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Article

Stem borer *Orientozeuzera rhabdota* (Lepidoptera, Cossidae) damaging *Manglietia conifera* and *Michelia mediocris* trees in Vietnam

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Abstract
The stem borer *Orientozeuzera rhabdota* Jordan, 1932 (Lepidoptera: Cossidae) is a new threat to *Manglietia conifera* and *Michelia mediocris* plantations in Vietnam. Field surveys in Tuyen Quang and Bac Kan provinces in 2023 showed that *O. rhabdota* frequently damaged two-year-old *Manglietia conifera* with damage incidence (P%) ranging from 50.3 to 52.7% and damage index (DI) from 1.60 to 1.71. Damage from *O. rhabdota* was most prevalent in *M. conifera* plantations (P% = 50.1–52.6%) and on roadside trees (P% = 58.6–60.2%). Mixed plantations of *M. conifera* + *Acacia mangium* and *M. conifera* + *Chukrasia tabularis* had low damage (P% = 5.8–7.2%). Damage from *O. rhabdota* in *M. mediocris* plantations was lower than in *M. conifera* plantations with P% = 1.1–6.6% and DI = 0.02–0.12. Further studies are recommended to identify biological characteristics and develop an integrated pest management plan for this pest.

Key words: Insect pest, Magnoliaceae, Zeuzerinae, Carpenter-Moths.

Introduction

Manglietia conifera is indigenous to northern Vietnam (Pham 2008), and *Michelia mediocris* naturally occurs in southern China and the Indochina peninsula (Lim 2012). These two species in the Magnoliaceae have been widely grown in China (Lim 2012; Wei *et al.* 2011) and have brought high economic returns to forest owners (Cuong *et al.* 2020; Lim 2012). The value of timber from *M. conifera* plantations was about 3,500 and 3,800 US$ per hectare at 7 years of age (Cuong *et al.* 2020) and 15 years of age (Thang *et al.* 2021), respectively. In addition to its very high wood value (Lim 2012; Nguyen 2007), the seeds of *M. mediocris* are harvested for use in the spice trade or distilled for essential oils – and fresh seeds are valued at approximately 60 US$/kg (Lim 2012). Because of these commercial values, the Vietnamese government has encouraged planting of these two tree species in economic afforestation in Vietnam (MARD 2014, 2021a). As a consequence, the area planted with these two species has reached about 200,000 hectares, and plantations are mainly located in the North of Vietnam (MARD 2021b).

The family Cossidae contains many pest species including *Zeuzera multistrigata* in *Eucalyptus* plantations (Chi *et al.* 2022a) and *Neurozerra conferta* in *Melaleuca* plantations (Chi *et al.* 2022b) in Vietnam. *Orientozeuzera rhabdota* (Jordan, 1932) (Cossidae) is widely distributed in SE Asia (Borneo, Sumatra, Java, Myanmar, Philippines (Palawan), Thailand and Vietnam). The species has previously been erroneously synonymized with *Orientozeuzera caudata* (Joicey & Talbot 1916) (distributed only in New Guinea) (Holloway 1986; Schoorl 1990), or considered as a subspecies − *O. caudata rhabdota* (Barlow 1982; Holloway 1976; Roepke 1955, 1957). *Orientozeuzera caudata* was recorded as a wood borer pest in Indonesia (Michaux 1996; Sutrisno 2015). To date, there have been no studies on the biological and habitat characteristics of *O. rhabdota.*

Only a small number of insect pests have been reported affecting the Magnoliaceae such as *Papilio argamemnon* and *Ploneta diducta* damaging *Michelia champaca* in Indonesia, and *Icerya pulcher* damaging *Mi. champaca* in Malaysia (Michelia 2023). Up to now however, there are no publications on the insect pests of *M. mediocris* trees, and very little on the pests of *M. conifera*. In Vietnam, a sawfly *Shizocera* sp. was reported to be a serious pest of *M. conifera* plantations in northern Vietnam (Doi *et al.* 2019). Although a stem borer was recorded as a pest on *M. conifera* plantations (MARD 2006), the taxon was not specified. In recent years, *M. conifera* and *Mi. mediocris* plantations in the northern provinces of Vietnam have been attacked by an *Orientozeuzera* stem borer. Factors driving variation in the patterns of host damage have been investigated in different families of the wood and stem boring insects, including the family Coisidae (Chi *et al.* 2022a; Hung *et al.* 2022). The aim of this paper was to identity the emerging insect pest and assess the influence of tree age, planting configuration and slope position on damage severity. The results are expected to provide helpful information for the future management of this pest.

