




# The stem borer *Zeuzera multistrigata* Moore (Lepidoptera, Cossidae): a serious pest undermining *Eucalyptus* plantations in Northern Vietnam

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## Abstract

*Zeuzera multistrigata* Moore, 1881 (Lepidoptera: Cossidae) is a dangerous stem borer that damages the *Eucalyptus* plantations in Vietnam. Field surveys in Lao Cai and Phu Tho provinces in 2022 showed that *Z. multistrigata* frequently damaged *Eucalyptus* hybrid plantations (clone DH32-29) at the age of 16–28 months with damage incidence ranging from 16.93 to 28.74% and the damage index from 0.49 to 1.08. This study showed that three *E. urophylla* clones (PN3d, PN46, PN54) were not damaged by *Z. multistrigata*, and five clones (PN10, PN21, PN24, PN47, PN108) were less damaged. Further studies are recommended to screen tolerance *Eucalyptus* varieties and develop an integrated pest management plan for this pest.

**Key words:** Cossidae, *Eucalyptus*, Myrtaceae, Vietnam, *Zeuzera multistrigata*, Zeuzerina.

## Introduction

*Eucalypts* have been grown in plantations in many other countries and they are considered to be among the most important plantation species in Southeast Asia and China (Harwood & Nambiar 2014; Arnold et al. 2020). Increased forest production has been improved through breeding practices (Harwood & Nambiar 2014; Chi et al. in press); however, extensive damage triggered by pests and diseases is a matter of concern for the industry. In Vietnam, clonal *Acacia* and *Eucalyptus* plantations has made a great proportion to the export of wood and timber products with US\$ 9.4 billion in 2018 (MARD, 2019), and US\$ 12.0 billion in 2020 (To et al. 2021).

Stem borers in the genus *Zeuzera* are among the most important insect pests of various plant species (Dell et al. 2012; Fekrat & Farashi 2022). Several species have been recognized as serious pests of crops and forest trees such as *Z. multistrigata* damage in *Casuarina equisetifolia* in China (Jinshui et al. 1988), in cherry (Bhardwaj 1982), *Persea bombycina* and *Litsaea polyantha* (Baruah & Saikia 2020) in India. *Z. pyrina* damage in olive in Egypt (Hegazi et al. 2015), apple in Bulgaria (Kutinkova 2006), walnut (*Juglans regia*) in Iran (Salari et al. 2021). *Z. coffeae* damage in *E. urophylla* in Vietnam (Thu et al. 2010), walnut in Pakistan (Ahmad 2017), *Tectona grandis* (Varma 2007), and *Santalum album* (Sundararaj 2019) in India.

In Vietnam, many insects and pathogens have been identified as pests of *E. urophylla* plantations including *Zeuzera coffeae* (Thu et al., 2010), *Sarothrocer lowi*, *Leptocybe invasa* (Dell et al. 2012) and *Cryptosporiopsis eucalypti*, *Ralstonia solanacearum* (Thu et al. 2010; Dell et al. 2012), and *Ceratocystis manginecans* (Chi et al. in press; Trang et al. 2022). Therefore, these plantation areas are being replaced by *Eucalyptus* hybrid clones (Chi et al. in press) with the estimated area has increased from 200,000 ha in 2013 (Harwood & Nambiar 2014) to 400,000 ha in 2020 (Thu et al. 2021). In recent years, *Eucalyptus* hybrid plantations in the northern provinces of the country have been attacked by other *Zeuzera* species. The aim of this paper was to identify the emerging insect pest and assess the damage severity of the main commercial *Eucalyptus* clones. The results are expected to provide helpful information for the effective management strategies of *Z. multistrigata*.

