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Virulence of entomopathogenic fungi against *Fiorinia fiornii* (Hemiptera, Diaspididae)

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Abstract
Fiorinia fiornii, Cockerell & Robinson (Diaspididae: Hemiptera), is a significant pest of nursery plants, particularly of ornamental palms.Armored scale insects are difficult to control using traditional contact insecticides because they spend the majority of their life cycle in a relatively impervious wax cover. Combinations of oils and insecticides have been used effectively. Scale insects are particularly susceptible to biological control. This study was carried out to investigate the virulence of some Entomopathogenic Fungi for controlling the *Fiorinia fiornii* on date palm trees at Giza Governorate, Egypt during November, 2021; two compounds of Entomopathogenic Fungi, Biosect, Biover and Biosect + Silica gel (ratio 2:1 & 1:1) were tested. The obtained results showed that all tested Entomopathogenic Fungi were able to decrease the infestation with the *F. fiornii* on date palm trees. Percent mortality of nymphs was 79.6 % after 7th days, at the concentration (3.2 X 10^4 spores/ ml.) of Biover but after 7th days of infection of adults was 71.63 % with the same concentration. While percent mortality of nymphs was 83.7 % after 21st days, at the concentration (3.2 X 10^4 spores/ ml.) of Biover but after 21st days of infection of adults was 83.28 % with the same concentration. Percent mortality of nymphs was 80.7 % after 7th days, at the concentration (3.2 X 10 ^{6} spores/ ml.) of Biosect but after 7th days of infection of adults was 78.00% with the same concentration. While percent mortality of nymphs was 84.3% after 21st days, at the concentration (3.2 X 10 ^{6} spores/ ml.) of Biosect but after 21st days of infection of adults was 85.00 % with the same concentration. The aim of this study was to know the virulence of some entomopathogenic fungi against *Fiorinia fiornii*.

Keywords: virulence, entomopathogenic fungi, *Fiorinia fiornii*, palm trees

Introduction
The genus Fiorinia (Hemiptera, Diaspididae) comprises 70 species (Muhammad *et al*.2021and Williams and Watson 1988) apparently native to (Normark *et al*. 2019). The genus, as presently defined, appears to represent a monophyletic group, according to a recent molecular phylogenetic analysis (McClure 1977). Species in the genus are pupillarial; i.e., the adult female remains inside the exuviae of the second-instar female and does not form a scale cover. Seven species have been reported to cause economic damage, including *F. externa* Ferris, 1942 (Beardsley and González 1975) [14], *F. fioriniae* (Targioni Tozzetti, 1867) (Tang 1984) [32], *F. japonica* Kuwana, 1902 (Ahmed 2018), *F. phantasma* Cockerell & Robinson, 1915 (Liu *et al*. 2020 and Miller and Davidson 1990), *F. pinicola* Maskell, 1897 (Ahmed and Stocks 2020), *F. proboscidaria* Green, 1900 (Gill 1997), and *F. theae* Green, 1900 (Takagi and Kawai 1967) [31]. *Fiorinia fiornii* investigated date palm leaves in Egypt. The invasive elongate hemlock scale (EHS), *Fiorinia sp.* (Hemiptera: Diaspididae), has been identified as one of the causal agents of this decline (Lambdin *et al*. 2005) [17]. Attempts to control this pest have not been successful. The unique shield-like cover of the scale provides protection from contact insecticides, natural enemies and adverse climatic conditions.
Because of its high reproductive rate, even when mortality exceeding 90% occurs, populations quickly rebound (Baranyovits 1953 and Johnson and Lyon 1988). A complex of entomopathogenic, phytopathogenic and saprophytic fungi was morphologically and molecularly identified as being associated with the diseased insects (Marcelino *et al*. 2009).One species, *Colletotrichum acutatum* var. *fioriniae* var. nov. inedit. ((Marcelino *et al*. 2008), was dominant in this complex and consistently recovered in *F. externa* populations in most of the epizootic localities. (Abdel-Raheem 2005) in Egypt could isolate *Metarhizium anisopliae* and *Beauveria bassiana* from Insects (*Scrobipalpa ocellatella* and *Cassida vittata*) from sugar beet crops. Also Abdel-Raheem used these fungi against many insect pests such as *Scrobipalpa, Cassida vittata* (Abdel-Raheem 2005 and Abla and Abdel-Raheem 2020), *Bemisia tabaci* (Abdel-Raheem *et al*. 2009), against some insect pests attacking peanuts and sugar beet (Zaki, and Abdel-Raheem 2010), the Green Stink Bug, *Nezara viridula* (Abdel-Raheem *et al*. 2011), *Schistocerca gregaria* (Abdel-Raheem *et al*. 2011), The red palm weevil, *Rhynchophorus*

