

MAHOGANY SHOOT BORER CONTROL IN MALAYSIA AND PROSPECTS FOR BIOCONTROL USING WEAVER ANTS

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LIM, G. T., KIRTON, L. G., SALOM, S. M., KOK, L. T., FELL, R. D. & PFEIFFER, D. G. 2008. Mahogany shoot borer control in Malaysia and prospects for biocontrol using weaver ants. In Malaysia, cultivation of trees in the family Meliaceae, which include valuable tropical timber species such as *Swietenia* spp. (mahogany) and *Khaya* spp. (African mahogany), have been severely curtailed by attacks of the mahogany shoot borer (*Hypsipyla robusta*, Lepidoptera: Pyralidae). Mahogany shoot borers pose an international dilemma. Acknowledging dwindling natural stands and the high value and demand for mahoganies, various biological, chemical and silvicultural control approaches have been undertaken worldwide since the 1920s to address the shoot borer problem. These control approaches have not been successful in reducing shoot borer damage to acceptable levels. Thus, the area under mahoganies remains low in Malaysia. Two major factors combine to make this problem very challenging: (1) *Hypsipyla* spp. biology with their cryptic habit and overlapping generations, and (2) the biology of mahogany with production of multiple leaders following loss of apical dominance after shoot damage. Tolerance to damage is effectively zero. This paper describes characteristics of mahogany and its pest that are pertinent to its management in Malaysian mahogany plantations. Previous control approaches are summarized, the characteristics of a promising biological control agent, *Oecophylla smaragdina* (Hymenoptera: Formicidae) are described, and critical research areas are identified.

Keywords: *Hypsipyla robusta*, *Khaya ivorensis*, *Oecophylla smaragdina*, weaver ant, biological control

LIM, G. T., KIRTON, L. G., SALOM, S. M., KOK, L. T., FELL, R. D. & PFEIFFER, D. G. 2008. Pengawalan ulat pengorek mahogani di Malaysia dan potensi kawalan biologi menggunakan semut. Di Malaysia, penanaman pokok daripada keluarga Meliaceae yang termasuk spesies pokok balak tropika yang bernilai tinggi seperti *Swietenia* spp. (mahogani) dan *Khaya* spp. (mahogani Afrika), dihadkan oleh serangan pengorek pucuk mahogani (*Hypsipyla robusta*, Lepidoptera: Pyralidae). Pengorek pucuk mahogani merupakan masalah antarabangsa. Memandangkan hasil balak mahogani dari hutan asli semakin merosot sedangkan permintaannya semakin meningkat, pelbagai cara kawalan biologi, kimia dan silvikultur telah diuji sejak tahun 1920-an untuk mengatasi masalah pengorek pucuk ini. Pendekatan kawalan tersebut masih belum dapat mengurangkan kerosakan ke tahap yang dapat diterima. Oleh sebab inilah kawasan yang ditanam mahogani masih kecil di Malaysia. Masalah ini amat sukar diatasi kerana dua faktor utama iaitu: (1) *Hypsipyla* spp. mempunyai peringkat hidup larva yang terlindung di dalam pucuk dan generasi yang bertindih-tindih, dan (2) pembentukan banyak cabang apabila pucuk utama mahogani rosak. Mahogani tiada langsung toleransi terhadap kerosakan. Kertas kerja ini menghuraikan ciri-ciri mahogani dan perosaknya yang penting untuk pengurusan ladang mahogani di Malaysia. Langkah-langkah kawalan yang telah diguna diringkaskan dalam kertas kerja ini. Selain itu, kami turut menerangkan ciri-ciri agen kawalan biologi iaitu *Oecophylla smaragdina* (Hymenoptera: Formicidae) yang berpotensi mengatasi masalah pengorek pucuk. Kami juga mengenal pasti beberapa bidang kajian yang penting.

INTRODUCTION

In Malaysia, cultivation of trees in the family Meliaceae, which include valuable tropical timber species such as *Swietenia* spp. (mahogany) and, to a lesser extent, *Khaya* spp. (African mahogany) have been limited by attacks of the mahogany shoot borer (*Hypsipyla robusta*, Lepidoptera:

Pyralidae) (Lee & Lim 2003). Both *Swietenia* and *Khaya* are exotic to Malaysia, having been introduced from Cote-d'Ivoire in the late 1950s in experimental plots. *Hypsipyla robusta* however is a native pest on many trees in the family Meliaceae that readily fed on the introduced mahogany

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species. Attack rates of 100% have been reported on *Swietenia macrophylla* and 60 to 100% on more recent plantings of *Khaya ivorensis* (G. T. Lim, personal observation).

