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Article

Neurozerra conferta (Lepidoptera: Cossidae) damaging *Melaleuca* plantations in Vietnam and its biological control

NGUYEN MINH CHI[1], VU DINH HUONG[2], DUY LONG PHAM[1], LE VAN BINH[1], NGUYEN VAN LUU[2], KIEU MANH HA[2], VU VAN LOI[1], ROMAN V. YAKOVLEV[3, 4*]

[1] *Forest Protection Research Centre, Vietnamese Academy of Forest Sciences, Hanoi 11910, Vietnam.*
https://orcid.org/0000-0002-2345-2398, https://orcid.org/0000-0002-0810-474X,
https://orcid.org/0000-0003-4614-9436, https://orcid.org/0000-0002-9645-6867
[2] *Forest Science Institute of South Vietnam, Vietnamese Academy of Forest Sciences, Ho Chi Minh 72100, Vietnam.*
https://orcid.org/0000-0001-8289-6821, https://orcid.org/0000-0001-5671-2566,
https://orcid.org/0000-0002-8516-0841
[3] *Altai State University, pr. Lenina 61, Barnaul, 656049 Russia.*
[4] *Tomsk State University, Lenina Prospekt 36, 634050 Tomsk, Russia.*
* *Corresponding author. E-mail: yakovlev_asu@mail.ru; https://orcid.org/0000-0001-9512-8709*

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Abstract
Melaleuca leucadendra and *M. cajuputi* are grown widely in Vietnam, with plantation areas in 2020 of 32,000 ha and 36,000 ha respectively. A stem borer, *Neurozerra conferta* (Walker) (Lepidoptera: Cossidae), has significantly damaged plantations of both species. Field surveys in 2021 found *N. conferta* damage to *M. leucadendra* in the four provinces of Ninh Binh, Long An, Dong Thap and Kien Giang with a damage incidence (P%, percentage of plants attacked) of 22.4–33.2% and an average damage index (DI) of 0.77–1.01. In Long An province, surveys in 2022 found frequent damage to *M. leucadendra* plantations at the age of 2–3 years with P% ranging from 22.7 to 27.3% and DI from 0.46 to 0.54. *Beauveria bassiana* and *Metarhizium anisopliae* were identified as potential biological agents with control effectiveness of 59.6–63.3%. Screening to identify resistant varieties of *M. leucadendra* and development of an integrated pest management strategy for *N. conferta* are recommended.

Key words: *Beauveria bassiana*, Biocontrol, *Melaleuca leucadendra*, *Metarhizium anisopliae*, Stem borer.

Introduction

Melaleuca species (family Myrtaceae) are native to Australia, New Zealand, Papua, New Guinea, Solomon Islands, Indonesia, Malaysia, Myanmar, Cambodia, Thailand, and Vietnam, where essential oils extracted from *Melaleuca* leaves have been used as traditional medicine (Hewitt 2015; Sharifi-Rad et al. 2017; Wahyudi et al. 2014). Cultivation of *Melaleuca alternifolia* began in Australia to increase production of the oil (Hewitt 2015). *Melaleuca* timber is also used for piles, pillars, plywood and pulp (Hewitt 2015; Nguyen et al. 2019), and wood properties could be improved through breeding (Wahyudi et al. 2014).

Melaleuca cajuputi grows naturally in many provinces in Vietnam (Cuong et al. 2004). The species has also been planted for production of oil and wood poles (Cuong et al. 2004; Hong et al. 2019; Nguyen et al. 2019). Commencing in 1993, *Melaleuca alternifolia*, *M. leucadendra*, *M. quinquenervia*, and *M. viridiflora* were introduced and tested in Vietnam (Cuong et al. 2004), and *M. leucadendra* was identified as a fast-growing species, with a 50–90% advantage in volume growth over *M. cajuputi* (Hong et al. 2010; Huong et al. 2017). *M. leucadendra* and *M. cajuputi* are now planted widely in Vietnam for wood pole production with total plntation areas of about 32,000 ha and 36,000 ha, respectively (Thu et al. 2021). However, *Neurozerra* stem borer has caused widespread damage in *Melaleuca* plantations in Vietnam.