ferrugineus (Abdel-Raheem 2013, Abdel-Raheem *et al*. 2020a, and Abdel-Raheem *et al*. 2020b), *Galleria mellonella* (Saleh *et al*. 2016), anti-soft scale insect *Pulvinaria tenuivalvata* (Newstead) Infesting Sugar-cane (Abdel-Rahman *et al*. 2017) all these insects the entomopathogenic fungi were very effective against it. (Mohamed Abdel-Raheem, *et al*. 2021) [] used many methods to control the scale insect pests, *Fiorinia phantasma* also studied the biology of it. Mohamed Abdel-Raheem and Jitamoni Bhattacharyya, (Mohamed Abdel-Raheem and Jitamoni Bhattacharyya 2021and Mohamed Abdel-Raheem 2021) [26] mentioned many methods for Scale Insects Control, (Mohamed Abdel-Raheem and Samah Yassien 2022) [25] mentioned many entomopathogenic fungi against Olive Pests. The aim of this study was to know the virulence of some entomopathogenic fungi against *Fiorinia fiornii***.**

Materials and Methods

Entomopathogenic Fungi

Commercial Compounds

These compounds were (Biosect (3.2 X 10^{6} spores/mg) and Biover (3.2 X 10^{4} spores/mg)), the two compounds contain *Beauveria bassiana*. Also used Silica gel where add Biosect with Silica gel ratio (2:1 & 1:1), Biosect: Silica gel.

Preparing Concentrations

The concentrations used were 3.2 X 10^{4}, 3.2 X 10^{5} and 3.2 X 10^{6} spores/mg of Biosect and add silica gel by ratio 2: 1 and 1:1 Biosect: Silica gel from concentration 3.2 X 10^{6}. The concentrations used were 3.2 X 10^{2}, 3.2 X 10^{3} and 3.2 X 10^{4} spores/mg of Biover.

Insects

The authors collected the leaves of palm tree from Elorman garden in Giza, Egypt and transported to the laboratory of Plant Protection Research Institute in November 2021.

Bioassay

Fiorinia fiornii adults and nymphs were dipping in all concentration for 30 seconds. Every day were examining the insects and recorded it to count the percent mortality at 25±2 ºC and 85±5 R.H.

Statistics

The statistical analysis was conducted by computer using SAS program. To separate between the means, the percentages of mortality were transferred to arc-sine, when "F" value was significant LSD values were determined (SAS Institute 1998).

Results

Table (1) showed that percent mortality of nymphs was 79.6 % after 7th days, at the concentration (3.2 X 10^{4} spores/ ml.) of Biover but after 7th days of infection of adults was 71.63 % with the same concentration. While percent mortality of nymphs was 83.7 % after 21st days, at the concentration (3.2 X 10^{4} spores/ ml.) of Biover but after 21st days of infection of adults was 83.28 % with the same concentration. In nymphs Percent mortality ranging between 79.6 % to 83.7 % and the average was 83.84 %. In adults Percent mortality ranging between 71.63% to 83.28 % and the average was 80.16%.

Table 1: Percent mortality of *Fiorinia fiornii* Nymphs and Adults after infected with Entomopathogenic fungi (Biover) at 25±2 ºC and 85±5 R.H.

Treatment	Nymphs				Adults			
	Days			Average	Days			Average
	7	14	21		7	14	21	
C_1	70.8	86.1	82.3	79.71 b	57.21	73.28	66.64	65.71 b
C_2	72.5	87.9	83.9	81.44 ab	70.78	82.67	78.24	77.23 a
C_3	79.6	88.3	83.7	83.84 a	71.63	85.56	83.28	80.16 a
L.S.D	74.31 c	87.41a	83.29 b	2.85	66.56 b	80.10 a	76.06 a	4.59
	2.85				4.59			

3.2 X 10^{2}(C_1), 3.2 X 10^{3} (C_2) and 3.2 X 10^{4} (C_3) spores/mg

Table (2) showed that percent mortality of nymphs was 80.7 % after 7th days, at the concentration (3.2 X 10^{6} spores/ ml.) of Biosect but after 7th days of infection of adults was 78.00% with the same concentration. While percent mortality of nymphs was 84.3% after 21st days, at the concentration (3.2 X 10^{6} spores/ ml.) of Biosect but after 21st days of infection of adults was 85.00 % with the same concentration. In nymphs Percent mortality ranging between 80.7% to 84.3% and the average was 85.54 %. In adults Percent mortality ranging between 78.00% to 85.00% and the average was 83.00 %.