The good growth performance of *K. ivorensis* and apparent absence (or no mention) of shoot borer problems in earlier plantings led to its selection by the Malaysian Timber Industry Board (MTIB) as one of the eight species targeted for large-scale planting in Malaysia in 1992 (Abdul Rasip *et al.* 2004). However, more than 10 years later, the area under *Khaya* was still less than 200 ha in Peninsular Malaysia (Krishnapillay & Ong 2003) and 350 ha in Sabah (Sabah Forest Department 2006). Three reasons for the lukewarm response to planting *Khaya* were the lack of incentives for planters (companies and individuals), the long gestation period for returns on investment compared with oil palm, and the emergence of *H. robusta* as a serious pest in subsequent trial plots. Nevertheless, *K. ivorensis* remains on the list of tree species selected for a new government-spearheaded initiative to establish at least 375 000 ha of plantations by 2020 (Lunjun 2005).

This mahogany shoot borer dilemma is also faced by many countries throughout the world. *Hypsipyla robusta* in the Asia Pacific region and *Hypsipyla grandella* in the Americas are the two most important shoot borer species preventing the cultivation of Meliaceae around the world (Horak 2001). Anticipating the need to cultivate mahogany due to dwindling natural stands and the high value and demand for mahoganies, various biological, chemical and silvicultural control approaches have been undertaken by the international scientific community since the 1920s to address the shoot borer problem (Wylie 2001). However, these control approaches have not been successful in reducing shoot borer damage to acceptable levels. Only in Sri Lanka has some success been achieved in growing pest-free mahogany in line plantings (R. Wylie, personal communication). Fijian mahogany plantations also remain free of the shoot borer due to a vigilant surveillance and interception programme (S. Lal, personal communication).

Two major factors combine to make the *Hypsipyla* problem very challenging, namely, (1) *Hypsipyla* spp. biology with their cryptic habit and overlapping generations (Grijpma 1976, Griffiths 2001), and (2) the biology of mahogany with production of multiple leaders

following loss of apical dominance after shoot damage. Tolerance to damage is very low, i.e. effectively zero (Wylie 2001). Building on a review by Newton *et al.* (1993) 15 years ago, this paper considers characteristics of tree species in the mahogany subfamily (Swietenioideae) and its pest that are pertinent to its management in Malaysian mahogany plantations. Previous control approaches are summarized, drawing from the Malaysian experience, and the characteristics of a promising biological control agent, *Oecophylla smaragdina* (Hymenoptera: Formicidae) are described. Critical research areas are identified and current research on mahogany shoot borer control is outlined.

CHARACTERISTICS OF MAHOGANY

The name mahogany refers to timber of the genus *Swietenia* (true mahogany) (Nzokou & Harris 2002), but related species with similar properties include the genera *Khaya* (African mahogany), *Cedrela* (cedar), *Lovoa*, *Toona*, *Entandrophragma* and *Chukrasia* (Newton *et al.* 1993). These trees belong to the family Swietenioideae in the family Meliaceae, and all are attacked by mahogany shoot borers (Newton *et al.* 1993). These trees are distributed throughout the tropics and exhibit a high degree of morphological variability within species because interfertile closely related members give rise to hybrids (Pennington & Styles 1975).

Diameters of up to 2 m and heights exceeding 40 m can be achieved for mahoganies grown in good conditions (Pennington & Styles 1975). For *K. ivorensis*, an exotic species in Malaysia, a mean diameter at breast height (dbh) of 30 cm and mean height of 30 m is expected in a 20–25 year rotation (Ahmad Zuhaidi *et al.* 2003).

Silvicultural characteristics vary among species, e.g. *S. macrophylla* is relatively shade tolerant (Lamb 1966) while *K. ivorensis* is a light-demanding, self-pruning species (Ahmad Zuhaidi *et al.* 2006). Trees of most genera are deciduous and flush annually, with intra-specific variation in flushing, fruiting and leaf abscission times (Newton *et al.* 1993).

