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Incidences on Eucalyptus of Two Wood-boring Insects, *Batocera horsfieldi* Hope, 1839 (Coleoptera: Cerambycidae) and *Endoclita signifer* Waller, 1856 (Lepidoptera: Hepialidae) in China

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ABSTRACT

Many native insect species in China, has shifted host to exotic eucalyptus and caused significant damage to plantations. Two wood-boring insects, *Batocera horsfieldi* Hope, 1839 (Coleoptera: Cerambycidae) and *Endoclita signifier* Waller, 1856 (Lepidoptera: Hepialidae), were the most severe on eucalyptus in southern China. Incidences of infestation of *B. horsfieldi* and *En. signifer* on eucalyptus and its relationships between canopy density, altitude, tree age and variety of eucalyptus were studied using the method of sampling survey in Hezhou City, Guangxi Zhuang Autonomous Region of China. Results showed that *B. horsfieldi* preferred the habitat with higher canopy density of eucalyptus. Incidence of infestation of *B. horsfieldi* was positively correlated with the age of eucalyptus, and negatively correlated with the altitude. There was no significant correlation between the incidence of infestation of *B. horsfieldi* and the variety of eucalyptus. *Endoclita signifer* preferred the habitat with higher canopy density of eucalyptus. Incidence of infestation of *En. signifer* had no significant correlation with the age of eucalyptus and the altitude. There was significant correlation between the incidence of infestation of *En. signifer* and the variety of eucalyptus. These results are an important base for the control (e.g., resistance screening) of the two wood-boring insects.

Key words: Eucalyptus, wood-boring insects, incidence, canopy density, China.

INTRODUCTION

Eucalyptus is known as one of the fast-growing tree species, which are widespread in tropical and subtropical regions (Yang *et al.*, 2011). Eucalyptus plays an important role in the fields of reforestation, production of timber, pulp, potential bio-energy feed stock, and other forest products (Rejmánek and Richardson, 2011). Up to 2012, eucalyptus has been introduced and cultivated in 96 countries. In China, there are now 1.54 $\times 10^7$ square hectares of eucalyptus plantations (Ji *et al.*, 2011), in which covers more than 1.8×10^6 square hectares in Guangxi Zhuang Autonomous Region (Huang and Zhao, 2014). However, biodiversity descended obviously in an ecosystem with the increasing of the cultivated area of eucalyptus resulting in a sharp rise of eucalyptus pest species (Paine *et al.*, 2011), such as *Heteronychus arator* Fabricius, 1775 (Coleoptera: Scarabaeidae), *Ceroplastes sinensis* Del Guercio, 1901 (Hemiptera: Coccidae), *Coccus hesperidum* L., 1758 (Hemiptera: Coccidae), *Diaspidiotus perniciosus* Comstock, 1881 (Homoptera: Diaspididae), *Xyleborinus saxeseni* Ratzeburg, 1864 (Coleoptera: Scolytidae) and *Platypus parallelus* Fabricius, 1801 (Coleoptera: Curculioninae). Records indicated that species of eucalyptus pests increased from 53 in 1980 to 282 in 2001 (Pang, 2001), such as *Leptocybe invasa* Fisher and La Salle, 2004 (Hymenoptera: Eulophidae), *Batocera horsfieldi* Hope, 1839 (Coleoptera: Cerambycidae), *Buasra suppressaria* Guenee, 1852 (Lepidoptera: Geometridae), *Endoclita signifer* Waller, 1856 (Lepidoptera: Hepialidae), *Acanthopsyche subferalbata* Hampson, 1992 (Lepidoptera: Psychidae), etc.

Forest canopy cover, also known as canopy coverage or crown cover, is defined as the proportion of the forest floor covered by the vertical projection of the tree crowns (Azizia *et al.*, 2008). Forest canopy density is a major factor in the evaluation of forest status and is an important indicator of possible management interventions. Furthermore, canopy density can influence the growth of trees and the forest form resulting in the fluctuation of the diversity of insect species. Previous studies revealed that incidence of infestation of wood-boring insects were negatively correlated with canopy density, such as *Chreonoma atritarsis* Pic., 1912 (Coleoptera: Cerambycidae) and *Erythrus blairi* Gressitt, 1939 (Coleoptera: Cerambycidae) (Wang, 1983), *Cossus cossus orientalis* Gaede, 1929 (Lepidoptera: Cossidae) and *Holcocerus vicarious* (Walker) Yang, 1977 (Lepidoptera: Cossidae) (Wei *et al.*, 1997), *Dendroctonus valens* LeConte, 1860 (Coleoptera: Scolytidae) (Zhang *et al.*, 2002), *Tomicus piniperda* L., 1895 (Coleoptera: Scolytidae) (Chen *et al.*, 2004), *Monochamus alternatus* Hope, 1842 (Coleoptera: Cerambycidae) (Yu, 2008). It can be presumed that less direct sunlight, lower air temperature, poorer air circulation, and higher relative humidity in forest, due to the increasing of canopy density, were disadvantage of living of some insect species (Wang, 1983; Wei *et al.*, 1997). Furthermore, as for the wood-boring insects, distribution and activity was also influenced by altitude, tree age and variety despite that they hide in the xylem of the trunk (Ongàmo *et al.*, 2006).