Table 2: Percent mortality of *Fiorinia fiornii* Nymphs and Adults after infected with Entomopathogenic fungi (Biosect) at 25±2 ºC and 85±5 R.H.

Treatment	Nymphs				Adults			
	Days			Average	Days			Average
	7	14	21		7	14	21	
C_1	68.97	89.66	79.3	79.31 b	65.75	79.45	72.60	72.60 b
C_2	75.0	93.2	81.8	83.33 ab	73.41	87.86	76.30	79.19 ab
C_3	80.7	91.6	84.3	85.54 a	78.00	86.00	85.00	83.00 a
L.S.D	73.49c	91.16 a	80.77 b	6.30	71.88b	83.74 a	77.90 ab	6.44
	6.30				6.44			

3.2 X 10 ^{4} (C_1), 3.2 X 10 ^{5} (C_2) and 3.2 X 10 ^{6} (C_3) spores/mg

Table (3) showed that percent mortality of nymphs was 79.73% after 7th days, at the concentration (3.2 X 10 ^{6} spores/ ml.) of Biosect and silica gel by ratio 1:1 but after 7th days of infection of adults was 71.19 % with the same concentration. While percent mortality of nymphs was 83.78 % after 21st days, at the concentration (3.2 X 10 ^{6} spores/ ml.) of Biosect and silica gel by ratio 1:1 but after 21st days of infection of adults was 77.97 % with the same concentration. In nymphs Percent mortality ranging between 79.73 % to 83.78 % and the average was 84.23 %. In adults Percent mortality ranging between 71.19 % to 77.97 % and the average was 78.53 %.
The percent mortality of nymphs was 86.42 % after 7th days, at the concentration (3.2 X 10 ^{6} spores/ ml.) of Biosect and silica gel by ratio 2:1 but after 7th days of infection of adults was 71.19% with the same concentration. While percent mortality of nymphs was 88.88% after 21st days, at the concentration (3.2 X 10 ^{6} spores/ ml.) of Biosect and silica gel by ratio 2:1 but after 21st days of infection of adults was 86.64 % with the same concentration. In nymphs Percent mortality ranging between 86.42% to 88.88% and the average was 88.34 %. In adults Percent mortality ranging between 84.35 % to 86.64% and the average was 85.93 %.

Table 3: Percent mortality of *Fiorinia fiornii* Nymphs and Adults after infected with (Biosect: Silica gel) at 25±2 ºC and 85±5 R.H.

Treatment	Nymph				Adult			
	Days			Average	Days			Average
	7	14	21		7	14	21	
1:1	79.73	89.19	83.78	84.23 b	71.19	86.44	77.97	78.53 b
2:1	86.42	89.72	88.88	88.34 a	84.35	86.80	86.64	85.93 a
L.S.D	82.5 b	89.43 a	85.95 ab	3.70	77.58 b	86.18 a	82.10 ab	4.40
	4.51				5.38			

Discussion

Percent mortality of nymphs was 79.6 % after 7th days, at the concentration (3.2 X 10^4 spores/ ml.) of Biover but after 7th days of infection of adults was 71.63 % with the same concentration. While percent mortality of nymphs was 83.7 % after 21st days, at the concentration (3.2 X 10^4 spores/ ml.) of Biover but after 21st days of infection of adults was 83.28 % with the same concentration. In adults of *Fiorinia fiornii* Percent mortality ranging between 78.00% to 85.00% and the average was 83.00 %. The results according with **(**Zaki, and Abdel-Raheem 2010) where used the same compounds against some insect pests attacking peanuts and sugar-beet in Egypt **(***Spodoptera littoralis; Spodoptera exigua; Aphis craccivora; Pegomyia mixta*) Also, according with (Abdel-Raheem *et al*. 2017 and Abdel-Rahman *et al*. 2017) where using of some Entomopathogenic fungi against the Oliver black scale insect, *Saissetia oleae* (Oliver) on olive trees. They found the three entomopathogenic fungi due to reduction in number the insects after being treated with *B. bassiana,* M. anisopliae and *V. lecanii* as compared the control and against *Pulvinaria tenuivalvata* (Newstead) Infesting Sugar-cane in Egypt.

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