The loss of apical dominance results in production of multiple leaders. If this occurs when the tree is young, before a clear (unbranched) height of at least 6 m is attained, its economic value is greatly diminished (Wylie 2001). Protection is needed for 3–5 years for trees to achieve this merchantable bole length (Wylie

2001). Spontaneous branching has also been reported on *K. ivorensis* trees that are grown in the open (Ahmad Zuhaidi *et al.* 2006).

CHARACTERISTICS OF THE MAHOGANY SHOOT BORER

The mahogany shoot borer refers to *Hypsipyla* spp., of which the most important are *H. grandella* occurring in the Americas and *H. robusta* in areas of Africa and the Asia/Pacific region. The taxonomic status of *Hypsipyla* spp. has recently been resolved (Horak 2001) and *H. robusta* is the species found in Malaysia (M. Horak, personal communication). These shoot borers are generally limited to feeding on meliaceous plants of the subfamily Swietenioideae and it is thought to be due to specific adaptation to unique limonoid compounds in trees of that group (Griffiths 2001). Larvae bore into tree shoots and occasionally feed on bark, flowers and fruit. The shoot borers have a one to three months life cycle, but can take up to five months if the larvae enter diapause.

Females need to mate only once, after which 200–450 eggs are laid over a period of five to eight nights. These eggs are laid singly or in clusters of up to four on the upper leaf surface, particularly around growing shoots and one to three eggs are laid per tree. Adults are strong fliers. Females can locate distant host trees and adult males can locate distant females and copulate with several females. Three potential semiochemicals have been identified from *H. grandella* ovipositor tips. Of these, Z9, E12-tetradecadienyl acetate, is common to both *H. grandella* and *H. robusta* (Bellas, 2001). The adults appear to be attracted to young trees that are flushing (Howard 1991, Yamazaki *et al.* 1992) and to damaged trees and frass (Griffiths 2001). Variation in frequency of *Hypsipyla* damage to *Toona ciliata* is correlated with variation in leaf chemistry, suggesting that *Hypsipyla* responds to intra-specific variation in plant chemistry (Cunningham & Floyd 2004). In addition, *Hypsipyla* spp. have a preferred range of host species. *Khaya ivorensis* at 4.5 months after planting was free from *H. robusta* attack in the presence of *Swietenia* spp. indicating the moth prefers the latter (Khoo 2001). The order of preference (expressed as damage frequency) was similar across trials in four Asia-Pacific countries with *Khaya* and *Cedrela* less frequently attacked than *Swietenia*, and all three of these exotic species were less damaged than *T. ciliata*,

which was endemic across the region of the study (Cunningham *et al.* 2005). This result and the pattern of damage to *Chukrasia* grown in trials in and outside its native range support the hypothesis that *Hypsipyla* prefers endemic hosts. The moths are able to disperse but tend to remain in the area, infesting new shoots produced by the trees previously attacked (Griffiths 2001).

Mortality of first instar due to predation and abiotic factors is high because they move around the plant to feed on several locations (Griffiths 2001). Mortality in the remaining 4–5 instars is much lower after the larvae tunnel into the shoot blocking the entrance hole with frass and webbing (Ramirez Sanchez 1964). Pupation takes place within the tunnel or in litter at the base of the tree (Griffiths 1997). There may be 10–12 overlapping generations per year and attack is continuous in regions where the moth does not undergo diapause (Gu & Liu 1984).

MAHOGANY SHOOT BORER MANAGEMENT

Silvicultural techniques, chemicals, host plant resistance and biological control are the main control approaches previously examined for *Hypsipyla* spp.

Silvicultural techniques

The numerous silvicultural control techniques attempted for mahogany shoot borers have met with limited success in Malaysia and around the world. Examples given of successful silvicultural control are frequently conflicting and largely anecdotal, and few reliable recommendations have been given due to lack of experimental evidence. In general, silvicultural interventions aim to interfere with location of the host plant, reduce host suitability, encourage natural enemies and assist recovery of the trees after attack (Hauxwell *et al.* 2001a). These measures include planting vigorous seedlings at good sites together with insect repellent species or other plant species that could interfere with the ability of the shoot borer to locate the host plant. These planting approaches could be followed by post-planting activities that promote vigorous growth, e.g. weeding and pruning to assist recovery of form after attack.