Neurozerra conferta Walker distributed in Sri Lanka, India, Taiwan, Vietnam, Thailand, Bangladesh, Andaman Islands (Arora 1971; Baksha and Islam 1999; Yakovlev 2004; Yakovlev 2011; Yakovlev 2014; Yakovlev and Witt 2009). Various host plants have been found, including *Avicennia lanata*, *A. marina*, *A. officinalis* (Avicenniaceae), *Ochroma lagopus* (Bombacaceae), *Barringtonia* (Lecythidaceae), *Sonneratia ovata*, *S. alba*, *S. apetala* (Lythraceae), *Aegiceras corniculatum* (Myrsinaceae), *Eucalyptus deglupta*, *Eugenia* (Myrtaceae), *Rhizophora apiculata*, *Rh. mucronata* (Rhizophoracaea), *Theobroma cacao* (Sterculiaceae), *Coffea* spp. (Rubiaceae), *Erythroxylum* sp. (Erythroxylaceae), *Elettaria cardamomum* (Zingiberaceae) (Baksha and Islam 1999; Robinson et al. 2001; Toxopeus 1948). This species has been recorded as a serious pest of *Aquilaria malaccensis* in India (Rishi et al. 2022), *A. malaccensis*, *A. sinensis*, and *Gyrinops* spp. in Malaysia (Syazwan et al. 2019). A stem borer was recorded as a serious insect pest of *M. leucadendra* in Southern Vietnam in 2001-2005 (Hong et al. 2010), and it may be a *Neurozerra* species.

This pest has damaged in a long time period with an estimated incidence of 18-20% (Hong et al. 2010). Recent surveys undertaken by Forest Protection Research Centre has revealed that the damage caused by the stem borer is more serious and spread through other areas in Vietnam. The incidence of stem borer attack has been evaluated on a range of *Melaleuca* provenances (Hong et al. 2010), but no resistant provenances were identified. In addition, no study has been done for the biocontrol of this pest. Therefore, the current study was conducted in order to (1) identify the stem borers in *Melaleuca* plantations in Vietnam, (2) determine current levels of damage to *Melaleuca* plantations and (3) evaluate biological control methods.

Materials and methods

Characterization and identification

60 trees of *Melaleuca leucadendra* and 30 trees of *M. cajuputi* with 1–3 borer holes per tree, were felled in May 2022, the boles cut into 0.8 m lengths from the ground and the logs taken to the Forest Protection Research Centre (FPRC) in Hanoi, Vietnam. *Neurozerra* larvae extracted from the logs were reared on sweet potato, and pupae, adults and eggs were obtained. Identification of 25 adult specimens was based on keys in Yakovlev (2011), and these specimens were deposited in the insect collection of the FPRC.

Assessment of symptoms of *Neurozerra conferta* damage in *Melaleuca* trees

Infested trees of *M. leucadendra* and *M. cajuputi* (30 trees per species), were used to describe the damage diagnostics. The number of boring holes and their diameters were measured on the trunk surface, up to 2 m above the ground. The characteristics of frass in the boring holes and around the base of infested trees were described. The infested trees were cut and sectioned to characterize tunnels in the wood.

Assessment of damage in *Melaleuca leucadendra* in four provinces

Field surveys were conducted during March to July 2021 in two-year-old *M. leucadendra* plantations in Gia Vien (Ninh Binh), Thanh Hoa (Long An), Thap Muoi (Dong Thap) and Hon Dat (Kien Giang) (Fig. 1), where there was local concern for damage and stem breakage in *M. leucadendra* plantations. Ninh Binh has a tropical monsoon climate. The weather is divided into 4 distinct seasons. The average annual temperature at this location is 24°C and average annual rainfall of 1,750 mm/year. The terrain is low, and the soil is red-yellow ferralite with typical depth of 80–100 cm. The climate in Long An, Dong Thap and Kien Giang is tropical with a pronounced dry season. The average annual temperature is 27°C average annual rainfall of 1,450 mm/year. The terrain is low, flat, alkaline soil at a depth of 80–120 cm.

The evaluated plantations were 6–25 ha in area with initial planting densities of 20,000 trees/ha. Three plantations were selected in each province and five plots (100 m^2 each) were randomly located within each plantation. All trees in each plot were checked for *N. conferta* damage signs which were grouped at five categories: 0 = intact trees; 1 = trees damaged with one boring hole on the bole and green foliage; 2 = trees damaged with two boring holes on the bole and mild leaf senescence; 3 = trees damaged with three boring holes on the the bole, about 50% canopy senescing; 4 = trees damaged with over three boring holes on the bole, full foliage senescing or death. The trunk surface holes were a combination of exit holes and exposed larval feeding sites.