## Materials and methods

### Characterization and identification

Thirty-six trees of DH32-29, a clone of *E. urophylla* × *E. grandis* in Lao Cai and Phu Tho provinces were felled (Fig. 1) in July 2022. The trees had one to four holes on the trunk surface, the bores were cut into 1.0 m lengths and then the logs were taken to the Forest Protection Research Centre (FPRC) in Hanoi. *Zeuzera* larvae were reared in the room conditions (30.5°C ± 0.2; 78.4% ± 0.3 RH) and fed with the carrots until emergence of pupae, adults and eggs. Characterization and identification of 16 adult specimens was based on keys in Yakovlev (2011, 2014), and these 16 specimens were deposited in the insect collection of the FPRC.

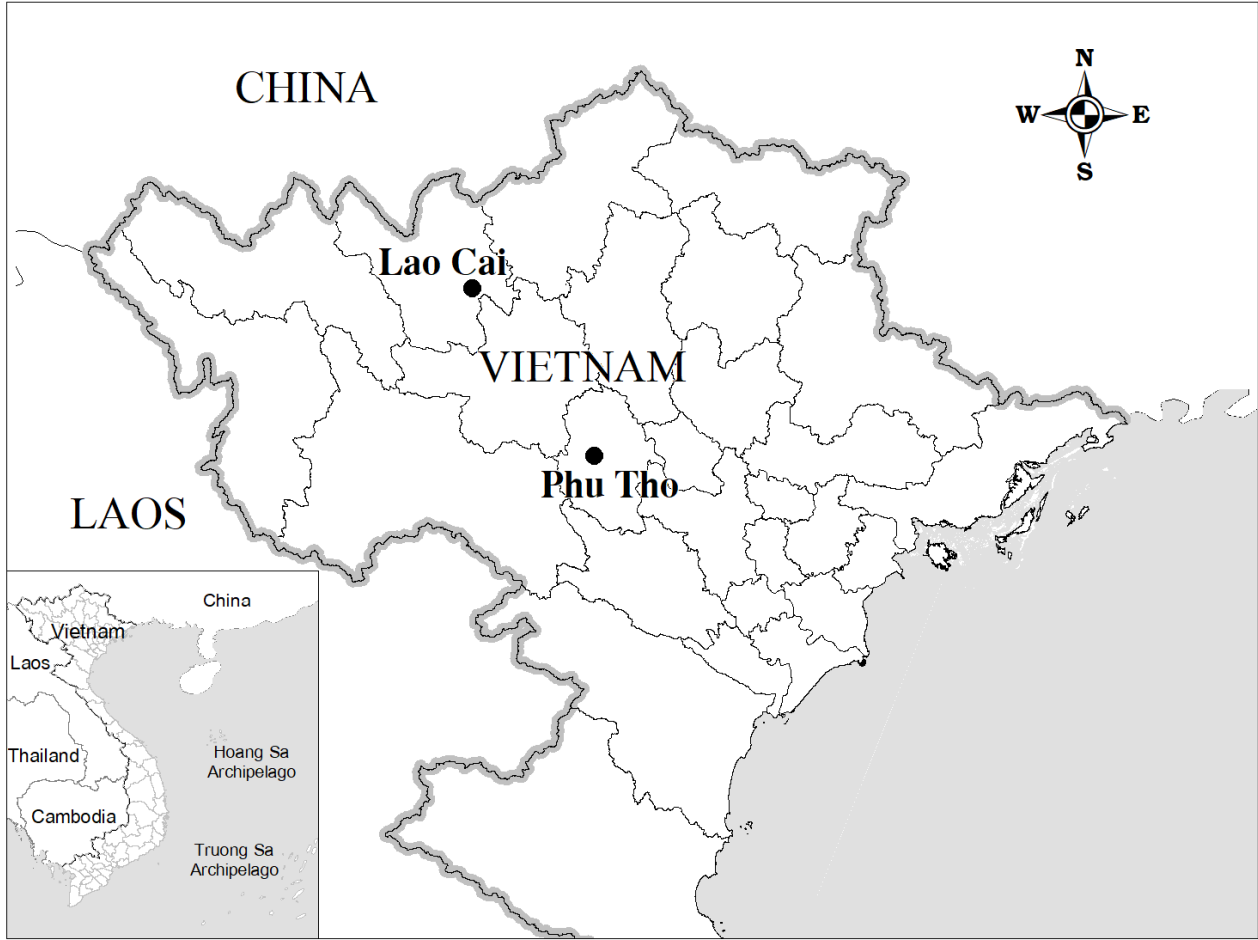
### Assessment of damage in *Eucalyptus* hybrid plantations