Selecting for vigour in mahoganies is likely to provide further challenges because of the

association between plant vigour and frequency of *Hypsipyla* damage. Surveys of *Hypsipyla* damage in extensive field trials of *T. ciliata* found a strong correlation between tree height and damage frequency, up to about 3.5 m (Cunningham & Floyd 2006). Although this damage did not prevent those trees from maintaining their status as the tallest trees in the trial, repeated damage did lead to poor form and multiple leaders.

In Malaysia, 5 ha of *K. ivorensis* planted between existing rubber trees in an area surrounded by a buffer of rubber and oil palm remained free of shoot borer attack for four years. The excellent growth performance and absence of shoot borer attack prompted the planting of an additional 16 ha of *K. ivorensis* as a pure stand. About one year after planting, *H. robusta* was detected in the plantation, infesting 60% of the young trees. Trees in the initial planting were also found to be heavily infested with the shoot borer (G. T. Lim, personal observation). Eradication of the shoot borer in the year-old plantings may have failed because the initial plantings were a reservoir for reinfestation of the year-old planting. Line planting *K. ivorensis* in an oil palm plantation has not prevented shoot borer attack either. The lines of trees appear to form incidental corridors for spread of the pest. Planting *K. ivorensis* with *S. macrophylla* as a trap crop is worth exploring. In a year-old 1 ha *K. ivorensis* planting interspersed with only a few *S. macrophylla* trees, attack rates were 60 and 100% respectively. This indicates the strong preference of the moth for *S. macrophylla*. The strong host-finding ability of the moth and its apparent preference for *S. macrophylla* could be exploited by providing sufficient *S. macrophylla* trees to secure egg masses of the pest and by regular rotational spraying of an ovicide on those trees.

Chemical control

Chemical control is generally regarded as not viable from an economic and environmental standpoint (Wylie 2001). Repeated and frequent applications are needed to prevent attack, e.g. once a week for *H. grandella* on *S. humilis* in Honduras (Goulet *et al.* 2005) and once a month for *H. robusta* on *K. ivorensis* in Malaysia (Ahmad Zuhaidi *et al.* 2006). In the examples above, control of *H. grandella* was achieved

with a sprayed contact insecticide to target ovipositing females while a systemic granular insecticide controlled tunnelling larvae in *H. robusta* up to the second year after out-planting. As generations of the pest overlap and the shoot borers are active year-round, continuous protection is needed to prevent any attack (Wylie 2001). Even the more promising controlled-release systemic insecticides cannot kill the larvae quickly enough to prevent shoot damage. Thus, chemical insecticides are anticipated to have limited use in nurseries or as part of an integrated pest management programme (Wylie 2001). The use of semiochemicals, specifically synthetic sex pheromones of *H. robusta* did not attract any males (Nakamuta *et al.* 2002). It was assumed that the three compounds isolated from the ovipositor tip of *H. robusta*, were sex pheromones, which may or may not be true. Additionally, the synthetic pheromone blend may not have been sufficiently similar to the composition of sex pheromones for the moth. The effect of different pheromone blends on *H. robusta* is currently an area of active research in Australia (R. Wylie, personal communication).

Host plant resistance

Host plant resistance as part of an integrated pest management programme has also been discussed with the recent completion of an international research programme on that subject (Watt *et al.* 2001, Cunningham & Floyd 2003). The programme reported that *H. robusta* preferred to lay eggs on leaves of open-planted *T. ciliata* and suggested that managing the light environment (by overstorey or gap-planting) could make the trees constitutively less susceptible to attack. Results of Mahroof *et al.* (2002) also support this finding. Genotypic variation in susceptibility to attack was evident between and within provenances of all species assessed. In spite of identifying species and provenances that are less attacked, the infestation rate exceeded acceptable levels in all cases and the conclusion was that selection could be used to produce better trees than present provenances (Cunningham & Floyd 2003). Provenances that tolerate attack via strong apical dominance and production of a single main stem following attack could also be evaluated (Watt *et al.* 2001).

