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Yellow banded ichneumonid wasp visits flower
Indian Entomologist published by the Entomological Society of India organised a photo contest. First prize was for a photo by Shashidharswamy Hiremath- 'Yellow banded ichneumonid wasp visits flower', Haveri, Karnataka. For more details see Indian Entomologist at https://dccc38f4-b4ba-41ec-b5bc-6b883fd2dac8.filesusr.com/ugd/375348_c9c3b394307b4b16b060487facc7c4dc.pdf
(Courtesy - Dr P R Shashank)

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EFFICACY OF INSECTICIDES AGAINST INVASIVE RUGOSE SPIRALLING WHITEFLY *ALEURODICUS RUGIOPERCULATUS* MARTIN ON BANANA

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ABSTRACT

Laboratory and field evaluation of some insecticides (buprofezin 25 SC, pymetrozine 50 WG, flonicamid 50 WG, dinotefuran 20 SG, thiamethoxam 25 WG, profenophos 50 EC), botanical (azadirachtin 10000 ppm) and entomopathogenic fungus (*Isaria fumosorosea* Wize) were carried out against the invasive rugose spiralling whitefly *Aleurodicus rugioperculatus* Martin on banana. The results revealed that azadirachtin 10000 ppm (86.49%), dinotefuran 20 SG (82.64%), pymetrozine 50 WG (72.72%) and thiamethoxam 25 WG (79.59%) caused significant mortality of first and second instar nymphs at 2 days after treatment (DAT). Profenophos 50 EC (77.61%) and azadirachtin 10000 ppm (71.53%) were significantly effective and on par with mortality at 2 DAT of third and fourth instar nymphs. Flonicamid 50 WG was the most toxic with the least LC_{50} value (507.8 and 646.1) and buprofezin 25 SC was the least toxic with maximum LC_{50} value (1245.1 and 1752.0) for early and late instar nymphs, respectively. Profenophos 50 EC and buprofezin 25 SC also showed maximum ovicidal effect. Under field conditions, *I. fumosorosea* with 100% mortality was significantly superior compared to dinotefuran 20 SG (97.23%), thiamethoxam 25 WG (95.02%) and azadirachtin 10000 ppm (94.98%) at 6 DAT.

Key words: Rugose spiralling whitefly, banana, instars, mortality, LC_{50} ovicidal effect, buprofezin, pymetrozine, flonicamid, dinotefuran, thiamethoxam, profenophos, azadirachtin, *Isaria fumosorosea*

The rugose spiralling whitefly (RSW), *Aleurodicus rugioperculatus* Martin an invasive species was initially reported as a pest on gumbo limbo *Bursera simaruba* (L.) Sarg from Miami-Dade country, Florida, USA in 2009. Martin (2004) first described the RSW from the samples collected in Belize on coconut palm leaves. In India, it was first detected on coconut palm in Tamil Nadu at Pollachi during August-September, 2016 (Selvaraj et al., 2016; Sundararaj and Selvaraj, 2017). Subsequently it was found infesting banana (*Musa* sp.), mango (*Mangifera indica* L.), sapota (*Manilkara zapota* L.), Indian almond (*Terminalia catappa* L.), custard apple (*Annona reticulata* L.) and several ornamental plants in Kerala, Karnataka and Andhra Pradesh (Selvaraj et al., 2016). RSW is highly polyphagous feeding on 118 plants (Stocks, 2012). In India, RSW found to colonize 35 host plants and its infestation ranged from 20-45% in coconut, 18-56% in banana and 21-52% in Indian almond (Selvaraj et al., 2016). Prolonged dry spell from June onwards could be one of the predisposing factors (Srinivasan et al., 2016). The deficit rainfall, increased temperature and reduced humidity caused its flare up (Josephrajkumar et al., 2018). RSW has four nymphal instars as in most whiteflies (Byrne and Bellows, 1991; Martin, 2004). The female lays eggs in spiral arrangements on the abaxial surface of leaves and cover them with white, fluffy wax, creating distinctive spiral patterns. Nymphs complete development on a broad range of native and non-native host plant of several plant families (Mannion, 2010).

