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A SURVEY ON THE OCCURRENCE OF PESTS AND DISEASES IN TONGKAT ALI (*EURYCOMA LONGIFOLIA*) PLANTATIONS IN PENINSULAR MALAYSIA

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The root of *Eurycoma longifolia* is widely used as a raw ingredient in traditional medicine and human health supplement. Commercial interest has led to intensified planting of *E. longifolia* in Malaysia, which inevitably invites infestation problems from pests and diseases. During a nation-wide survey in Peninsular Malaysia between 2012 and 2013, conducted on 28 plantations of three different planting regimes, several pests and diseases were identified and new ones recorded. A total of five pests (tiger moth larvae, scale insect, *Zeuzera* stem borer, termite and spider mite) and four diseases (sooty mold leaf disease, algal leaf spot disease, Sudden Death Syndrome and *Colletotrichum* leaf disease) were identified. Infestation by the tiger moth (*Atteva sciodoxa*) is a new record found in all survey sites. The moth's attack on monoculture *E. longifolia* plantation was the most destructive as reflected from the severity level (58.3%) measured as Damage Severity Index (DSI), in comparison to polyculture (33.3%) and in existing natural forest growth (32.7%). Since the last survey in 2011, a number of new pests and diseases have emerged, causing further damage and increase in pest and disease management cost. The study concluded that *A. sciodoxa* is the most severe pest of *E. longifolia* and planting the tree with other tree species in polyculture is an advantageous approach to curb the infestation.

Keywords: *Atteva sciodoxa,* Damage Severity Index, medicinal plant, monoculture, polyculture, tiger moth larvae

INTRODUCTION

Eurycoma longifolia (Simaroubacae), locally known as tongkat ali or Pasak Bumi in Malaysia, is endemic to the Southeast Asian region and is famous for its reputation of being effective against several diseases and its aphrodisiac property (Asiah et al. 2007, Bhat & Karim 2010). This shrub can grow up to 12 meters in height in the wild, often unbranched with reddish brown petioles (Zanoli et al. 2009). In the wild, *E. longifolia* is a common understorey shrub or tree, growing in beach forests up to lower montane forests (Kochummen 1983). The propagation means for *E. longifolia* is through its seeds. However, not all populations could produce high concentrations of the compound eurycomanone in its root extract, which is an essential medicinal constituent specific to this plant (Zaki et al. 2014). Although *E. longifolia* is not threatened in the wild and natural populations are widely distributed in Peninsular Malaysia, it may not last as the harvesting process is destructive, mainly targeting its taproot. In order to avoid species loss, the Malaysian government has restricted *E. longifolia* harvesting from natural forest, and has been promoting large-scale cultivation to meet the demand. Large scale planting of *E. longifolia* in Malaysia first began in 2000 when demand for the raw material, especially from companies producing health products, escalated dramatically. Medicinal plant demand by traditional medicine industries in Peninsular Malaysia is estimated at about half a million kilogram per year, where approximately 54,000 kg is for *E. longifolia* (Mohd-Azmi et al. 2004). The Malaysian Ministry of Health has projected the yearly increment in demand as 15%, and the value increasing from RM 7 billion in 2010 to RM 29 billion in 2020, with *E. longifolia* being the most sought after herb (Anonymous 2012).

The study on suitable plantation regime for *E. longifolia* was initiated by local research institutions such as the Forest Research Institute of Malaysia (FRIM), the Malaysian Agriculture Research Department (MARDI) and the Malaysian Palm Oil Board (MPOB) (Mohd-Noh & Mohd-Ilham 2000, Mohd-Noh et al. 2004). The tree's growth performance is best on different beach ridges interspersed with swales (BRIS) soil series, where it could reach an average height of 0.72 to 0.96 m at three years old (Rasidah et al. 2010, Iskandar et al. 2014). Using agro-forestry approaches, this species is often planted in between crops such as coconut, cocoa and banana, in between timber species like teak (*Tectona grandis*), or planted as a single crop in open planting system (Abdul-Rasip & Ong 2000, Mohd-Noh & Mohd-Ilham 2000, Mohd-Ilham et al. 2000, Shaharuddin et al. 2004). These models have been applied by other government agencies in Malaysia like the Federal Land Development Authority (FELDA), South Kelantan Development Authority (KESEDAR), Middle Terengganu Development Authority (KETENGAH) and various State Forestry Departments.