Biological control

Biological control prospects using natural enemies of the shoot borers in classical or conservation biological control are considered poor despite the long list of natural enemies recorded for *Hypsipyla* spp. (Sands & Murphy 2001). That review suggested that the efficacy of parasitoids and predators could be enhanced by freeing them of their native natural enemies, but inundative parasitoid releases were not economically viable. Since there are beneficial moths in the same subfamily (Phycitinae) as *Hypsipyla* spp., e.g. *Cactoblastis cactorum* which is an important biological control agent of weed cacti, host specificity studies in screening is recommended for parasitoid biological agent candidates (Sands & Murphy 2001). The conservation of indigenous ant species, e.g. *O. smaragdina* was considered a possible approach to reduce shoot borer attack (Khoo 2001, Sands & Murphy 2001). *Oecophylla smaragdina* was also observed to be an opportunistic predator suppressing an outbreak of a geometrid defoliator in an Australian hoop pine plantation (Wylie 1974). The success of entomopathogens for controlling *Hypsipyla* spp. has been limited by the cryptic nature of the larvae, their low density and the low damage threshold of mahogany (Hauxwell *et al.* 2001b). This was in spite of substantial mortality inflicted by pathogens in the field and laboratory, some of which are commercially available products such as *Bacillus thuringiensis*. More pathogens of *Hypsipyla* spp. should be identified for screening of potential biological control agents.

WEAVER ANTS

The use of *O. smaragdina* has been proposed for control of *H. robusta* by various authors (Khoo 2001, Sands & Murphy 2001, Lim & Kirton 2003) and a study found that *K. ivorensis* trees from which the ant was excluded had substantially greater shoot borer infestation rates than ant-occupied trees (G. T. Lim & L. G. Kirton, personal observation). Application of the weaver ant as a biological control agent of the mahogany shoot borer is currently an area of active research in Australia (Christian & Peng 2007, M. Griffiths, personal communication) and Malaysia. *Oecophylla smaragdina* has been

successfully used as a biological control agent of insect pests in a number of fruit and cash crop species such as cashew and mango in Australia (Peng & Christian 2005, 2006, Peng *et al.* 1997a, 1999), citrus in Vietnam (van Mele & Cuc 2000) and cocoa in Malaysia (Way & Khoo 1991). Research is also active in using the ant on mango in Thailand and Vietnam (ACIAR 2005). Additionally, *O. longinoda* has recently been used to control mango fruit fly in Africa (van Mele *et al.* 2007).

Weaver ants are found in Africa (*O. longinoda*) (Ledoux 1950) and in South-East Asia, Australia and western Pacific islands (*O. smaragdina*) (Dodd 1902, Dutt 1912, Chen 1962, Stapley 1980, van Mele & Cuc 2000). The two species are very similar in their biology and other characteristics and the following discussion refers to them collectively unless otherwise specified. The weaver ant is effective as a biological control agent of many defoliating insect pests because it is a vigilant and territorial predator of living creatures in its arboreal domain (Hölldobler & Wilson 1990). Its ability to modify its environment to suit its needs by constructing nests from the living foliage of numerous host plant species allows it to exploit a wide range of habitats (Hölldobler 1983). Larger nests contain brood and reproductives while smaller nests without reproductives are called 'pavilions' (Blüthgen & Fiedler 2002). Final instars produce the silk that binds the colony's nests together (Way 1954, Vanderplank 1960). Trophobionts such as mealybugs and scale insects are tended by workers for the honeydew that comprises a substantial portion of the ants' diet (Blüthgen & Fiedler 2002). The ants also forage for plant nectar on a diverse number of plant species (Blüthgen *et al.* 2004).

Although *K. ivorensis* itself is a host plant of *O. smaragdina* in Malaysia (Khoo 2001), regular nest abandonment has been observed. This abandonment results in periods where trees are left unoccupied (G. T. Lim, personal observation) and likely results from ants relocating to younger foliage on other trees as the foliage of their current nest ages (Blüthgen & Fiedler 2002). Since mahogany has an extremely low damage threshold for shoot borer attack (Taveras *et al.* 2004), perpetual ant presence at fairly high levels is probably needed to provide satisfactory protection. Minimum ant density on the tree has

yet to be estimated for protecting *K. ivorensis*. It is a crucial prerequisite for economic analyses and subsequent cost comparison with other control methods.