Figure 1. Distribution of *Neurozerra conferta* in *Melaleuca* plantations in Vietnam.

Assessment of damage in *Melaleuca leucadendra* and *M. cajuputi* at different age stages

The survey was carried out in August 2022 on *M. leucadendra* and *M. cajuputi* plantations at the ages of 1, 2, 3 and 4 years at Thanh Hoa forestry station, Thanh Hoa district, Long An province (Fig. 1). Plantations of each *Melaleuca* species were established using a single seed source, with a density of 20,000 trees/ha. Plantation forests of each species at each age period ranged from 5 to 10 ha. Standard plots of 100 m^2 were randomly established in 5 plantations of each age class, 3 plots per plantation, giving a total of 15 plots per age class for each species. Scoring of borer damage used the classes was described above.

Biocontrol test on larval *Neurozerra conferta*

Field trials were undertaken to investigate whether sprayed biological treatments could control *N. conferta* larvae in infested trees, thereby reducing tree damage. *M. leucadendra* was selected for study because it is vulnerable to damage from *N. conferta* attack. Plantations were surveyed in Gia Hung ward, Gia Vien district, Ninh Binh province (Fig. 1) and a 5 ha compartment was chosen with about 23% damage incidence for the experiment. The plantation was established in August 2020 using four-month-old seedlings, at a density of 20,000 trees/ha, with 0.5 m between and 1 m within rows.

Four biological agents (Table 1) were evaluated for inhibition of *N. conferta* damage to the *M. leucadendra* at the age of two years. The biological agents were mixed in an aqueous solution with emulsifier, Tween 80 (Merck, Germany), at 1% concentration. The experiment was set up with four randomly selected blocks, each contained five plots (100 m^2, 200 trees) and each plot had at least 40 damaged trees with 1–3 active holes/tree (damage holes with new droppings). The plots were separated by > 5 m buffers. The treatments were sprayed to the bole at 0–2 m above the ground using an electric sprayer at a rate of 0.1 l/tree. The treatments were applied in the late afternoon on August 9, 2022 and reapplied on August 19, 2022 at the same dose. Treatments were administered in clear days without rain and untreated plots were considered as control group.

Table 1. Biological agents for control of *Neurozerra conferta* larvae.

Trade name	Active ingredient	Rate applied (g/l)*
Delfin 32WG (SDS Biothech, Tokyo, Japan)	*Bacillus thuringiensis* 32,000 BIU/kg	3.75
Bitadin WP (Nong Sinh Co. Ltd., Hanoi, Vietnam)	*Bacillus thuringiensis* var. *kurstaki* 16,000 IU + Granulosis virus 10^8 PIB	3.75
Muskardin (CPC, Can Tho, Vietnam)	*Beauveria bassiana* 1×10^8 CFU/g	3.75
Metarhizium (META, Ho Chi Minh, Vietnam)	*Metarhizium anisopliae* 2×10^3 CFU/g	3.75

* As recommended by the Ministry of Agriculture and Rural Development, Vietnam.

The trees were assessed at the time the trial was established (August 9, 2022) and again after 30 days (September 9, 2022). The presence of *N. conferta* holes and droppings were examined. Damage of the trial was assessed as the number of damage holes (active holes) with new droppings. On September 10, the trees were felled and the boles were dissected in order to count the number of dead and live larvae.

Data analysis

Following the results of damage classification, damage incidence (P%) was calculated using equation 1 (Chi et al. 2021):

$$P\% = (n/N) \times 100 \quad (1)$$

where: n is the number of trees attacked by *N. conferta*; N is total number of trees assessed.

The average damage index (DI) in each plot was calculated using equation 2 (Chi et al. 2021):

$$DI = (\Sigma n_i \times v_i)/N \quad (2)$$

where: n_i is the number of infected trees at damage index i; v_i is the damage index at level i; and N is total number of trees assessed.

The damage severity level was ranked based on the average damage index as follows: no damage (DI = 0); slight damage ($0 < DI \leq 1$); medium damage ($1 < DI \leq 2$); severe damage ($2 < DI \leq 3$); very severe damage ($3 < DI \leq 4$).

The corrected efficacy of each agent in the field trial was calculated according to the following formula 3 of Henderson and Tilton (1955):

$$E = (1 - (Ca \times Tb)/(Cb \times Ta)) \times 100 \quad (3)$$

where: E is an inhibitory effect (%); Cb is active holes (damage holes with new droppings) in the control plot before treatment; Tb is active holes in the treatment plot before treatment; Ca is active holes in the control plot after treatment; and Ta is active holes in the treatment plot after treatment.