Materials and methods

Characterization and identification

Sixty trees of *M. conifera* in Tuyen Quang and Bac Kan provinces, thirty trees per province, and twenty trees of *M. mediocris* in Quang Ninh province were felled in Febuary 2023. The trees had one to five exit holes on the trunk surface. The boles were cut into 0.8 m lengths and the logs were taken to the Forest Protection Research Centre (FPRC) in Hanoi. *Orientozeuzera* larvae were reared in a room (26 ºC ± 0.2; 70% ± 1.5 RH) and fed with sweet potato until the formation of pupae, adults and eggs. Characterization and identification of 22 adult specimens was based on keys in Yakovlev (2014) and Yakovlev & Witt (2015). Specimens FPRC 93−106 were deposited in the insect collection of the FPRC, and 4 specimens (FPRC 107−110) were deposited in the insect collection of the Vietnam National Museum of Nature, Hanoi, Vietnam.

Assessment of symptoms of *Orientozeuzera rhabdota* damage in *M. conifera* and *M. mediocris* trees

Infested trees of *M. conifera* and *Mi. mediocris* (30 trees per species), were used to describe the damage diagnostics. The number of bore holes and their diameters were measured on the trunk and branch surface, up to 4 m above the ground. The characteristics of frass in the bore holes and around the base of infested trees were described. The infested trees and branches were cut and sectioned to characterize tunnels inside the boles and branches.

Assessment of damage in *M. conifera* and *M. mediocris* with tree age

Field surveys were conducted during March and April 2023 at *M. conifera* plantations in Tuyen Quang and Bac Kan provinces, and *Mi. mediocris* plantations in Quang Ninh province, Vietnam, where there was local concern for the decline and death of these species. Plantations were 10–15 ha in size and the tree density was 1,660 trees/ha. The climate of the study sites is tropical monsoon with four distinct seasons. The annual rainfall range is is 2,200–2,700 mm, and the annual temperature range is 24–26 ^{o}C. Plantations comprising six stand ages (12, 24, 36, 48, 60 and 72-month-old) were selected at each of 4 locations in each province. Three replicate plots (500 m^2 each) were established in each stand age. Fourty trees in each plot were checked for *Orientozeuzera* damage symptoms and signs based on the presence of entry and exit holes on the trunk and branch surface. The damage incidence was grouped at five categories, where: 0 = intact trees; 1 = damaged trees with one hole on the bole or branches; 2 = damaged trees with 2–4 holes on the bole or branches; 3 = damaged trees with 4–8 holes on the the bole or branches, or about 50% canopy senescing; 4 = damaged trees with >8 holes on the bole or branches, or full foliage senescing, trees dead or broken.

Assessment of damage among *M. conifera* planting configurations

In April 2023, field observations were carried out in 24-month-old plantations of *M. conifera* in Tuyen Quang and Bac Kan provinces. Four plantations (11–15 ha each) per province were established in April 2021 with the following configurations: (1) monoculture using seedlings, (2) monoculture using sprouts, (3) mixed planting of *M. conifera* + *Acacia mangium* (1:1) from seedlings, (4) mixed planting of *M. conifera* + *Chukrasia tabularis* (1:1) from seedlings. The *M. conifera* seed was obtained from wild mother trees, sprouts with attached roots were obtained from the base of wild trees and the seed for *A. mangium* and *C. tabularis* were commercially improved seed. Before planting, the woody weeds and forest harvest residues in all plots were removed and burnt. Planting holes were dug manually with the dimension of 30 × 30 × 30 cm, 200 g of NPK (5–10–3) was placed in the base of each hole, and the holes were backfilled. Planting density was 1,660 trees/ha, with 3 m between and 2 m within rows. The weeds were manually cut every six months. Twelve plots, each 500 m^2, were randomly laid out in each configuration. The plots were separated by at least 10 m buffers. All 40 trees in each plot (ca. 3–5 cm in diameter at breast height and 3–4 m height) were checked for *Orientozeuzera* damage severity using the five categories described above.