Field surveys were conducted during August 2022 at *E. urophylla* × *E. grandis* plantations (clone DH32-29) in Bao Yen-Lao Cai and Yen Lap-Phu Tho provinces, Vietnam (Fig. 1), where there was local concern for the decline and death of *Eucalyptus* hybrid trees. Plantations were 10–20 ha in size and the tree density was 1,500–1,600 trees/ha. The weather of study sites is typical of tropical monsoon regions with four distinct seasons. The annual rainfall range is 1,600 - 2,600 mm, and the annual temperature range is 24–28°C. Three plantation sites were selected in each of five different stand ages (12, 16, 28, 40 and 52-month-old) in each province and four plots (500 m<sup>2</sup> each) were chosen in each plantation sites. Thirty trees in each plot were checked for *Zeuzera* damage signs which were grouped at five categories, where: 0 = intact trees; 1 = trees were damaged with one boring hole on the bole and green foliage; 2 = trees were damaged with two boring holes on the bole and mild leaf senescence; 3 = trees were damaged with three boring holes on the bole, about 50% canopy senescing; 4 = Trees were damaged with over three boring holes on the bole, full foliage senescing or trees dead. The trunk surface holes were a combination of exit holes and exposed larval feeding sites.

### Assessment of damage among *Eucalyptus* varieties

In August 2022, five field observations were carried out in 16-month-old plantations of *Eucalyptus* clones in Phu Tho province (Fig. 1). The plantation sites have reddish yellow ferrallite soils, 50–60 cm in depth and they have experienced three different cultivation years. Twelve plantations (11–13 ha each) of the main eucalypt clones established in April 2021 were used to examine the impact of the pest. The detailed information of the clones was illustrated in Table 1. 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 chemical NPK fertilizer (5–10–3) were 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 cut every four months. Six plots, each 500 m<sup>2</sup>, were randomly laid out in each clone in each plantation.

The plots were separated by at least 6 m buffers. All 30 trees in each plot (ca. 7–10 cm in diameter at breast height and 9–11 m height) were checked for *Zeuzera* damage severity at five different categories as described above.



**Figure 1.** Distribution of *Zeuzera multistrigata* in *Eucalyptus* plantations in Northern Vietnam.

### Data analysis

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

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

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

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

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

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.

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

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 and different *Eucalyptus* varieties on the average indices and damage index of *Z. multistrigata* were tested with one-way analysis of variance (ANOVA), followed by Duncan's Multiple Range Test.

**Table 1.** Genetic background of the selected *Eucalyptus* clones and their productivities in clonal plantations.

Taxon	Clone	Origin of clone*	MAI**	Classified variety***
<i>E. urophylla</i> × <i>E. grandis</i>	DH32-29	China	25	Technically advanced clone <sup>7</sup>
<i>E. urophylla</i> × <i>E. pellita</i>	PNCT3	China	24	Technically advanced clone <sup>5</sup>
<i>E. urophylla</i> × <i>E. pellita</i>	PNCT <sub>IV</sub>	China	25	Technically advanced clone <sup>5</sup>
<i>E. urophylla</i>	PN3d	Vietnam	28	National advanced clone <sup>4</sup>
<i>E. urophylla</i>	PN10	Vietnam	22	Technically advanced clone <sup>3</sup>
<i>E. urophylla</i>	PN21	Vietnam	23	Technically advanced clone <sup>4</sup>
<i>E. urophylla</i>	PN24	Vietnam	22	Technically advanced clone <sup>4</sup>
<i>E. urophylla</i>	PN46	Vietnam	36	Technically advanced clone <sup>2</sup>
<i>E. urophylla</i>	PN47	Vietnam	28	Technically advanced clone <sup>2</sup>
<i>E. urophylla</i>	PN54	Vietnam	29	National advanced clone <sup>6</sup>
<i>E. urophylla</i>	PN108	Vietnam	24	National advanced clone <sup>6</sup>
<i>E. urophylla</i>	PN14	Vietnam	22	Technically advanced clone <sup>1</sup>