Plot mean values for P% and DI were calculated, and plot mean data was analysed using GenStat Release 12.1 software package (VSN International Ltd., Hemel Hempstead, UK). The Kolmogorov-Smirnov Test was used for testing data distribution. The damage index and damage incidence were log-transformed before analysis. The effect of biological control treatments on damage by *N. conferta* in *M. leucadendra* was tested using one-way analysis of variance (ANOVA). Significant effects of the damage of *N. conferta* in *M. leucadendra* and *M. cajuputi* at different ages were analyzed with two-way ANOVA (species × plantation age), followed by Turkey's Multiple Range Test for comparisons of means.

Results

Characterization and identification

Based on the external morphological characters of the adults (Fig. 2a, b) in this study and compared with those previously given by Yakovlev (2011), the pest infesting *M. leucadendra* and *M. cajuputi* trees in Vietnam was confirmed as *Neurozerra conferta* Walker, 1856 (Lepidoptera: Cossidae). The characteristic features of this pest, based on morphological examination of 25 specimens, are as follows:

Male adults (n = 6) (Fig. 2a): Body whitish, forewing length 31.3–41.2 mm, body size 22.9–25.3 mm long, 4.2–4.3 mm wide. Head, thorax, and abdomen thinly covered with dark grey hairs. Antennae setaceous, light brown in basal part, filiform, dark brown at the top; thorax with six black dots. Adomen with three rows of black dots. Forewing consisted of sparsely dark-grey lines and strikes on the light ground, hindwing white with few black spots.

Female adults (n = 19) (Fig. 2b): Body whitish, forewing length 36.5–68.1 mm, body size 28.6–31.2 mm long, 4.5–7.1 mm wide; Head, thorax and abdomen thickly covered with hairs; antennae filiform, black; Thorax with six black dots; Forewing consisted of densely dark-grey lines and strikes on the gray ground; Hindwing light gray.

Eggs initially creamy white, and then gradually turn into light yellow, cylindrical, 1.5–1.8 mm long, 0.7–0.8 mm wide, eggs laid in cluster of 10–23 eggs (Fig. 2c).

Larvae redish brown; cylindrical, last insatar body 25.1–31.12 mm long, 5.2–6.1 mm wide, the body is segmented with brown dots along the sides of the body; head dark brown (Fig. 2d).

Cylindrical pupae are light brown at first, then darken, 19.8–42.6 mm long, 5.1–8.2 mm wide, male pupae smaller than female pupae (Fig. 2e).

Symptoms of *Neurozerra conferta* damage in *Melaleuca* trees

N. conferta was associated with tree damage and stem breakage. Infested *M. leucadendra* and *M. cajuputi* trees have circle holes with a diameter of 0.7–0.8 cm in the boles, located 10–150 cm above ground. There are many droppings around the base of the damaged trees (Fig. 3a, b). Droppings are discrete, semi-circular faeces, white at first, then yellow, dark yellow and brown. The tunnels go straight into the boles and then vertically up the centre of the stem. The tunnels are circular, 0.7–0.9 cm in diameter, 16–39 cm long (Fig. 3c). Before pupating, the larvae often create wide burrows (10–13 cm in length and 1.5–3.6 mm in width) in the boles. Severely damaged trees can have 3–6 larvae in the bole, and trees can break in the wind.

Neurozerra conferta damage in *Melaleuca leucadendra* plantations

The damage incidence (P%) of *N. conferta* in all 12 plantations at the age of two years in 2021 was between 22.4% and 33.2%. The average damage index (DI) was between 0.77 and 1.01 (Table 2), and damage index of damaged trees was from 2 to 4. In Dong Thap and Kien Giang provinces, the average damage incidence in all plantations was 31.9% and 32.5%, respectively, higher than in Ninh Binh and Long An provinces (24,4% and 28,1%, respectively).

Table 2. Damage incidence and average damage index of *Neurozerra conferta* in *Melaleuca leucadendra* plantations in Ninh Binh, Long An, Dong Thap and Kien Giang provinces in Vietnam.