A large number of insect species seriously threaten development of eucalyptus industry, farmer income, and forest tenure reform. Recent data revealed that species of wood-boring pest of eucalyptus increased from 18 to 25 (Yu *et al.*, 2011), in which the damage of both *B. horsfieldi* and *En. signifer* was the most severe on eucalyptus in Guangxi (Huang *et al.*, 2013). As for *B. horsfieldi*, which is a polyphagous insect that damages loquat, fig, citrus, mountain ebony, paulownia, apple, peach, pear, walnut, Chinese chestnut except for eucalyptus (Li *et al.*, 2009). As for *En. signifer*, which is a polyphagous insect that damages china fir except for eucalyptus (X. H. Yang, Unpublished data). Heavy infestation of these insects could result in destruction of the cambium layer and the rapid death of the tree. As we know, it is difficult to detect the larvae in early-stage due to the concealed lifestyle, and when they were found it is already too late to control them. In fact, forestry control (e.g., daily management, resistance screening, etc.) could effectively mitigate the damage of wood-boring insects. To investigate the wood-boring insects of eucalyptus in different habitats and varieties under natural conditions will helpfully provide essential information for the further forestry control.

In this study, our objectives are to investigate the relationships between the incidences of infestation of *B. horsfieldi* and *En. signifer* and (i) the canopy density, altitude and tree age, and (ii) the eucalyptus variety.

MATERIALS AND METHODS

Hezhou City

Study sites of this study located at Babu District, Daguishan Nationalized Forest Farm, Fuchuan Yao Autonomous County, Zhongshan County, Zhaoping County and Pinggui District in Hezhou City (23°39′0″-25°09′0″ °N, 111°05′0″-112°03′0″ °E). Annual-average air temperature and precipitation are 20 °C and 1,536 mm, respectively. Plantation area of eucalyptus in this City is 6×10^4 square hectares (Zhou, 2010), in which *Eucalyptus urophylla* S. T. Blake, 1977 (Myrtales: Myrtaceae), *Eu. grandis* W. Hill, 1862 (Myrtales: Myrtaceae) and *Eu. urophylla* × *Eu. grandis* are the main cultivated varieties.

Investigation method

Cultivated regions of eucalyptus in Babu and Pinggui Districts, Zhongshan and Zhaoping Counties, Fuchuan Yao Autonomous County, and Daguishan Nationalized Forest Farm of Hezhou City were investigated using the sampling survey from July to August, 2014. Total of 521 sampling sites were investigated. Each sampling site was 15,000 m^2. The geographic information (e.g., latitude, longitude, altitude, etc.) was recorded using GPS (Trimble Juno 3D, Trimble Corporation, Sunnyvale, USA). Estimates of canopy density used the line-intercept method in each sampling site (Fiala *et al.*, 2006). Variety and tree age were also noted according to the record of each forestry administration. Five-point sampling model was adopted, and the area of each point was 1,000 m^2. Total of 200 trees were randomly investigated in each point. According to our preliminary experiment, symptoms attacked by *B. horsfieldi* was a closed crack circle at the 0-2 m trunk of eucalyptus and piles of sawdust frass (insect waste) could be found on the trunk or the ground under the infested tree. Symptoms attacked by *En. signifer* was insect waste together with silk to form a spheroid (the same as the trunk tumor) which located at the exterior of the boring hole after they bored into its hosts. Symptoms attacked by the two insects were taken with a digital camera (Nikon Coolpix P500, Nikon Corporation, Tokyo, Japan). Number of each eucalyptus variety attacked by the two wood-boring insects was recorded. Percent incidence of infestation was calculated as following:

$$\text{Incidence of infestation (\%)} = \frac{\text{Number of attacked tree}}{\text{Total number of investigated tree}} \times 100$$

Statistical analysis

Statistical analysis was performed using SPSS 16.0 (SPSS, Chicago, IL, USA). Linear regressions were conducted to determine the relationship between the incidence of infestation of the two wood-boring insects and the canopy density, variety, tree age, and altitude. Pearson's coefficients were used to examine the correlations among the study variables. Effects of eucalyptus variety on incidence of infestation of *B. horsfieldi* and *En. signifer* were analyzed by one-way ANOVA followed by Duncan's test for multiple comparisons. Proportionate data were subjected to square root arcsine transformation prior to analysis. A level of $P < 0.05$ was accepted as statistically significant for all statistical analysis.