Notes: \* China is clone imported from China; Vietnam is from family trial in Vietnam (Hai & Dao, 2013; MARD, 2017; Arnold et al., 2020). \*\* MAI is mean annual increment (m<sup>3</sup>/ha/year). \*\*\* Advanced clones were recognized by Vietnam's Ministry of Agriculture and Rural Development. Decision No: <sup>1</sup> 3645/QĐ/BNN-KHCN dated 28/12/1998; <sup>2</sup> 2722/QĐ/BNN-KHCN dated 7/9/2004; <sup>3</sup> 1773/QĐ-BNN-TCLN dated 19/7/2005; <sup>4</sup> 1686/QĐ/BNN-KHCN dated 9/6/2006; <sup>5</sup> 388/QĐ-BNN-TCLN dated 7/3/2014; <sup>6</sup> 3893/QĐ/BNN-TCLN dated 20/9/2016; <sup>7</sup> 4572/QĐ-BNN-TCLN dated 8/11/2017

## Results

### Identification

Based on the external morphological characters of female adults (Fig. 2a, b) in this study and compared with those previously given (Bhardwaj 1982; Jinshui et al. 1988; Yakovlev 2014, 2016), the pest infesting *Eucalyptus* hybrid trees in Vietnam was confirmed as *Zeuzera multistrigata* Moore, 1881 (Lepidoptera: Cossidae).

Female adults (Fig. 2a, b): Body gray brown, wingspan 65.1–69.3 mm, body size 30.1–32.3 mm long, 6.9–7.1 mm wide; the wings and body light brown; antennae setaceous. Head covered with gray fluff, atop many black dots. Chest covered with white hairs, with many dark brown spots. Legs have many spines. The forewings are transparent, with many black veins in the center and six dark brown dots near the base, with many small spots along the edges. The hindwings white, with a few longitudinal black spots on the lower edge. Abdomen white, dorsal with faint dots.

Eggs initially light yellow, and then gradually turn into dark yellow, cylindrical, 1.1–1.3 mm long, 0.6–0.8 mm wide, eggs laid in line consisting of 3–12 eggs (Fig. 2c).