Province	**Plantation 1**		**Plantation 2**		**Plantation 3**	
	P%	**DI**	**P%**	**DI**	**P%**	**DI**
Ninh Binh	22.4±2.3	0.79±0.07	26.9±1.9	0.77±0.06	23.9±2.6	0.89±0.05
Long An	26.0±3.5	0.97±0.09	30.1±2.7	0.96±0.08	28.2±2.7	0.92±0.10
Dong Thap	32.0±3.2	0.93±0.06	30.8±3.6	0.95±0.05	32.9±3.9	1.01±0.11
Kien Giang	32.3±4.1	0.95±0.11	32.1±3.0	0.91±0.07	33.2±3.4	0.95±0.08

Neurozerra conferta **damage in** ***Melaleuca leucadendra*** **and** ***M. cajuputi*** **at different age stages**

The results of two-wat analysis of variance (Table 3) showed that there was a significant difference in damage incidence and damage index between the two host species, tree ages and their interaction ($P < 0.001$).

Damage index (DI) and damage incidence (P%) due to *N. conferta* in *M. cajuputi* plantations at all 4 age stages were very low, 0.02–0.04 and 2.0–3.3%, respectively. DI and P% in *M. leucadendra* plantations were significant higher than in *M. cajuputi* plantations. By year 1, *M. leucadendra* trees were slightly damaged with (DI = 0.14 and P% = 4.6%). By year 2, damage was severe with DI and P% 0.46–0.54 and 22.7–27.3%, respectively.