Assessment of damage among slope positions

In April 2023, the influence of slope on pest damage in *M. conifera* was examined at four positions (foot-hill, middle-hill, top-hill and road side) in Tuyen Quang and Bac Kan provinces. Four plantations (15–20 ha each), including roadside plantings, established in April 2021 were used to examine the impact of the pest. There were 96 randomly established plots (12 plots/plantation × 4 plantations/province × 2 provinces). All 40 trees in each 500 m^2 plot were checked for *Orientozeuzera* damage severity using the five categories described earlier.

Data analysis

Based on the damage classification, we initially calculated damage incidence (P%) using equation 1 (Chi *et al.* 2021):

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

where: *n* is the number of trees attacked by *Orientozeuzera*; *N* is total number of trees observed.

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 observed.

Data analysis was performed using GenStat Release 12.1 software package (VSN International Ltd., Hemel Hempstead, UK). The Kolmogorov-Smirnov Test was used to check for the data distribution. The average damage index and damage incidence were log-transformed before analysis. Significant effects of the plantation ages, planting configurations and slope positions on the average indices and damage index of *Orientozeuzera* were tested with one-way analysis of variance (ANOVA), followed by Turkey's Multiple Range Test at P = 0.05.

Results

Identification

Based on the external morphological characters of female adults (Fig. 1a, b) in this study and compared with those previously given (Yakovlev 2014; Yakovlev & Witt 2015; Yakovlev *et al*. 2020), the pest infesting *M. conifera* and *M. mediocris* trees in Vietnam was confirmed as *O. rhabdota*.

Male adults (n = 10) (Fig. 1a): Body brown, forewing length 35.3–42.5 mm, body size 20.2–25.4 mm long, 4.0–4.5 mm wide. Head, thorax, and abdomen thinly covered with dark brown hairs. Antennae cup-shaped, black in basal part, filiform, gray or black at the top, bipectinate in proximal half and filamentous in distal half; thorax with eight black dots. Upperside of thorax with large spot consisting of pale hairs and with two pairs of rounded dark spots. Forewing oblong, with pointed apex, with row of black spots at costal margin, with very weakly developed pattern of grey transverse strokes between veins, developed coal-coloured discal stroke and row of grey strokes at anal margin. Hindwing short, translucent, with distinctive incisure at anal angle and zone of dark hairs in basal part of wing; incisure marked by black semicircular spot.