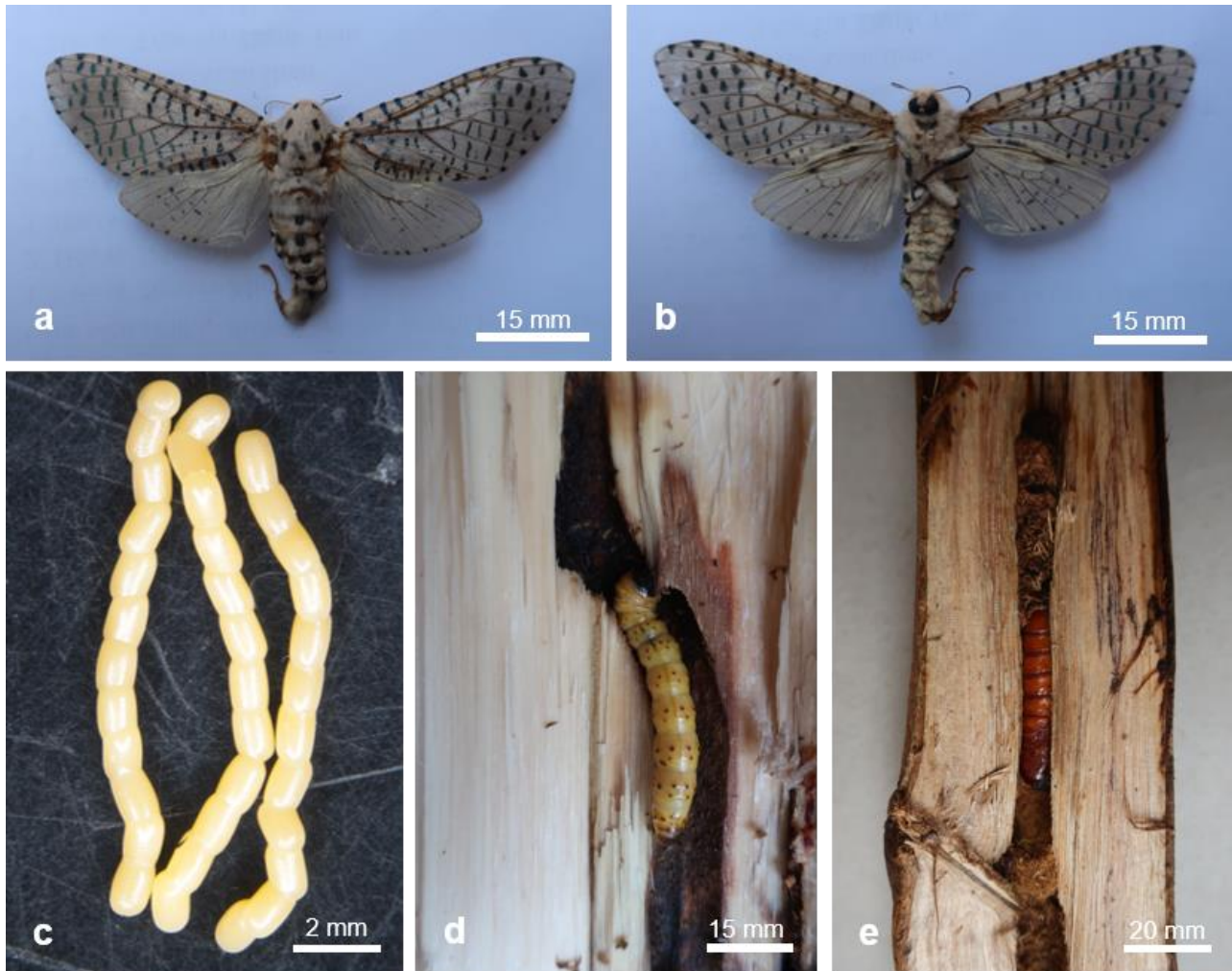
Larvae yellow to dark yellow; cylindrical, body 37.1–41.1 mm long, 7.9–9.1 mm wide, the body is segmented with brown dots along the sides of the body; head dark brown (Fig. 2d).

Cylindrical pupae are light brown at first, then darken, 3.9–4.2 mm long, 0.6–0.8 mm wide (Fig. 2e).

### *Zeuzera multistrigata* damage in *Eucalyptus* hybrid

Affected *Eucalyptus* stands were observed in plantations containing trees 16 months of age. In general, all *Eucalyptus* stands damaged by *Z. multistrigata*, trees were found to be declined and broken. Boring holes were clycle with inner diameter of 0.6–1.0 cm (Fig. 3a), situated at 0.5–4.5 m above the ground. The tunnels

were circular, 0.8–0.9 cm in diameter, 20–40 cm in length (Fig. 3b), and they run throughout the wood portion. Before pupation, the larvae often excavated horizontally long tunnels around the trunk of the tree, and consequently the damaged trees were easily broken during the strong winds (Fig. 3c).