Natural parasitism by the parasitoids *Encarsia guadeloupae* Viggiani (Hymenoptera: Aphelinidae) from 40.0-80.0% and *Encarsia dispersa* Polaszek with 0-7% parasitism had been observed (Selvaraj et al., 2016; Poorani and Thanigairaj, 2017). Augmentation and conservation of *E. guadeloupae* and foliar application of neem oil @ 0.5% had been recommended for the management of RSW in India. Pest spreads rapidly to newer location without natural enemies, and parasitoid population is not uniform across the infested locations. Therefore, there is need for alternative strategies such as insecticides especially biorationals to tackle its further spread and management. Keeping this in view, the present study evaluates efficacy of some

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insecticides, insect growth regulators, botanical and a microbial against RSW on banana.

MATERIALS AND METHODS

Aleurodicus rugioperculatus was collected from culture maintained on banana in a greenhouse at 28±2°C with a natural photoperiod (L: D) of approximately 12:12 hr at the ICAR- National Bureau of Agricultural Insect Resources (13°.05˙.48¨N, 770.34'.30''E). Banana plants were grown in field as per recommended package of practices and RSW culture collected from infested plants were inoculated. Different lifestages such as early instar (first and second) and late instar nymphs (third and fourth) collected from this culture and were used for bioassay. Insecticides, botanicals, insect growth regulators and microbial pesticides such as buprofezin 25 SC, pymetrozine 50 WG, flonicamid 50 WG, dinotefuran 20 SG, thiamethoxam 25 WG, profenophos 50 EC, azadirachtin 10000 ppm and *Isaria fumosorosea* were evaluated to determine their dose mortality response and to evaluate their efficacy under laboratory and field conditions.

Banana leaf bits of 4 cm² with eggs, early (first and second) and late (third and fourth) instars were kept separately to evaluate ovicidal and toxicity at the ICAR-NBAIR. Each leaf bit with 25-30 numbers of eggs, early and late instars were counted with 40x stereozoom microscope. To determine median lethal concentration (LC_{50} value) on lifestages, bracketing was done. To determine the toxicity and LC_{50} value, each insecticide was evaluated with five concentrations viz., 1%, 0.5%, 0.25%, 0.125%, 0.06%, prepared by adoption of serial dilution techniques using distilled water, and Triton-X was used as surfactant. The concentrations, giving 20-80% mortality, taken as ideal range were used for determination of LC_{50} value. The range of concentrations, which do not give mortality of 20-80%, further lower or higher concentrations were taken to get the desired range of mortality and used for determination of LC_{50} value. These treatments were sprayed on leaf bit using hand sprayer gently and allowed for air drying and further placed on wet filter paper in petri plates. There were nine treatments, including seven insecticides and two controls (water spray and untreated control) and replicated five times. Pretreatment count was made and mortality observed up to 3 days after treatment (DAT). Change in nymphs colour from yellowish green to dark reddish brown was considered as dead. Similar experiment was carried out for late instars on the same day.

Selected insecticides were evaluated on banana crop in a randomized block design at ICAR-NBAIR. Total 10 treatments viz., buprofezin 25 SC (1.75 ml/ l), pymetrozine 50 WG (0.85 g/ l), flonicamid 50 WG (0.85 g/ l), dinotefuran 20 SG (0.93 g/l), thiamethoxam 25 WG (0.84 g/ l), profenophos 50 EC (1.3 ml/ l), azadirachtin 10000 ppm (1.71 ml/ l) and *Isaria fumosorosea*-ICAR-NBAIR pfu-5 (5 g/ l) including two controls (water spray and untreated control) were imposed with five replications and Triton-x was used as surfactant. Insecticides were sprayed on the under surface of leaves using high volume knapsack sprayer during late evening. Observations on populations (all lifestages) were made from randomly sprayed plants by cutting the 10 leaf bits/ plant to observe the mortality. The numbers of observed lifestages was fixed for all the observation days. Cumulative mortality of the lifestages (eggs, nymphs, adults) were observed at 2, 4, 6 and 8 DAT.