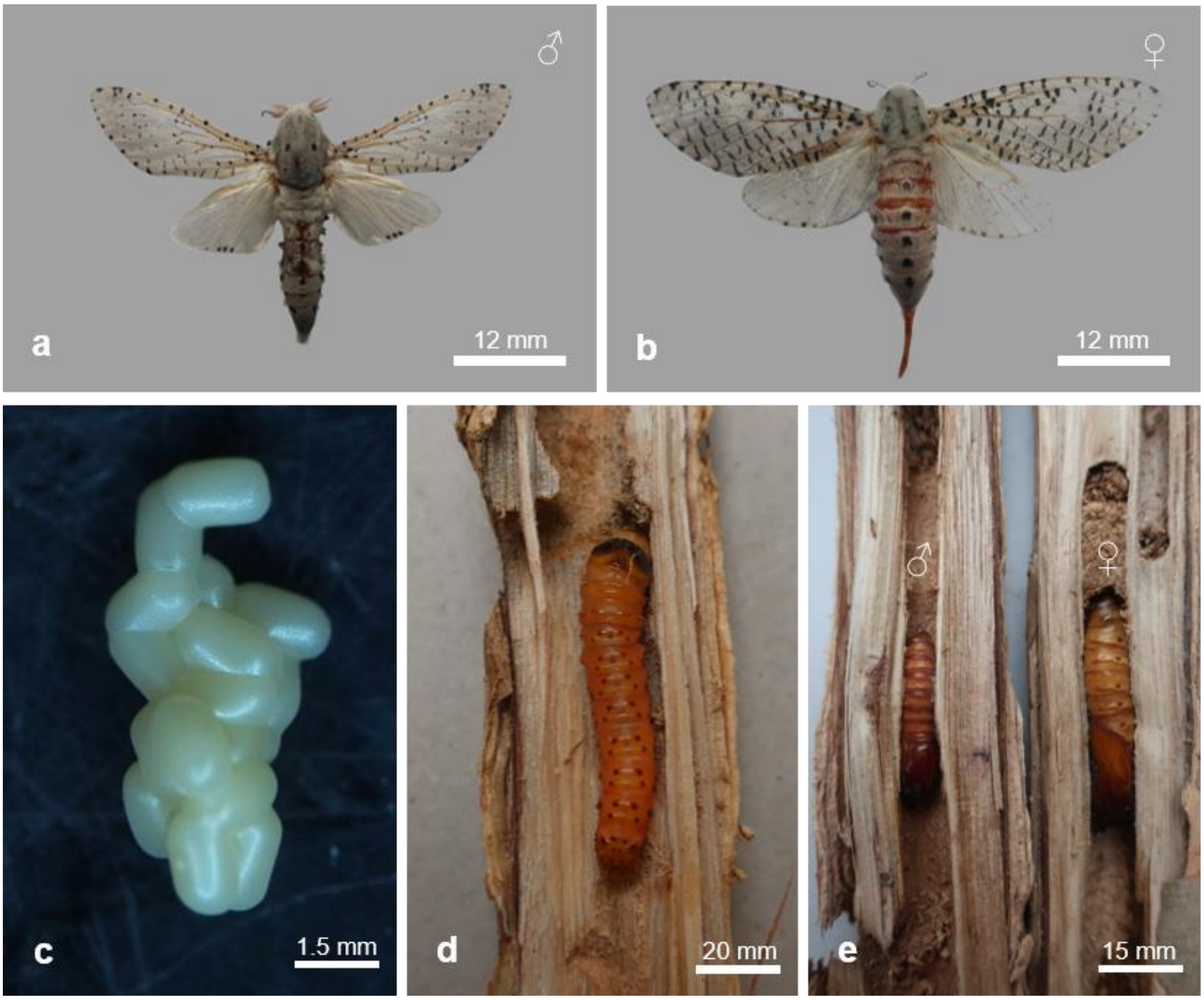

Figure 2. Morphological characteristics of *Neurozerra conferta*: **a**, **b** adults; **c** eggs; **d** larva; **e** pupae.

Figure 3. Symptoms of *Neurozerra conferta* in *Melaleuca leucadendra*: **a** plantation with damaged trees; **b** damaged tree; **c** damage to the wood.

Table 3. Damage incidence and average damage index of *Neurozerra conferta* in *Melaleuca leucadendra* and *M. cajuputi* plantations in Long An province at different age stages.

Age (months)	***Melaleuca leucadendra***		***Melaleuca cajuputi***	
	DI	**P%**	**DI**	**P%**
12	0.14±0.01[a]	4.6±0.3[a]	0.02±0.01[a]	2.0±0.04[a]
24	0.54±0.03[c]	27.3±1.9[d]	0.04±0.01[b]	3.2±0.06[bc]
36	0.46±0.02[c]	22.7±2.2[c]	0.04±0.01[b]	3.3±0.05[c]
48	0.29±0.02[b]	15.2±1.3[b]	0.04±0.01[b]	2.7±0.07[b]
Lsd	**0.08**	**2.91**	**0.01**	**0.46**
P	**< 0.001**	**< 0.001**	**0.001**	**< 0.001**

Difference letters represent significant ($P < 0.05$) differences between ages
Species comparison: $P < 0.001$
Species × age interaction: $P < 0.001$

Efficacy of biological agents

The average number of active holes before the experiment ranged from 2.26 to 2.31 holes per damaged tree, and there was no significant difference between treatments ($P = 0.984$), indicating homogeneity of the experiment before treatment with biological agents.

The number of active holes in the untreated control did not significantly change over time, while all biological control treatments resulted in a decline in *N. conferta* damage to *M. leucadendra* (Table 4) There was a significant ($P < 0.001$) difference between the biological treatments in reducing damage (Table 4). Thirty days after treatment, trees spayed with *Beauveria bassiana* (Fig. 4a) and *Metarhizium anisopliae* (Fig. 4b) had the lowest number of active holes with new droppings (0.85 and 0.92 holes/damaged tree, respectively), and the greatest damage inhibition effect (63.3 and 59.6%, respectively). *Bacillus thuringiensis* and *B. thuringiensis* + *Granulosis* virus were less effective with damage inhibition effect sof 47.8 and 49.5%, respectively.

The number of dead larvae 30 days after spraying also differeed significantly ($P < 0.001$) between treatments. Treatment with *B. bassiana* resulted in the highest number of dead larvae (mean of 1.42 dead larvae per damaged tree), while the control had only 0.03 dead larvae per damaged tree.

Table 4. Effect of biological treatments on *Neurozerra conferta* larvae in two-year-old *Melaleuca leucadendra* trees.

Treatment	Mean number of active holes per tree		Mean number of dead larvae per tree	Damage inhibition effect (%)
	August 9, 2022	September 9, 2022		
Bacillus thuringiensis	2.30±0.10[a]	1.22±0.08[b]	1.04±0.09[b]	47.8
Bacillus thuringiensis + *Granulosis* virus	2.31±0.09[a]	1.18±0.10[b]	1.08±0.08[bc]	49.5
Beauveria bassiana	2.28±0.12[a]	0.85±0.08[a]	1.42±0.11[d]	63.3
Metarhizium anisopliae	2.26±0.13[a]	0.92±0.07[a]	1.28±0.10[cd]	59.6
Control	2.26±0.11[a]	2.29±0.14[c]	0.03±0.01[a]	-
Lsd	**0.22**	**0.09**	**0.15**	
P	**0.984**	**< 0.001**	**< 0.001**	

Values with different letters in a column are significantly different at $P < 0.05$

