy of *I. fumosorosea* can be attributed to its ability to produce hydrolytic enzymes such as chitinase, chitosanase, and lipase, which enable physical penetration of the insect cuticle and effective disruption of the host's physiological and regulatory systems (Ali *et al.*, 2010) [2]. The present findings are in close conformity with the reports of Boopathi *et al.* (2013, 2015) [6, 7] and Chalapathirao *et al.* (2020) [10], who documented that *I. fumosorosea* NBAIR pfu-5 reduced early nymphal instars of RSW by 52-68% and 35-40% in Godavari Ganga hybrid and Gauthami Ganga coconut varieties, respectively.

Further support to the present results is provided by Selvaraj *et al.* (2020) [18], who identified *I. fumosorosea* NBAIR pfu-5 as a promising strain for managing RSW populations in coconut and oil palm ecosystems of Karnataka and Andhra Pradesh through two spray applications at 15-day intervals. Similarly, Visalakshi *et al.* (2021) [23] reported a reduction of 58.10 to 97.03% in RSW intensity on coconut palms treated with *I. fumosorosea* (NBAIR pfu-5) @ 2×10^8 spores ml^{-1} (5 g L^{-1} of water). Although Pradhan *et al.* (2020) observed 100% mortality of whiteflies following *I. fumosorosea* application, complete mortality was not recorded under the present field conditions, possibly due to environmental and host-related factors influencing fungal performance.

Sumalatha *et al.* (2020) [18] further demonstrated that among the two strains of *I. fumosorosea* (ICAR-NBAIR pfu-1 and pfu-5), only the pfu-5 strain exhibited virulence against RSW. The pfu-5 strain induced mean mortalities of 44.03%, 44.80%, 36.42%, and 28.82% in eggs, first, third, and fourth instar nymphs, respectively, reinforcing its potential as an effective biocontrol agent.

Azadirachtin 10, 000 ppm emerged as the next most effective treatment after *I. fumosorosea*, significantly suppressing all developmental stages of both RSW. Azadirachtin interferes with insect growth and development by inhibiting ecdysone-20-monooxygenase activity in the haemolymph, thereby preventing the conversion of ecdysone into its active moulting hormone, 20-hydroxyecdysone. Consequently, it functions as a potent growth regulator, antifeedant, and repellent against a wide range of phytophagous insects (Copping and Duke, 2007) [12]. The bioactive limonoid triterpenoid nature of azadirachtin affects digestive, endocrine, and reproductive systems of insects and induces strong antifeedant responses. The present findings corroborate earlier reports by Chandrika *et al.* (2017) [11], Elango and Jayarajan (2020) [13], Alagar *et al.* (2021) [1], and Krishnarao and Chalapathirao (2019), who recorded significantly lower adult intensity of RSW following azadirachtin 10, 000 ppm application.

Cladosporium perangustum exhibited moderate efficacy in reducing nymphal and adult populations of both RSW. Species of *Cladosporium* are known to act as insect pathogenic microorganisms, and ethyl acetate extracts derived from *C. cladosporioides* have been reported to be effective against nymphs and adults of cotton aphid, *Aphis*

gossypii (Omar *et al.*, 2019) [16]. Similar trends of moderate suppression were observed in the present study, indicating its potential role as a supplementary biocontrol agent.

In contrast, *Metarhizium anisopliae* failed to provide satisfactory control of RSW under field conditions. Its relatively poor performance may be attributed to lower conidial density, reduced persistence, or suboptimal environmental compatibility, which limited its ability to suppress pest populations effectively. Comparable observations were earlier reported by Boopathi *et al.* (2013) [6], who also recorded reduced field efficacy of *M. anisopliae* against RSW.

Conclusion

Among the treated biopesticides *Isaria fumosorosea* NBAIR pfu-5 @ 5 ml/L water was found to be superior in reducing the RSW population followed by Azadirachtin 10, 000 ppm @ 1 ml/L water. In contrast, *Metarhizium anisopliae* was found to be least effective in reducing the pest population.

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