Mortality was corrected using Abbott's formula (Abbott, 1925). When the % corrected mortality lies in the range of 20-80, the LC_{50} value was determined for early and late instars following probit analysis in IBM SPSS 20 software. The data were subjected to ANOVA in simple completely randomized design as described by Panse and Sukhatme (1961) using RStudio software and interpreted at $p = 0.01$. Field evaluations of the selected insecticides were carried out to assess the efficacy. The data were subjected to ANOVA in randomized complete block design using RStudio software and interpreted at $p = 0.05$. Duncans multiple range test was applied for comparing treatment means (Duncan, 1955).

RESULTS AND DISCUSSION

LC_{50} (median lethal concentration): The % mortality at 2 DAT was taken as baseline to determine LC_{50}. The % mortality at 3 DAT was found to be >85% in all the treatments except water spray and untreated control in both early and late instars. In case of profenophos and buprofezin, five concentrations (1.0, 0.5, 0.25, 0.125, and 0.06%) gave mortality in the range of 20-80%, whereas flonicamid, thiamethoxam, dinotefuran, pymetrozine and azadirachtin, six concentrations (1, 0.5, 0.25, 0.125, 0.06, and 0.03 %) gave mortality in the range of 20-80% (Table 1). The LC_{50} values for insecticides viz. profenophos 50 EC, buprofezin 25 SC, flonicamid 50 WG, thiamethoxam 25 WG, dinotefuran 20 SG, pymetrozine 50 WG and azadirachtin 10000 ppm were 1103.7, 1245.1, 507.8, 857.6, 676.4, 679.6 and 607.8 ppm, respectively for

Table 1. LC_{50} value of insecticides on early and late instars of *A. rugioperculatus*

Insecticides	No. of insects/ treatment	LC_{50} (ppm)	Fiducial limit (ppm)	Slope ± SE	Regression equation	χ2 value	Df
			Early instar nymphs				
Profenophos 50EC	30	1103.7	908.609 - 1298.981	1.615 ± 0.135	$\hat{Y}$= - 4.916 + 1.615X	4.053	3
Buprofezin 25SC	25	1245.1	986.539 - 1507.136	1.278 ± 0.124	$\hat{Y}$= - 3.956 + 1.278X	1.903	3
Flonicamid 50WG	29	507.8*	177.797 - 870.106	1.243 ± 0.103	$\hat{Y}$= - 3.363 + 1.243X	16.469	4
Thiamethoxam 25WG	30	857.6	690.717 - 1034.952	1.165 ± 0.095	$\hat{Y}$= - 3.363 + 1.243X	1.676	4
Dinotefuran 20SG	27	676.4**	552.600 - 804.643	1.390 ± 0.106	$\hat{Y}$= - 3.933 + 1.390X	2.823	4
Pymetrozine 50WG	27	679.6**	425.979 - 954.036	1.496 ± 0.108	$\hat{Y}$= - 4.237 + 1.496X	9.435	4
Azadirachtin 10000 ppm	30	607.8**	499.577 - 718.793	1.528 ± 0.113	$\hat{Y}$= - 4.253 + 1.528X	1.737	4
			Late instar nymphs				
Profenophos 50EC	30	1310.008	996.690 - 1629.909	1.079 ± 0.12	$\hat{Y}$= - 3.364 + 1.079X	2.383	3
Buprofezin 25SC	28	1752.083	1392.995 - 2143.75	1.091 ± 0.117	$\hat{Y}$= - 3.540 + 1.091X	0.702	3
Flonicamid 50WG	27	646.112*	518.703 - 777.658	1.291 ± 0.101	$\hat{Y}$= - 3.627 + 1.291X	2.523	4
Thiamethoxam 25WG	30	836.042**	631.846 - 1054.617	0.927 ± 0.091	$\hat{Y}$= - 2.709 + 0.927X	0.826	4
Dinotefuran 20SG	25	933.16	743.723 - 1137.205	1.094 ± 0.094	$\hat{Y}$= - 3.248 + 1.094X	3.147	4
Pymetrozine 50WG	29	847.187**	578.773 - 1140.394	0.705 ± 0.087	$\hat{Y}$= - 2.065 + 0.705X	2.714	4
Azadirachtin 10000 ppm	30	1708.225	1177.782 - 2466.41	1.136 ± 0.093	$\hat{Y}$= - 3.672 + 1.136X	7.445	4

