

Host Preference of the Vector Beetle, Host Resistance, and Expanding Patterns of Japanese Oak Wilt in a Stand

Kazuyoshi Futai,¹ Hiroaki Kiku,¹ Hong-ye Qi,¹ Hagus Tarn,¹ Yuko Takeuchi,¹
and Michimasa Yamasaki²

Introduction

Since the early 1980s, an epidemic forest disease, Japanese Oak Wilt (JOW), has been spreading from coastal areas along the Sea of Japan to the interior of Honshu island and has been devastating huge areas of forests by killing an enormous number of oak trees in urban fringe mountains, gardens, and parks. The disease is caused by a fungus, *Raffaelea quercivora*, and is spread by the vector beetle, *Platypus quercivorus* (Coleoptera: Platypodidae). On the thorax of female *P. quercivorus*, are several holes, so called mycangia, where several species of yeasts are kept as the beetles' food. Together with such yeasts, the pathogenic fungus *R. quercivora* exists in the mycangia and is thereby transferred to the next tree. The spreading pattern of this disease is, therefore, determined by the searching and host preference behavior of the vector beetle. To control epidemic spreading of JOW, it is essential to understand the spread dynamics of JOW in infected trees. The object of this study was to analyze the spread dynamics of JOW in infected trees in relation to the host selection behavior of vector beetles in a stand.

Materials and Methods

Study Site

We have been studying the spreading pattern of this disease at a nearby low elevation mountain (109 m, 35°01'N, 135°47'E) in Kyoto city. The experimental site established at the mountain in the spring of 2009 is 1.36 ha and involved 288 living oak trees (*Quercus serrata* Murray) with DBH ranging from 10 to 90 cm.

Categorization of Host Damage

Based on the quality of frass produced from beetle tunnels, the density of beetle attacks (= number of entrance holes per given area of trunk surface), exudates from the trunks, and symptoms (alive or killed, and if killed, which year it was killed), we diagnosed the damage of each tree and classified the different levels of damage into seven categories (Cat.) (table 1).

Spatial Relationships Between Two Categories of Trees

To examine if the trees attacked by *P. quercivorus* in a given year influenced the occurrence of newly attacked trees in the following year, we analyzed the overlap between the trees attacked in 2009 and those newly attacked in 2010 using Iwao's m-m* method (Iwao 1977). When the individuals

¹ Laboratory of terrestrial microbial ecology, Graduate school of Agriculture, Kyoto University, Sakyo-ku, 606-8502, Kyoto, Japan.

² Laboratory of forest biology, Graduate school of Agriculture, Kyoto University, Sakyo-ku, 606-8502, Kyoto, Japan.
Corresponding author: futai@kais.kyoto-u.ac.jp.

Table 1—Categorization of host trees based on their damage history

Boring attack in		Condition in October 2010	Category (Cat.)
2009	2010		
+	+	Alive	I
+	+	Dead	II
+	-	Alive	III
+	-	Dead	IV
-	+	Alive	V
-	+	Dead	VI
-	-	Alive	VII

belonging to species X and Y are distributed over the same space, the mean crowding on sp. X by sp. Y can be given by

$$\bar{m}_{XY}^* = \frac{\sum_{j=1}^Q x_{Xj} x_{Yj}}{\sum_{j=1}^Q x_{Xj}}$$

and mean crowding on sp. Y by sp. X by

$$\bar{m}_{YX}^* = \frac{\sum_{j=1}^Q x_{Xj} x_{Yj}}{\sum_{j=1}^Q x_{Yj}}$$

where x_{Xj} and x_{Yj} are the numbers of individuals of sp. X and sp. Y in the j quadrat respectively, and Q is the total number of quadrats contained in the whole area. The mean crowding within each species is denoted by

$$\bar{m}_X = \frac{\sum_{j=1}^Q x_{Xj} (x_{Xj} - 1)}{\sum_{j=1}^Q x_{Xj}} \quad \text{and} \quad \bar{m}_Y = \frac{\sum_{j=1}^Q x_{Yj} (x_{Yj} - 1)}{\sum_{j=1}^Q x_{Yj}}$$

and

Then, as a measure of the degree of spatial correlation or the degree of overlapping relative to the independent distributions, we have

$$\omega_{(+)} = \sqrt{\frac{\bar{m}_{XY}^* \bar{m}_{YX}^* - m_X m_Y}{(\bar{m}_X + 1)(\bar{m}_Y + 1) - m_X m_Y}} \quad \text{or} \quad \omega_{(-)} = \sqrt{\frac{\bar{m}_{XY}^*}{m_X} \frac{\bar{m}_{YX}^*}{m_Y}} - 1$$

where the value ω changes from its maximum of +1 for complete overlapping, to the minimum of -1 for complete exclusion. In this method, we calculated the ω value as an index of spatial overlapping of two categories of trees while changing the unit size from 25 m² to 625 m² (Iwao 1972).

The Densities of Beetle Holes on the Stems of Host Trees

To estimate the number of beetles visiting each host tree, the densities of beetle holes on the host stems were compared among five categories of trees. We also examined the density of beetle holes in relation to the distance from the trees of Category III.

Results and Discussion

Disease Spreading in the Stand

There were 288 trees in the spring of 2009. Then in June and July 2009, 177 trees were attacked; 111 trees remained without attack. Among the 177 trees attacked, only 10 trees were killed and the remaining 167 trees survived. In the following year, 2010, 113 (67.7 percent) of 167 trees that survived the 2009 attack were re-attacked, while the other 54 trees avoided the attack.

Among 111 trees that avoided the attack in 2009, 103 trees (92.8 percent) were newly attacked in 2010. So, only 8 trees remained free from *Platypus* attack over 2 successive years. Thus, the probability of being attacked in 2010 was markedly lower in the trees that had survived the attack in 2009 (67.7 percent) than those not attacked in 2009 (92.8 percent).