**Figure 2.** Morphological characteristics of *Zeuzera multistrigata*: **a, b.** female adult; **a.** dorsal view **b.** ventral view; **c.** eggs; **d.** larva; **e.** Pupa

The infestation level (P%) and the average damage index of *Z. multistrigata* in *Eucalyptus* hybrid plantations at the age of 12–52 months are shown in Table 2. In both Lao Cai and Phu Tho provinces, the damage varied significantly among the tree ages ( $P < 0.001$ ). The damage were highest in the plantations of 16-month-old and none of damage was observed in 52-month-old plantation. The damage in the plantations at the age of 12–40 months in the Phu Tho was higher than those in the Lao Cai.

#### ***Zeuzera multistrigata* damage in *Eucalyptus* clones**

The infestation level (P%) and the average damage index of *Z. multistrigata* in different *Eucalyptus* clones are shown in Table 3. There were significant ( $P < 0.001$ ) differences in the damage among 12 clones. Among the observed clones, clone DH32-29 were the most damaged clone by *Z. multistrigata* ( $P\% = 28.93\%$ ,  $DI = 1.08$ ). The clone PN14 had 8.42% of the trees were damaged, but all the damaged trees were severely damaged ( $DI = 3-4$ ). The clone PNCT3 and PNCT<sub>IV</sub> were less affected ( $P\% = 7.35-7.92\%$ ;  $DI = 0.08-0.10$ ). Among the remaining eight clones, three of them were unharmed and five of them were very moderately damaged ( $P\% < 2\%$ ) (Table 3).

**Table 2.** Damage incidence and average damage index of *Zeuzera multistrigata* damage in *Eucalyptus* hybrid plantations (*E. urophylla* × *E. grandis*, clone DH32-29).

Age (month)	Lao Cai		Phu Tho	
	P%	DI	P%	DI
12	14.63 <sup>c</sup>	0.40 <sup>c</sup>	17.97 <sup>c</sup>	0.53 <sup>c</sup>
16	24.28 <sup>e</sup>	0.87 <sup>e</sup>	28.74 <sup>e</sup>	1.08 <sup>e</sup>
28	16.93 <sup>d</sup>	0.49 <sup>d</sup>	19.90 <sup>d</sup>	0.61 <sup>d</sup>
40	5.66 <sup>b</sup>	0.14 <sup>b</sup>	8.37 <sup>b</sup>	0.21 <sup>b</sup>
52	0.00 <sup>a</sup>	0.00 <sup>a</sup>	0.00 <sup>a</sup>	0.00 <sup>a</sup>
<b>Lsd</b>	<b>1.93</b>	<b>0.07</b>	<b>1.89</b>	<b>0.07</b>
<b>P</b>	<b>&lt; 0.001</b>	<b>&lt; 0.001</b>	<b>&lt; 0.001</b>	<b>&lt; 0.001</b>

Note: Upper case letters represent significant difference among *Eucalyptus* clones

**Table 3** Damage incidence and average damage index of *Zeuzera multistrigata* damage in *Eucalyptus* clones.

Clone	P%	DI
DH32-29	28.93 <sup>c</sup>	1.08 <sup>d</sup>
PNCT3	7.92 <sup>b</sup>	0.10 <sup>b</sup>
PNCT <sub>IV</sub>	7.35 <sup>b</sup>	0.08 <sup>b</sup>
PN3d	0.00 <sup>a</sup>	0.00 <sup>a</sup>
PN10	0.83 <sup>a</sup>	0.01 <sup>a</sup>
PN21	1.33 <sup>a</sup>	0.02 <sup>a</sup>
PN24	1.50 <sup>a</sup>	0.02 <sup>a</sup>
PN46	0.00 <sup>a</sup>	0.00 <sup>a</sup>
PN47	1.50 <sup>a</sup>	0.02 <sup>a</sup>
PN54	0.00 <sup>a</sup>	0.00 <sup>a</sup>
PN108	0.83 <sup>a</sup>	0.01 <sup>a</sup>
PN14	8.42 <sup>b</sup>	0.18 <sup>c</sup>
<b>Lsd</b>	<b>1.65</b>	<b>0.03</b>
<b>P</b>	<b>&lt; 0.001</b>	<b>&lt; 0.001</b>