*- significantly effective

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early instar (first and second) nymphs and it was 1310.0, 1752.0, 646.1, 836.0, 933.1, 847.1 and 1708.2 ppm, respectively for late instar (third and fourth) nymphs. Thus flonicamid 50 WG proved to be more toxic with least LC_{50} value and buprofezin 25 SC was the least toxic with maximum LC_{50} value for early and late instar nymphs of *A. rugioperculatus.*

Ovicidal effect: The eggs were treated with the above treatments at 1, 0.5, 0.25, 0.125, 0.06% concentrations along with the LC_{50} value of the respective treatments. It was observed that at all concentrations of profenophos 50 EC and buprofezin 25 SC showed ovicidal effect at 5 DAT as the colour of the eggs changed to dark brown as shown by Ishaaya et al. (1987) and Mariam (1999) on *A. dispersus*.

Efficacy against nymphs: With early instars, maximum reduction over control was observed in azadirachtin 10000 ppm (36.49%), dinotefuran 20 SG (30.00%) and pymetrozine 50 WG (37.76%). These varied significantly superior with more mortality with least early instar nymphs at 1 DAT (Table 2). At 2 DAT, azadirachtin 10000 ppm (86.49%), dinotefuran 20 SG (82.64%), pymetrozine 50 WG (72.72%) and thiamethoxam 25 WG (79.59%) were significantly effective and superior. At 3 DAT, all the treatments were significantly effective, except water and untreated control (Table 2). Against late instars, azadirachtin 10000 ppm (35.77%) was significantly superior with higher mortality at 1 DAT (Table 2). At 2 DAT, profenophos 50 EC (77.61%), azadirachtin 10000 ppm (61.31%) were significantly effective with maximum mortality. Azadirachtin 10000 ppm was significantly superior (94.89%) as compared to other treatments

Table 2. Efficacy of insecticides against early and late instar nymphs of *A. rugioperculatus* (*in vitro* conditions)