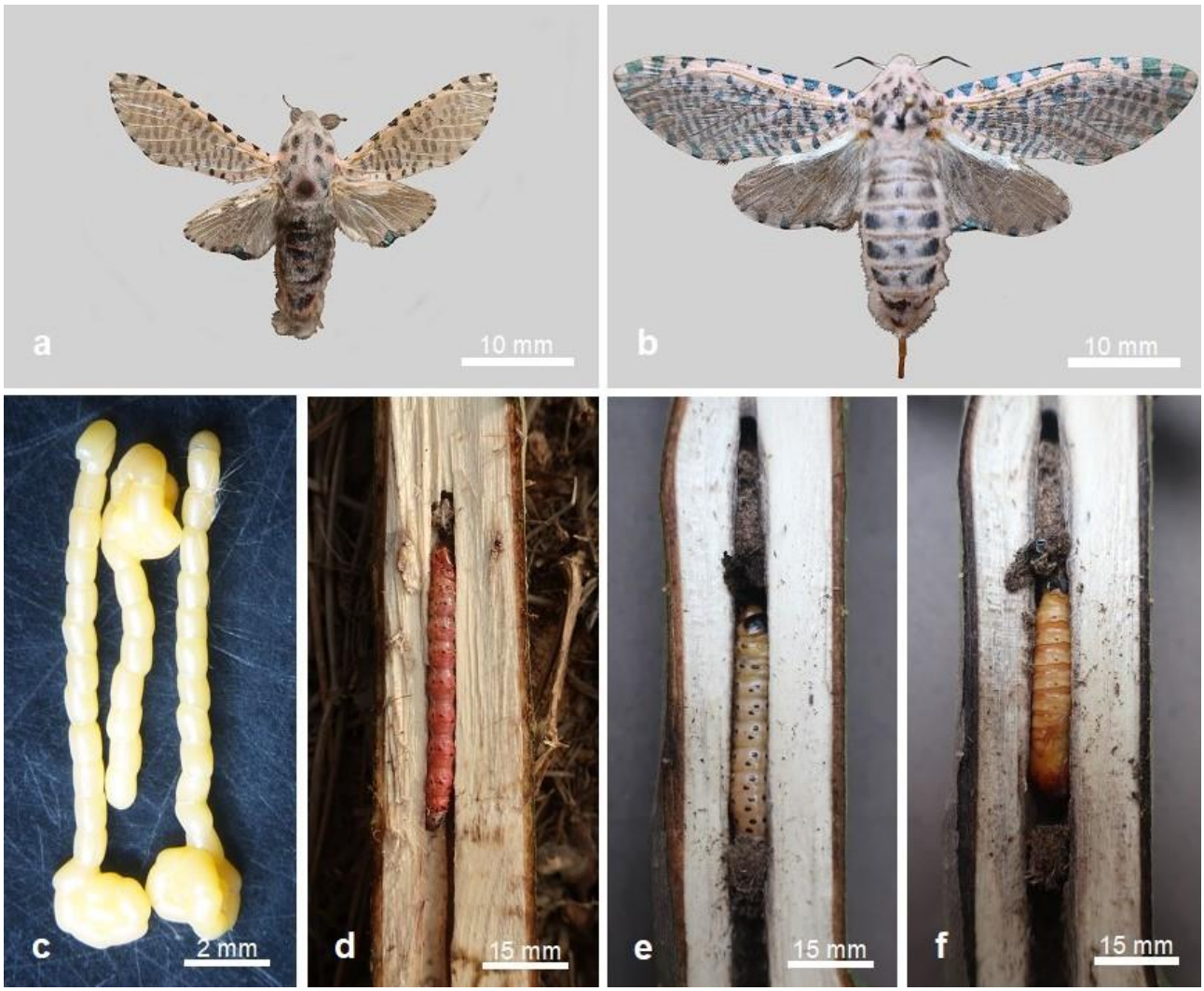

Figure 1 Morphological characteristics of *Orientozeuzera rhabdota*: **a**, **b**. adults; **a**. male; **b**. female; **c**. eggs; **d**. larva; **e**. prepupa; **f**. pupa.

Female adults (n = 12) (Fig. 1b): Body gray brown, forewing length 50.5–63.2 mm, body size 28.3–30.5 mm long, 4.6–6.8 mm wide; Head, thorax and abdomen thickly covered with dark brown hairs; antennae filiform, black; Thorax with eight black dots; Forewing light gray, consisted of densely black lines and strikes on the black ground; Hindwing light gray.

Eggs initially light yellow, and then gradually turn into yellow, cylindrical, 0.8–1.0 mm long, 0.5–0.6 mm wide, eggs laid in cluster of 15–30 eggs (Fig. 1c).

Larvae redish; cylindrical, last instar light yellow, body 38.2–45.5 mm long, 5.0–6.5 mm wide, the body is segmented with black dots along the sides of the body; head gray or black (Fig. 1d, e).