RESULTS

The symptoms of eucalyptus attacked by *B. horsfieldi* and *En. signifer*

The exterior symptom attacked by *B. horsfieldi* was a closed crack circle at the 0-2 m trunk of eucalyptus, which causes piles of sawdust frass (insect waste) found on the trunk or the ground under the infested tree (Fig. 1A). *Batocera horsfieldi* larvae were found in xylem after the trunk of infested eucalyptus was dissected (Fig. 1B). Number of larvae per tree was unequal. *Endoclita signifer* larvae mainly distributed at the 0-1 m trunk of eucalyptus. Larvae could spin to stick insect waste together to form a spheroid (the same as the trunk tumor) located at the exterior of the boring hole after they bored into its hosts (Fig. 1C). Larvae could be found in galleries in the trunk after the spheroid was destroyed (Fig. 1D). One larva was living in a spheroid, and the number of larvae per tree was unequal.

Relationship between incidence of infestation and canopy density, altitude, and tree age

Incidence of infestation of *B. horsfieldi* on eucalyptus was positively correlated with the canopy density (Fig. 2A) and the tree age (Fig. 2E), and was negatively correlated with the altitude (Fig. 2C). There was positive correlation between the incidence of infestation of *En. signifer* and the canopy density (Fig. 2B), but there was no significant correlation between the incidence of infestation and the altitude (Fig. 2D) and tree age (Fig. 2F).

Effect of variety on incidence of infestation

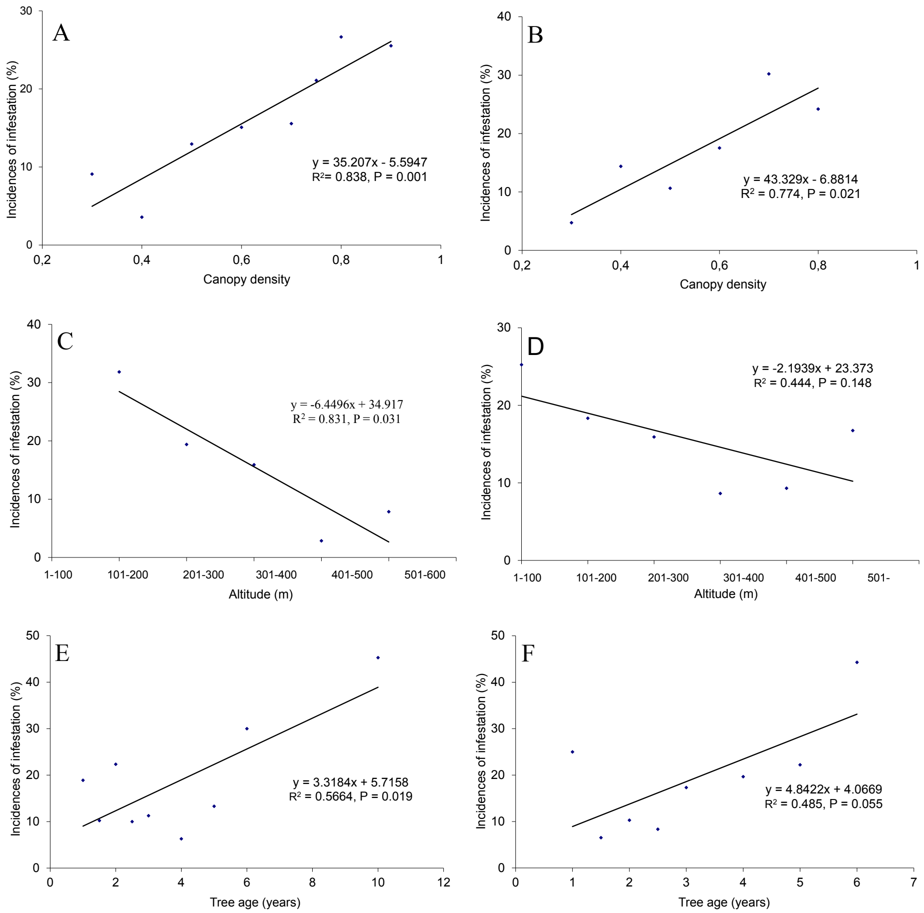
Eucalyptus variety had no significant effect on the incidence of infestation of *B. horsfieldi* ($F = 1.898$, df = 2, 43, $P = 0.163$; Fig. 3A). Conversely, the incidence of infestation of *En. signifer* on eucalyptus was markedly affected by the variety ($F = 4.265$, df = 2, 29, $P = 0.025$; Fig. 3B). Data showed the incidence of infestation of *Eu. urophylla* attacked by *En. signifer* was higher than *Eu. grandis* and *Eu. urophylla* ×*Eu. grandis* in the field (Fig. 3B).