Treatments	Mean No. of live insects (early instars)				Mean No. of live insects (late instars)			
	Pre-treatment	1 DAT	2 DAT	3 DAT	Pre-treatment	1 DAT	2 DAT	3 DAT
Profenophos 50EC	29.40 (5.47)	16.00 (4.06)^{b}	6.60 (2.66)^{b}	0.60 (1.05)^{ab}	28.60 (5.39)	20.60 (4.59)^{b}	8.00 (2.92)^{a}	1.60 (1.45)^{b}
Buprofezin 25SC	28.80 (5.41)	19.40 (4.46)^{c}	7.60 (2.85)^{bc}	0.80 (1.14)^{b}	28.20 (5.36)	23.20 (4.87)^{bc}	14.00 (3.81)^{b}	3.40 (1.97)^{c}
Flonicamid 50WG	29.60 (5.49)	20.80 (4.62)^{c}	9.40 (3.15)^{c}	0.60 (1.05)^{ab}	28.40 (5.38)	23.40 (4.89)^{bc}	12.80 (3.65)^{b}	3.40 (1.97)^{c}
Thiamethoxam 25WG	29.40 (5.47)	15.80 (4.04)^{b}	1.40 (1.38)^{a}	0.00 (0.71)^{a}	27.80 (5.32)	24.20 (4.97)^{c}	12.60 (3.62)^{b}	3.00 (1.87)^{c}
Dinotefuran 20SG	28.00 (5.34)	12.40 (3.59)^{a}	1.40 (1.38)^{a}	0.00 (0.71)^{a}	29.00 (5.43)	25.00 (5.05)^{cd}	12.20 (3.56)^{b}	4.00 (2.12)^{c}
Pymetrozine 50WG	28.60 (5.39)	12.60 (3.62)^{a}	2.40 (1.70)^{a}	0.40 (0.95)^{ab}	28.00 (5.34)	24.40 (4.99)^{c}	13.60 (3.75)^{b}	3.60 (2.02)^{c}
Azadirachtin 10000 ppm	29.60 (5.49)	11.20 (3.42)^{a}	1.20 (1.30)^{a}	0.00 (0.71)^{a}	27.40 (5.28)	15.20 (3.96)^{a}	7.20 (2.77)^{a}	0.00 (0.71)^{a}
Water	28.00 (5.34)	24.40 (4.99)^{d}	19.40 (4.46)^{d}	15.80 (4.04)^{c}	28.80 (5.41)	26.20 (5.17)^{cd}	23.20 (4.87)^{c}	19.20 (4.44)^{d}
Untreated control	28.80 (5.41)	28.40 (5.38)^{c}	27.00 (5.24)^{c}	26.60 (5.21)^{d}	28.60 (5.39)	28.40 (5.38)^{d}	28.00 (5.34)^{d}	27.80 (5.32)^{c}
F test	NS	**	**	**	NS	**	**	**
SEM ±	(0.05)	(0.07)	(0.11)	(0.09)	(0.08)	(0.10)	(0.10)	(0.09)
CD at p=0.01	-	(0.26)	(0.44)	(0.36)	-	(0.37)	(0.38)	(0.35)
C.V. (%)	-	3.66	9.77	12.72	-	4.42	5.69	8.23

DAT- Days after Treatment; **- Significant at p=0.01; NS- Non-significant; Values in parentheses square root transformation= $\sqrt{(x+0.5)}$; Means followed by same letter in a column do not differ significantly (DMRT, p= 0.01)

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at 3 DAT (Table 2). Shishiny (1984) and Rodolphe (1984) observed that insecticides gave good control when applied on early nymphal stages compared to late ones. Prabhakar et al. (1997) observed that crawlers of *Bemisia tabaci* were highly vulnerable to pesticidal spray than other stages.

Water spray was found to give mortality in the range of 30-40% at 3 DAS in both the instars agree with earlier report by Wen et al. (1995) on *A. dispersus*. The early instars were more susceptible as compared to late instar nymphs as they show almost complete mortality at 3 DAT. The neonicotinoids, dinotefuran and thiamethoxam, along with profenophos, an organophosphate, showed faster mortality due to nerve poisoning (Ali and Treacy, 2006). Pymetrozine being selective stylet feeding blocker, showed good mortality in case of early instars. The insect growth regulator (buprofezin) gave good control but it took more time (Boopathy et al., 2017).

Efficacy on adults and parasitoids: There was no emergence of adults of RSW and parasitoid even after 10 DAT except in untreated control when 30 numbers of unparasitized and parasitized pupae were taken for each treatment. Thus, none of the insecticides were safe to the *E. guadeloupae* parasitoid. Results on the effect of insecticides on RSW adults revealed that there was 100 % mortality within 3 DAT.

Field efficacy: Observations showed that, RSW population during pre-treatment count were not significant while it varied significantly during post-treatment counts between the treatments but not significant among the replications (Table 3). *Isaria fumosorosea* (70.00%) was significantly superior as compared to other treatments at 2 DAT, followed by profenophos 50 EC (47.88%), azadirachtin 10000 ppm (46.38%) and thiamethoxam 25 WG (39.32%) which were significantly superior. Overall mean mortality with buprofezin was 79.6 and 79.0 % during the 10 week assessment period under field conditions in 2014 and 2015, respectively (Kumar et al., 2018). *Isaria fumosorosea* (100%) was significantly superior at 6 DAT, followed by dinotefuran 20 SG (97.23%), thiamethoxam 25 WG (95.02%) and azadirachtin