Weaver ants can be used to protect plant species that host or provide food resources (trophobiont honeydew and/or plant nectar) to the ant by conserving and augmenting existing colonies, or harvesting and redistributing colonies to the trees that require protection. These relocated colonies also need to be conserved and augmented. Practices that aid conservation of the ant include limiting pesticide applications, using pesticides that are less harmful to the ant (van Mele *et al.* 2002), and supplementing the ants' diet with dried fish during the food-scarce dry season (van Mele & Cuc 2003). The direct provision of food has also been observed to augment weaver ant populations in a Malaysian mahogany plantation (S. H. Lim, personal communication). However, types of food preferred by the ant, and other aspects of food supplementation such as timing and duration have yet to be fully investigated. Provision of mealworm larvae (*Tenebrio molitor*; Coleoptera: Tenebrionidae) and a liquid 'weaver ant formula' (15 g cane sugar, 1 g EnerPro™ protein powder by Nutralife (NZ Ltd.)) dissolved in 100 g water (based on Blüthgen *et al.* 2004) to weaver ant colonies relocated to a *K. ivorensis* plantation in Malaysia was found to improve the establishment of those colonies (Lim 2007). Additionally, the short- and long-term effects of food supplementation on colonies of the ant on mahogany are not known and ants may be conditioned to supplemented food (van Mele & Cuc 2003). To further advance the use of weaver ants in *K. ivorensis* forestry, farmer-friendly guidelines are needed and these must detail the types of food to be supplemented, the timing and duration of supplementation and anticipated effects of supplementation on ant colonies.

Indirect provision of food has been suggested via mixed-planting of alternate host plant species that favour the ant together with the main crop (Way & Khoo 1991, Peng *et al.* 1997b, van Mele & van Lenteren 2002). The preference of the ant for certain host plant species is due to availability of nectar from active plant nectaries and/or honeydew from trophobionts supported by the plant, and suitable foliage for nest-building (Way & Khoo 1991, Blüthgen & Fiedler 2002). A few

host plant species are thought to be preferred by the ant, e.g. mango, guava (Way & Khoo 1991), citrus, clove and cashew trees (Way 1954). In Malaysia, *O. smaragdina* has been reported nesting on several fruit trees (Miller 1931, Corbett 1937, Fiedler & Maschwitz 1989), cash crops, e.g. coffee, cocoa and coconut (Miller 1931, Way & Khoo 1991, Way & Bolton 1997), mangroves (Macnae 1968) and forest plants (Fiedler & Maschwitz 1989, Saarinen 2006). The ant demonstrated an innate attraction to some host plant species over others in a laboratory study (Djipto-Lordon & Dejean 1999). A survey of diverse Malaysian habitats indicated that *Morinda citrifolia* (Rubiaceae, common names: noni, mengkudu) and *Talipariti tiliaceum* (Malvaceae, common names: sea hibiscus, bebaru) are among the host plant species preferred by *O. smaragdina* (Lim 2007). However, the ant can probably utilize any plant as long as the leaves can be incorporated into woven nests (G. T. Lim, personal observation). Studies to determine the effects of mix-planting *M. citrifolia* with *K. ivorensis* on weaver ant populations is on-going. No other studies have qualified or quantified ant preference for various host plant species and research is needed in this area. The selection of an alternate host plant species candidate for mixed-planting should draw from a larger list of host plant species than what is presently available. Screening for candidate host plant species to interplant with mahogany should include a pest risk assessment for the trophobiont species. Information on trophobiont species associated with the ant and host plants is very limited for both *Oecophylla* spp. The presence of *O. smaragdina*-tended trophobionts on cocoa is not considered detrimental to the crop (Way & Khoo 1991). Seven new weaver ant trophobiont-host plant associations were found in Malaysia (Lim 2007) and in all instances the trophobiont-occupied host plants appeared healthy (G. T. Lim, personal observation).

Finally, in order to conduct repeated assessments of treatment effects on ant colonies in the field, a non-destructive method of estimating ant population levels is needed. The model should provide a more direct reflection of ant population levels than other indirect estimation methods, e.g. nest counts (Offenberg *et al.* 2004), ant counts on plant parts (Blüthgen & Fiedler 2002), and counts of ant trails on tree

stems or branches (Peng & Christian 2005). A simple model developed to estimate the number of ants within weaver ant nests on *K. ivorensis* in Malaysia is currently being tested for predictive ability for other host plant species of *O. smaragdina* in Malaysia.

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