Spatial Relationships Between Two Categories of Trees

As shown in fig. 1, the distribution of a group of trees (Category III) that had survived beetle attack in 2009 and avoided the attack of 2010 did not overlap the distribution of the trees newly attacked in 2010 (Category V, VI). On the other hand, the distribution of Category I trees that had survived the attack in 2009 and were reattacked in 2010 overlapped the trees that were newly attacked in 2010. Iwao's $m\text{-}m^*$ analysis revealed that the trees newly attacked in 2010 (Category V, VI) were spatially segregated from the trees of Category III at the quadrat sizes of 100 m² and 225 m² (fig. 2). Thus, beetles of *P. quercivorus* seem to be repelled from the trees of Category III, and are thereby segregated from the trees newly attacked in 2010.

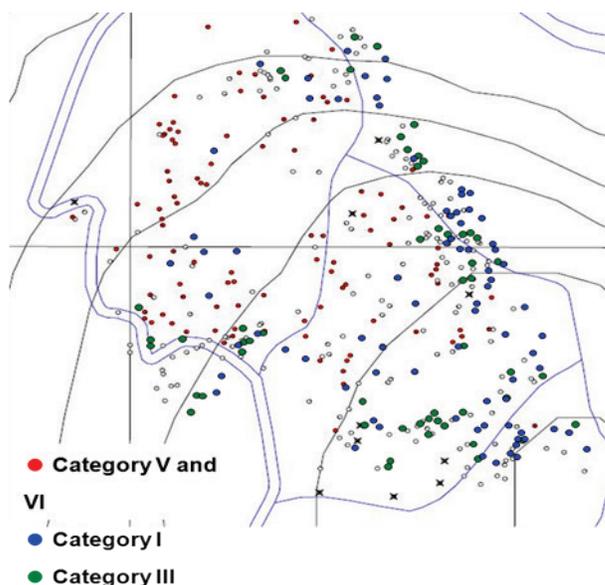


Figure 1—Distribution of the trees newly attacked in 2010 (Category V and VI) and those that had survived beetle attack in 2009 and were re-attacked (Category I) or avoided the attack (Category III) in 2010.

The Densities of Beetle Holes

As shown in fig. 3, the density of beetle holes on the surviving trees, such as those in Cat. I and III, were significantly lower than those on the stems of dead trees (Cat. II and VI). This suggests that the density of boring attack affects host survivability. More importantly, *Platypus* beetles seem to select host trees, preferring the trees of Cat. II and VI, while seeming to be repelled by the trees of Cat. I and III.

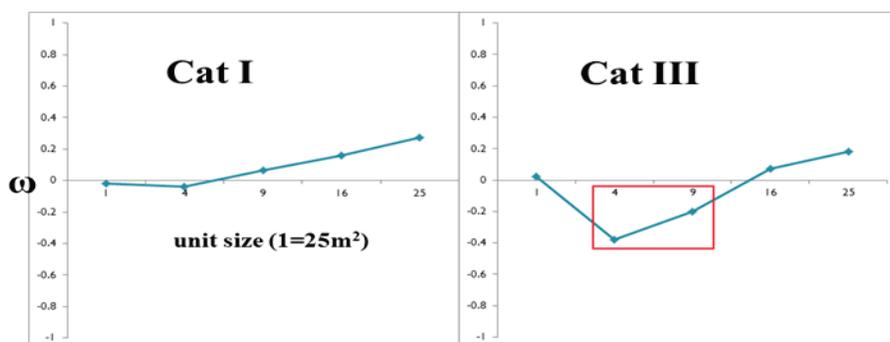


Figure 2—Spatial overlapping between the trees newly attacked in 2010 (Category V, VI) and the trees that had survived beetle attack in 2009 and were re-attacked (Category I) or avoided the attack (Category III) in 2010.

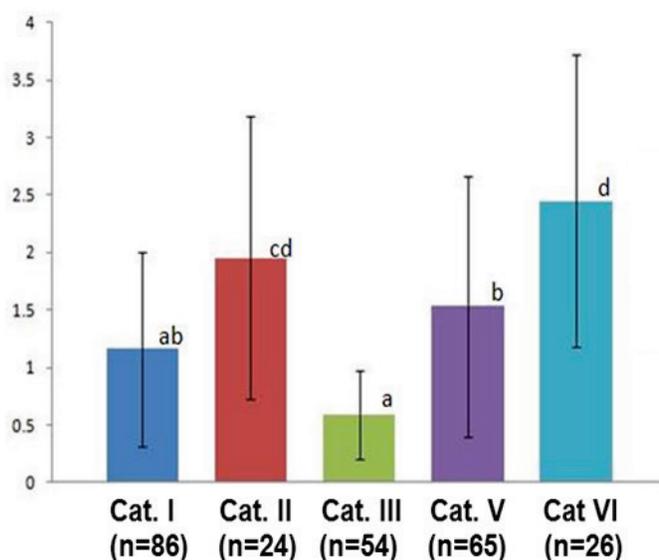


Figure 3—The density of beetle holes made on the stems of five categories of trees. For categories see table 1.

We also examined the density of beetle attack in relation to the distance from the trees of Category III, and found that the density of beetle attack was lower within a 5 m radius around the trees of Category III than that of the outer area, suggesting the lower flight frequency in the vicinity of the Category III trees. The trees that exuded sap were mainly found among the trees surviving the beetle attack in 2009, such as those in Category I and III.

From these findings we hypothesize that there are some differences in resistance against the attack of *P. quercivorus* beetle among oak trees in a stand. Resistant trees may survive the first attack of the beetle and then release some repellent from the trunk and thereby escape the following attack.

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