Cylindrical pupae are light brown at first, then darken, 32.6–45.5 mm long, 5.8–8.1 mm wide, male pupae smaller than female pupae (Fig. 1f).

Symptoms of *O. rhabdota* damage in *M. conifera* and *M. mediocris* trees

Orientozeuzera rhabdota was associated with tree damage and stem or branch breakage. Infested *M. conifera* and *Mi. mediocris* trees have circular holes with a diameter of 0.2–0.6 cm in the boles (Fig. 2a, d) or branches (Fig. 2b), located 15–380 cm above the ground. There are many droppings around the base of the damaged trees (Fig. 2a). Droppings are discrete, semi-circular faeces, white at first, then brown, and gray. The tunnels go directly into the boles and then straight down the middle of the stems, then back up again. The tunnels are 60–80 cm long and 0.7–1.1 cm in diameter. There are webs of mixed wood mulch blocking the openings of the entrance holes (Fig. 2f).

Figure 2. Symptoms of *Orientozeuzera rhabdota* attack in *Manglietia conifera* and *Michelia mediocris*: **a**, **b**, **c**, **g**, **h**, **i**. *M. conifera*; **d**, **e**, **f**. *M. mediocris*; **a**, **d**. damaged tree with holes in the main stem; **b**. broken tree after serious damaged from *O. rhabdota*; **c**. damaged tree with symptom on a branch (white arrow); **e**. larva eating on the stem; **f**, **g**. damage to the wood; **h**, **i**. entry holes (white arrows) and exit holes (black arrows) on stems.

Last instar larvae and prepupae make exit holes just above the entrance holes (Fig. 2h, i) but retain the thin bark of the tree for protection. Before maturing, the pupae push at the thin bark at the exit holes and squeeze out one third of the pupa's head (Fig. 2i). Severely damaged trees can have 6–12 larvae in the bole and branches, and the damaged trees (Fig. 2b) or branches are easily broken during strong winds.

Effect of tree age on *O. rhabdota* damage in *M. conifera* and *M. mediocris*

The results of one-way analysis of variance (Table 1) showed that there was a significant difference in damage incidence and damage index between tree age ($P < 0.001$) for both host species. Damage incidence (P%) and damage index (DI) in *M. conifera* plantations aged 1 to 5 years-old ranged from 3.1–52.7% and 0.07–1.71, respectively. Damage from *O. rhabdota* was similar for Tuyen Quang and Bac Kan provinces. Six-year-old trees were not attacked by *O. rhabdota*. The P% and DI in *Mi. mediocris* plantations were significantly lower than in *M. conifera* plantations. One–three years old stands of *Mi. mediocris* in Quang Ninh province were slightly damaged with P% = 1.1–6.6% and DI = 0.02–0.12. In both host species, bole damage from *O. rhabdota* was highest at 2 years of age with P% of 50.3–52.7% and 6.6%, respectively. Trees older than 3 years often had some *O. rhabdota* damage in the larger branches.

Table 1. Damage incidence and average damage index of *Orientozeuzera rhabdota* damage in *Manglietia conifera* and *Michelia mediocris* plantations.

Age (month)	*M. conifera*				*M. mediocris*	
	Tuyen Quang		**Bac Kan**		**Quang Ninh**	
	P%	**DI**	**P%**	**DI**	**P%**	**DI**
12	7.5 ± 1.1^{bc}	0.12 ± 0.01^{ab}	8.0 ± 0.9^{bc}	0.14 ± 0.01^{bc}	1.1 ± 0.6^{ab}	0.02 ± 0.01^{ab}
24	50.3 ± 4.6^{e}	1.60 ± 0.12^{d}	52.7 ± 5.0^{e}	1.71 ± 0.15^{e}	6.6 ± 0.5^{c}	0.12 ± 0.02^{c}
36	18.1 ± 1.8^{d}	0.52 ± 0.05^{c}	19.4 ± 2.1^{d}	0.59 ± 0.05^{d}	1.5 ± 0.1^{b}	0.03 ± 0.01^{b}
48	9.2 ± 1.3^{c}	0.21 ± 0.02^{b}	10.1 ± 1.2^{c}	0.23 ± 0.02^{c}	0.0^{a}	0.00^{a}
60	3.1 ± 0.6^{ab}	0.07 ± 0.01^{ab}	3.8 ± 0.4^{ab}	0.09 ± 0.01^{ab}	0.0^{a}	0.00^{a}
72	0.0^{a}	0.00^{a}	0.0^{a}	0.00^{a}	0.0^{a}	0.00^{a}
Lsd	**3.75**	**0.10**	**3.40**	**0.09**	**0.77**	**0.02**
P	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**