Fig. 1. A-B. *Batocera horsfieldi* Hope, 1839 (Coleoptera: Cerambycidae). A. The symptoms of eucalyptus and; B. The larvae in the galleries of the trunk; C-D. *Endoclita signifier* Waller, 1856 (Lepidoptera: Hepialidae). C. The exterior symptom of eucalyptus and; D. The larva in the galleries of the trunk.

DISCUSSION

In the current study, data showed that the incidences of infestation of *B. horsfieldi* and *En. signifer* at higher canopy density were heavier than those at lower canopy density (Fig. 2). We speculated that there had two main reasons. Firstly, eucalyptus is a fast-growing tree species, which may develop higher forest canopy density in a short time. However, *B. horsfieldi* has a long life cycle (2-3 years / generation) and severe generation overlapping (Peng *et al*., 1998). Secondly, the eucalyptus forest has a good air circulation based on the straight trunk and little branches, though apical dominance is so obvious in eucalyptus that higher canopy density was easily formed. So, this eucalyptus forest could not impact the living of wood-boring insects. Finally, it appeared a positive correlation between incidences of infestation of *B. horsfieldi* and *En. signifer* and canopy density.

Furthermore, the positive correlation between the incidence of infestation of *B. horsfieldi* and tree age of eucalyptus could be attributed to the long life cycle, but it needs further to validate. However, the positive correlation has not appeared in *En. signifer*. We inferred it could be related that *En. signifer* preferred 1-2 years old eucalyptus (Yu, 2012; Huang *et al*., 2013; Yang *et al*., 2013).



Figs. 2. A-F. The relationships between the incidence of infestation. A-B the canopy density, C-D the altitude, and E-F the tree age. A, C, and E represents *Batocera horsfieldi* Hope, 1839 (Coleoptera: Cerambycidae); B, D, and F represents *Endoclita signifer* Waller, 1856 (Lepidoptera: Hepialidae).

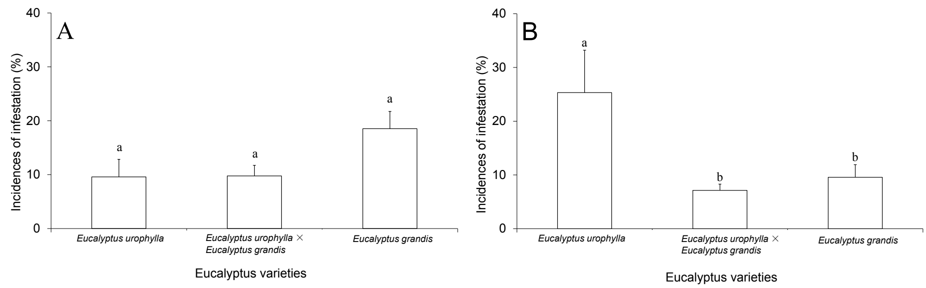


Fig. 3. Effects of eucalyptus variety on incidences of infestation of *Batocera horsfieldi* Hope, 1839 (Coleoptera: Cerambycidae) (A) and *Endoclita signifer* Waller, 1856 (Lepidoptera: Hepialidae) (B).

Altitude affects not only the species richness but also the species composition of insect communities (Mani, 1968). Numerous studies supported the conclusion that an overall decline in the species richness of insect species with increasing altitude (Hodkinson, 2005). Results from the present study showed that the incidence of infestation of *B. horsfieldi* on eucalyptus at lower altitude was obviously higher than those at higher altitude (Fig. 2C). It is well known that the temperature lapse rate, with respect to increasing altitude, generally lies between 5.5 and 6.5 °C for each 1000 m of ascent (Anslow and Shawn, 2002). Therefore, the lower incidence of infestation at higher altitude can be attributed to the low air temperature, which is disadvantageous for growth and development in pests.

Many studies have assumed that the feeding preferences of herbivores are governed by one of the following two criteria: (1) the need to maximize the intake of some limiting nutrient, often considered to be nitrogen, and (2) the need to avoid high concentrations of potentially toxic secondary chemicals (Lambdon and Hassall, 2005). Therefore, different plant species differ in nutrient contents and contain a different array of secondary metabolites, which may affect development, reproduction (Kairo and Murphy, 1999). In this study, eucalyptus variety had no significant effect on the incidence of infestation of *B. horsfieldi* (Fig. 3A). We considered that it could be attributed to its polyphagous habit, namely the nutrition was enough for *B. horsfieldi* to develop despite the kinds of host plant that they feed. As for *En. signifer*, results suggest that this insect preferred to some eucalyptus variety (e.g., *Eu. urophylla*), which is consistent with the results from Yang (2013) and Yang *et al.* (2013). Although the selective mechanism of *En. signifer* for host plant is still unclear, results from the current study indicate that the cultivated area of *Eu. urophylla* should be decreased in plantations.

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