Note: Upper case letters represent significant difference among *Eucalyptus* clones

## Discussion

This is the first report of *Zeuzera multistrigata* damage in *Eucalyptus* hybrid (*E. urophylla* × *E. grandis*) and *E. urophylla*, in which the hybrid clone DH32-29 was frequently damaged in the Northern Vietnam. *Z. multistrigata* is a dangerous pest, and it has been recorded as a serious pest of *Casuarina equisetifolia* in China (Jinshui et al. 1988). In addition, they have also been reported to cause damage in some other plant species in India including *Prunus avium*, *Persea bombycina* and *Bitsaea polyantha* (Bhardwaj et al. 1982; Baruah et al. 2020).



**Fig. 3** Symptoms of *Zeuzera multistrigata* in *Eucalyptus* hybrid: **a.** damaged tree; **b.** damage to the wood; **c.** broken tree after severe damage by *Z. multistrigata*.

The rapid increase in commercial *Eucalyptus* plantations in Vietnam, from 200,000 ha in 2013 (Arnold et al., 2020) to 400,000 ha in 2020 (Thu et al. 2021) is would to be the cause of outbreaks of *Z. multistrigata*.

Increase of stem borers has occurred at a time that the commercial plantation area of *Eucalyptus* has increased markedly in Vietnam, from 200,000 ha in 2013 to 400,000 ha in 2020. The large-scale afforestation combined with climate change has contributed to exacerbating the damage of pests and diseases, especially eucalypt pests (Quang et al. 2022). Impacts of climatic changes on the worldwide potential geographical dispersal range of *Z. pyrina* (Fekrat & Farashi 2022). Further large-scale planting is being encouraged in forest development programs for *Eucalyptus* species in Vietnam (To et al. 2021). Hence, *Z. multistrigata* is of great concern as it can be outbreaks and it is a threat to further investment in reforestation. Moreover, with the advantages of fast growth and easy propagation, the *Eucalyptus* hybrid, clone DH32-29 is being used very popularly in production afforestation in Vietnam with about 40-50% of the existing *Eucalyptus* forests area (To et al. 2021; Quang et al. 2022). This further increases the risk of this pest outbreak.

The present study shows that the clone DH32-29 was commonly damaged by *Z. multistrigata*. In addition, this clone has also been shown to be susceptible to longhorn beetle *Batocera lineolata* in Vietnam (24). Therefore, it is necessary to consider the use of the clone DH32-29 in production forest programs. Regarding the plantations using *E. urophylla* clones, the clones PN3d, PN46 and PN54 were not affected by *Z. multistrigata*, and the clones PN10, PN21, PN24, PN47 and PN108 were less damaged. Therefore, this finding suggests that these *E. urophylla* clones can be potential materials to replace the clone DH32-29 in Vietnam.

Some chemical pesticides and biological agents have been applied to manage stem borer *Z. multistrigata* damaging *Casuarina equisetifolia* China (Jinshui et al. 1988; Yang et al. 1990; Jin-shui & Qing-yuan, 1990). The spraying of Decanmethrin 2.5% at the concentration of 1/3000 or Omethoale 40% at the concentration of 1/300 on the trunk surface were effective to kill this borer (Jinshui et al. 1988). In addition, the injection of *Beauveria bassiana* (Jinshui et al. 1988; Jin-shui & Qing-yuan 1990) and *Steinernema feltiae* (Yang et al. 1990) solution into the tunnels have killed more than 86% and 93% of larvae, respectively. However, the application of these methods in the thousand of *Eucalyptus* plantations will be costly and difficult. Therefore, the use of the tolerant varieties in this study would be a possible strategy. Further studies are needed to screen *Eucalyptus* varieties tolerant to *Z. multistrigata* for development of integrated pest management plan for this pest.

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