Note: Lower case letters within a column show significant difference among ages.

Effect of planting configuration on *O. rhabdota* damage in *M. conifera*

The infestation level (P%) and the average damage index from *O. rhabdota* in *M. conifera* established as monocultures and mixed plantingsin Tuyen Quang and Bac Kan provinces are shown in Table 2. There were significant ($P < 0.001$) differences in damage among planting configurations in the two provinces. Monoculture plantations established with seedlings had the most serious damage (P% = 50.1–52.6%, DI = 1.59–1.70), followed by the sprouted monocultures (P% = 17.8–18.9%, DI = 0.51–0.57). The mixed species configurations of *M. conifera* + *A. mangium* and *M. conifera* + *C. tabularis* had significantly lower damage incidence and damage index (P% = 5.8–7.2%, DI = 0.09–0.17).

Table 2. Damage incidence and average damage index of *Orientozeuzera rhabdota* damage in *Manglietia conifera* plantation established as monocultures and mixed plantings in two provinces.

Planting type	Tuyen Quang		Bac Kan	
	P%	**DI**	**P%**	**DI**
Monoculture *M. conifera* seedlings	50.1 ± 5.1^{c}	1.59 ± 0.12^{c}	52.6 ± 5.0^{c}	1.70 ± 0.13^{c}
Monoculture *M. conifera* sprouts	17.8 ± 1.8^{b}	0.51 ± 0.04^{b}	18.9 ± 1.7^{b}	0.57 ± 0.05^{b}
Mixed planting *M. conifera* + *Acacia mangium*	5.8 ± 0.6^{a}	0.09 ± 0.01^{a}	5.9 ± 0.5^{a}	0.11 ± 0.01^{a}
Mixed planting *M. conifera* + *Chukrasia tabularis*	6.8 ± 0.6^{a}	0.16 ± 0.02^{a}	7.2 ± 0.7^{a}	0.17 ± 0.02^{a}
Lsd	**4.36**	**0.11**	**3.85**	**0.10**
P	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**

Note: Lower case letters within a column show significant differences among planting type.

Effect of slope on *O. rhabdota* damage in *M. conifera*

There was a significantly difference ($P < 0.001$) in damage incidence and damage index between the plots close to the road and other locations (Table 3). Trees planted in the foot-hill, middle-hill or top-hill positions showed no difference in damage from this pest (P% = 43.0–45.6%, DI = 1.33–1.42). However, trees planted along the roadside were significantly more severely damaged by *O. rhabdota* in both Tuyen Quang and Bac Kan provinces (P% = 58.6–60.2%, DI = 1.88–1.97).

Table 3. Damage incidence and average damage index of *Orientozeuzera rhabdota* damage in *Manglietia conifera* plantation for slope position in two provinces.

Slope position	Tuyen Quang		Bac Kan	
	P%	DI	P%	DI
Foot-hill	44.7±4.3[a]	1.37±0.12[a]	45.6±4.2[a]	1.42±0.13[a]
Middle-hill	43.9±3.9[a]	1.35±0.12[a]	43.5±4.1[a]	1.38±0.13[a]
Top-hill	43.0±4.1[a]	1.33±0.11[a]	43.6±4.4[a]	1.40±0.12[a]
Road side	58.6±5.2[b]	1.88±0.15[b]	60.2±5.6[b]	1.97±0.16[b]
Lsd	**3.70**	**0.16**	**3.32**	**0.15**
P	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**

Note: Lower case letters within a column show significant difference among slope position.