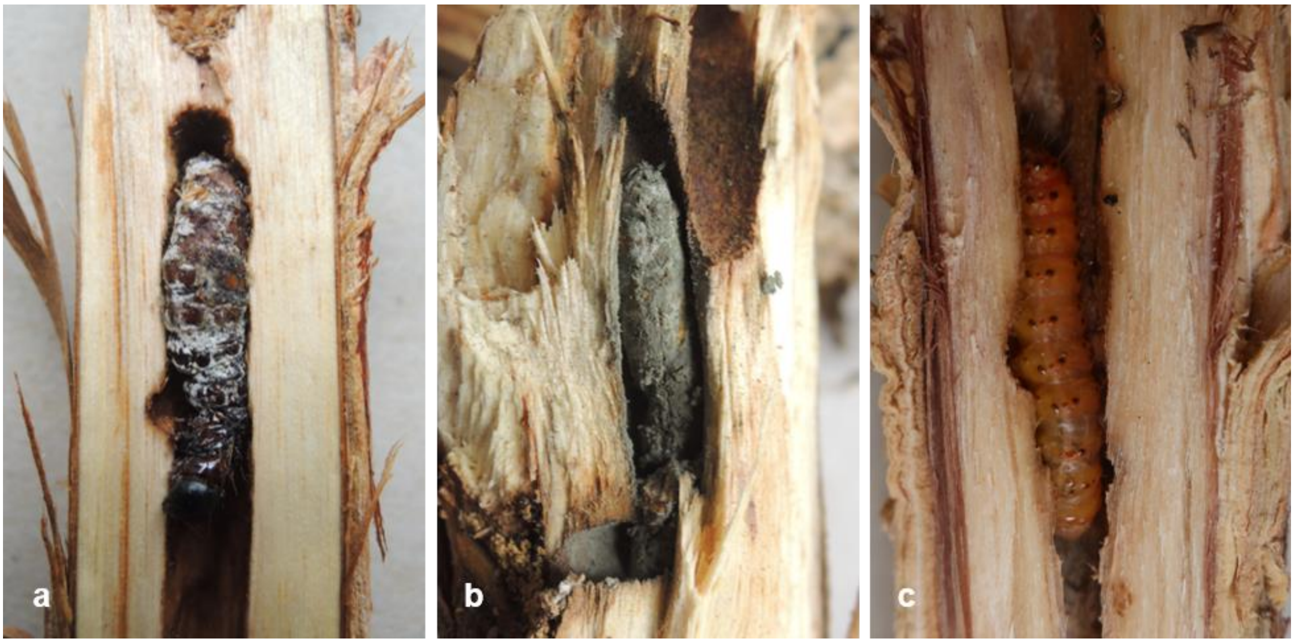

Figure 4. Parasitized larval *Neurozerra conferta* 30 days after commencement of experiment: **a** *Beauveria bassiana*; **b** *Metarhizium anisopliae*; **c** control.

Discussion

This is the first record of *Neurozerra conferta* damaging *Melaleuca* spp. in Vietnam. This pest was reported in Andaman Islands, Bangladesh, India, Sri Lanka, Taiwan, Thailand, and Vietnam (Arora 1971; Yakovlev 2004, 2011, 2014). *N. conferta* (*Z. conferta*) damaged *Aquilaria malaccensis* plantations in India (Khakhlari and Sen 2021; Rishi et al. 2022), damage incidence was 21–24% at over eight-year-old trees (Kalita et al. 2015). It was recorded as damaging *Rhizophora apiculata* in Malaysia (Ong et al. 2010), and *Sonneratia apetala* Bangladesh (Saenger and Siddiqi 1993). *N. conferta* caused damage in *A. sinensis* plantations in China (Yan et al. 2010), *A. malaccensis* and *A. sinensis* plantations in Malaysia (Syazwan et al. 2019), and *Eucalyptus* plantations in south-eastern Asia (Yakovlev 2011).

Some insect pests have been recorded as damaging *Melaleuca* spp, for example *Oxyops vitios* (Balciunas et al. 1994), *Fergusonina turneri* (Scheffer et al. 2004) in *M. quinquenervia*, and *Trioza* *melaleucae* in *M. alternifolia* (Martoni and Blacket 2021) in Australia. *Helopeltis theivora* has been reported to cause widespread damage on young shoots of *M. leucadendra* and *M. cajuputi* in Vietnam (Thu et al. 2021). However, *N. conferta* is a very common pest of *M. leucadendra* plantations in Vietnam with damage incidence over 22%. It burrows in the boles of *M. leucadendra*, releases a lot of droppings around the base of the tree, and can result in stem breakage from winds or storms. The damage symptoms resulted from this stem borer in *M. leucadendra* since 2000 is similar to those observed in the present study (Hong et al. 2010). *N. conferta* (*Z. conferta*) also damages the branches of *R. apiculata* with broken branches, dead brown foliage, and sawdust or droppings around the base of the damaged trees (Solomon 1995).