Table 3. Efficacy of insecticides against *A. rugioperculatus* (field conditions)

Treatments	Pre-treatment	Mean No. of live insects (late instars)			
		2 DAT	4 DAT	6 DAT	8 DAT
Profenophos 50EC (1.3 ml)	29.20	15.20	8.80	4.00	0.20
	(5.45)	(3.96)^{b}	(3.05)^{cd}	(2.12)^{c}	(0.84)^{a}
Buprofezin 25SC (1.75 ml)	29.00	26.80	14.60	6.40	3.20
	(5.43)	(5.22)^{ef}	(3.89)^{e}	(2.63)^{d}	(1.92)^{c}
Flonicamid 50WG (0.85 gm)	28.20	25.20	16.20	12.20	3.20
	(5.36)	(5.07)^{de}	(4.09)^{e}	(3.56)^{e}	(1.92)^{c}
Thiamethoxam 25WG (0.84 gm)	28.00	17.00	4.80	1.40	0.20
	(5.34)	(4.18)^{bc}	(2.30)^{b}	(1.38)^{b}	(0.84)^{a}
Dinotefuran 20SG (0.93 gm)	29.20	24.20	3.40	0.80	0.20
	(5.45)	(4.97)^{d}	(1.97)^{b}	(1.14)^{b}	(0.84)^{a}
Pymetrozine 50WG (0.85 gm)	29.40	18.60	9.80	4.80	1.20
	(5.47)	(4.37)^{c}	(3.21)^{d}	(2.30)^{cd}	(1.30)^{b}
Azadirachtin 10000 ppm (1.71 ml)	28.00	15.00	7.00	1.40	0.40
	(5.34)	(3.94)^{b}	(2.74)^{c}	(1.38)^{b}	(0.95)^{a}
Isaria fumosorosea (5g/l)	30.00	9.00	1.00	0.00	0.00
	(5.52)	(3.08)^{a}	(1.22)^{a}	(0.71)^{a}	(0.71)^{a}
Water	29.20	28.60	24.40	18.80	14.40
	(5.45)	(5.39)^{f}	(4.99)^{f}	(4.39)^{f}	(3.86)^{d}
Untreated control	27.60	27.60	27.60	27.20	27.00
	(5.30)	(5.30)^{ef}	(5.30)^{f}	(5.26)^{g}	(5.24)^{e}
F test	NS	**	**	**	**
SEM ±	0.05	0.09	0.13	0.13	0.12
CD at p=0.05	-	0.25	0.37	0.39	0.35
C.V. (%)	-	4.38	8.82	12.22	15.22

DAT- Days after treatment; **-Significant at p=0.05; NS- Non-significant; Values in parentheses square root transformation= $\sqrt{(x+0.5)}$; Means followed by same letter in a column do not differ significantly by DMRT (p= 0.05)

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10000 ppm (94.98%). This fungus is being used as potential biocontrol agent against RSW and Bondar's nestling whitefly *Paraleyrodes bondari* on coconut (Ali et al., 2015; Kumar et al., 2016, 2018). Profenophos 50 EC (99.29%), thiamethoxam 25 WG (99.32%), dinotefuran 20 SG (99.29%) and azadirachtin 10000 ppm (98.56%) were observed to be significantly superior at 8 DAT. It was followed by pymetrozine 50WG (95.79%) (Table 3).

Insecticides do not adequately control the spiralling whitefly *A. dispersus* since the nymphs are covered with heavy waxy flocculent materials and waxy threads produced by the insect (Waterhouse and Norris, 1989; Neuenschwander, 1994). For egg and nymphal mortality of *A. dispersus,* three sprays of 5% soap solution could also be recommended, which dissolves the waxy coating of the whitefly and leads to impairment of respiration, leading to death (Ranjith et al., 1997). These observations reveal that *A. rugioperculatus* can be managed effectively, when the insecticides are sprayed at early instar nymphs. Selected insecticides were killing potential parasitoid, and hence integration of these insecticides not advocated.

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