Discussion

This is the first report of *O. rhabdota* causing damage in *M. conifera* and *M. mediocris*. This stem borer has been recorded as a serious pest in Indonesia (Michaux 1996; Sutrisno 2015). However, these studies did not specify the host plant of this pest. The biology of *O. rhabdota* has not been documented, and the presence of stem borers in wild stands of *Michelia* and *Manglietia* has not been investigated.

Manglietia conifera has been planted in northern Vietnam since the 1960s, primarily for the paper, wood chip and plywood industries (Nguyen 2007; Pham 2008). Previous studies recorded nine species of insect pests damaging *M. conifera* plantations in Vietnam, of which the sawfly *Shizocera* sp. was the most serious pest (MARD 2006). Repeat outbreaks of *Shizocera* sp., especially in the years 2013–2015, has damaged many thousands of hectares of plantations (Doi *et al.* 2019). Furthermore, as *Acacia* and *Eucalyptus* plantations have become severely affected by insect pests and diseases (Chi 2022a; Quang *et al.* 2022; Thu *et al.* 2021; Trang *et al.* 2022), many of the severely damaged areas have been converted to other plant plantation species, including *M. conifera* and *Mi. mediocris* (MARD 2021b). Recent expansion of the planted forest area of these members of the Magnoliaceae (MARD 2021b; Thang *et al.* 2021) may have facilitated an increase in outbreaks of *O. rhabdota*. As further large-scale planting is being encouraged in forest development programs for native species in Vietnam (Vietnam 2021), *O. rhabdota* now poses a threat to further reforestation.

Orientozeuzera rhabdota caused severe damage to *M. conifera* plantations at two years of age and damage was concentrated in the boles. Severely damaged trees were often broken in strong winds, causing economic loss. Therefore, control measures need to be investigated to manage this pest from the first year after planting in order to limit the population density of the pest in the second year and reduce damage. Previous studies have shown that *N. conferta* damage in *Melaleuca* trees (Chi *et al.* 2022b) and *Z. multistrigata* damage in *Eucalyptus* trees (Chi *et al.* 2022a) were also concentrated at 16–24 months of age. An initial investigation has demonstrated positive benefits from early intervention (Chi *et al.* 2022b).

This study shows that the damage from *O. rhabdota* was concentrated on roadside trees. The higher damage adjacent to roads could be a consequence of road corridors aiding the dispersal of adults. Away from roads, mixed plantations of *M. conifera + A. mangium* and *M. conifera + C. tabularis* had less damage than *M. conifera* monocultures. Mixed planting of some species has been used to effectively control pests (Chi 2022b; Wazihullah *et al.* 1996). For example, intercropping of *C. tabularis* with *Fernandoa brillettii*, *M. conifera* or *Acacia* spp. effectively limited the shoot-tip borer *Hypsipyla robusta* (Chi 2022b). In another study, Wazihullah *et al.* (1996) found that damage caused by *N. conferta* in *Bruguiera conjugata* was 51% in monoculture stands and 32% in mixed stands. However, intercropping of tree species may cause difficulties for planting and exploitation (MARD 2021b). Therefore, the composition of suitable mixed-species plantings

and their layout should be investigated to limit *O. rhabdota* damage and facilitate future planting and harvesting operations. The lower level of damage in the sprout stands than in the seedling stands suggests that tree genetics may be a contributing factor as the mother trees differed between the two sources of planting stock.

Several studies have explored the management of some insect pests damaging members of the Magnoliaceae. For example, insecticides were used to control three *Xylosandrus* ambrosia beetles attacking *Magnolia* species in Southeastern United States (Knox *et al.* 2012). Also, Naik & Kumar (1995) showed the potential of leaf extracts of the neem tree (*Azadirachta indica*) to reduce larval populations of the tropical butterfly *Graphium eurypylus*. Further research into the biology and life cycle of *O. rhabdota* are precursors to developing control measures for this pest.

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