This study found low levels of damage to *M. cajuputi* with from *N. conferta*. This species also had a low damage in a previous study in Vietnam (Hong et al. 2010). In Bangladesh, there was a significant relationship between the number of *Bruguiera conjugata* trees and the damage incidence caused by *N. conferta* (*Z. conferta*) in the coastal subdivisions. In monoculture stands, 51% of trees were attacked by *N. conferta*, while 32% were attacked in mixed stands. Therefore, to reduce the attack of *N. conferta*, planting of *B. conjugata* mixed with other species has been recommended for the coastal areas of Bangladesh (Wazihullah et al. 1996). The current study showed that the indigenous *M. cajuputi* was less susceptible to this pest than the introduced *M. leucadendra*, and it is suggested further studies should consider intercropping of the two *Melaleuca* species to limit the damage to *M. leucadendra*.

This study identified two potential biological agents (*Beauveria bassiana* and *Metarhizium anisopliae*) to control larval *N. conferta*, with control efficiencies of 63.3 and 59.6% respectively. *Melaleuca* plantations in Vietnam are wetland areas (Hong et al. 2010; Huong et al. 2017). In order to reduce negative impacts of pesticide useage, Vietnamese government has required to use biological agents for the management of insect peasts and diseases (MARD 2020). There have been very few studies on the management of *N. conferta*, but some studies on the management of other species of the genera *Zeuzera* have shown some biological agents were highly effective for killing larvae (El-Ashry et al. 2018; Jinshui et al. 1988; Yang et al. 1990). To control *Z. multistrigata* damaging *Casuarina equisetifilia* in China, the injection of *B. bassiana* (Jinshui et al. 1988) and *Steinernema feltiae* (Yang et al. 1990) solution into the tunnels have killed 86% and 93% of larvae, respectively. The entomopathogenic nematode *Heterorhabditis bacteriophora* mixed with *B. thuringiensis* was used to control *Z. pyrina* damage in apple trees in Egypt with percentage mortality reached 77.5% (El-Ashry et al. 2018). *B. bassiana* was recorded as a natural epizootic in *Z. pyrina* (Ibrahim et al. 2019). These biological agents are potentially of value for the control of stem borers. Successful integrated management of *Z. coffeae* in *Juglans regia* (Ahmad 2017) involving cultural, chemical and biological espects might be an useful model for studies on the management of *N. conferta*. Although the sparying of *B. bassiana* and *M. anisopliae* in this study is not sufficiently high to control larval *N. conferta*. However, this measure is applicable to deploy in wide areas of *Melaleuca* plantations, especially in integrated pest management programs.

Due to the influence of climate change and changes in water flow of the Mekong River, the agricultural farming environment in the Mekong delta region of Vietnam has been changing in a negative direction (Ho et al. 2022; Huy et al. 2021). As a result, many areas of agricultural cultivation and fruit trees have been contaminated with salt or alum (Ho et al. 2022), and the Government of Vietnam has developed a strategy to replace with forest tree species in some severely affected areas (Vietnam 2021). *M. leucadendra* has been identified as a major planting species for the Mekong delta (MARD 2014) with superior growth compared to *M. cajuputi* (Hong et al. 2010; Huong et al. 2017), and the area planted with this species is expanding in recent years (Thu et al. 2021). However, a major obstacle to this plan is the damage of a stem borer (*N. conferta*). For effective management of *N. conferta*, further studies are needed to develop an integrated pest management plan for this pest. At the same time, it would be appropriate to carry out genetic screening to search for varieties of *M. leucadendra* that are resistant to this pest.

Conclusion

Melaleuca leucadendra plantations in Vietnam have been seriously damaged by *Neurozerra conferta*. This pest usually causes severe damage to *M. leucadendra* trees at 2–3 years of age, but it causes much less damage to the indigenous *M. cajuputi*. *Beauveria bassiana* and *Metarhizium anisopliae* are potential biological agents used for the management of *N. conferta*.

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