Unfortunately, establishment of *E. longifolia* plantations did not proceed as planned due to the emergence of pests and diseases (Table 1). In the year 2000, outbreaks of tiger moth larvae, scale insects and *Zeuzera* stem borers in *E. longifolia* plantations appeared throughout the country (Mohd-Noh 2000). Several years later, the number of known pests and diseases occurrence increased and new ones like the Sudden Death Syndrome, shoot dieback and a virus disease were recorded (Patahayah et al. 2011). Of these problems, tiger moth infestation is the major threat to *E. longifolia* as this pest attacks the plant regardless of age, vigor, locality and height (Mohd-Farid et al. 2014). *Atteva sciodoxa* is a pantropical insect, widely distributed in the Southeast Asia region especially in countries like Brunei, Indonesia, Malaysia and Thailand. In Malaysia, this pest can be found on wild *E. longifolia* trees in lowland and montane forests (Robinson et al. 1994). The rapid increase in *E. longifolia* planted area has led to the widespread and frequent tiger moth outbreaks throughout the country (Musa et al. 2005, Abood et al. 2009).

At present, the larvae are known to feed only on *E. longifolia,* as no alternative hosts have been found. In plantations, the moth's larvae are considered robust pests as they can withstand high daytime temperatures throughout the year and have very few natural predators (Mohd-Farid et al. 2014). Occurrence of the larvae is often abundant after the flushing of new shoots. They mainly attack young tender leaves, where they feed upon voraciously, leaving only the petioles after a few days. When infestation is severe, older leaves are also fed upon. Tiger moth infestation and damage in *E. longifolia* plantations can vary from mild to serious (Patahayah et al. 2011). Damage is often more obvious on young plants compared to mature plants. In 1998, infestation

Table 1 Chronology of *Atteva sciodoxa* findings and outbreaks in Peninsular Malaysia

Year	Event	Reference
1994	First identified *Atteva sciodoxa* in wild Malaysian forest	Robinson et al. 1994
1998+	First report outbreak of *A. sciodoxa* in *E. longifolia* plantation throughout Peninsular Malaysia.	Mohd Noh 2000
2002–2004+	*Atteva sciodoxa* infestation getting severe and reported to cause death to new sapling transferred to field. Heavy defoliation and stunting on older trees.	Mohd Noh et al. 2004
2010++	Most of affected *Eurycoma longifolia* plantations were abandoned. Infestation of *Atteva sciodoxa* still occurred in plantation with emergence of other P&D.	Patahayah et al. 2011
2012–2013++	Survey on *Atteva sciodoxa* infestation at different cultivation regimes including mono- and poly- culture, and forest-planted areas were conducted.	Present study

++ survey was conducted by FRIM, + survey was conducted by MARDI of this pest on newly transferred *E. longifolia* in Sungkai, Perak, had caused death to over 80% of the saplings. In contrast, a plantation in Kluang, Johor, which had older trees (3-year-old), was able to bring the damages under control (Mohd-Noh et al. 2004). A survey was conducted on cultivated *E. longifolia* in natural forests and small-scale plantations throughout Peninsular Malaysia. Here, the study reports the status of pests and diseases in these plantations, while taking into consideration the various planting regimes and their impact on the occurrence and severity of tiger moth infestation.

MATERIALS AND METHODS

Survey on pests and diseases of *Eurycoma longifolia*

Surveys on pests and diseases of *E. longifolia* were conducted from December 2012 to April 2013 in a total of 13 natural forests and 15 small-scale plantations throughout Peninsular Malaysia (Figure 1). In natural forest, *E. longifolia* trees were inter-planted amongst various species of indigenous trees in the stand. In plantations, the tree was cultivated as monoculture or polyculture by integrating with another tree/herb species for the latter. These study sites belong to government agencies, private sectors and individual farmers. Proper permissions were granted by the authorised agencies namely the Forestry Department of Peninsular Malaysia (FDPM), FRIM, KESEDAR, FELDA, KETENGAH and individual plantation owners. During the survey, notable insect pests and diseases in the fields were recorded. Symptomatic plant samples were photographed, collected and brought back to the laboratory at FRIM, Selangor, Malaysia, for identification. Background information about the plantations such as previous disease history, fertiliser application, type of planting, plantation size and year of planting were also documented (Table 2).

Figure 1 Distribution of the *Eurycoma longifolia* plantations in Peninsular Malaysia surveyed in this study; plantation names correspond to the numbers listed in Table 2

Assessment of *Atteva sciodoxa* occurrence and severity

At each study site, 30 *E. longifolia* trees were randomly selected and observed. Those found harboring *A. sciodoxa* larvae were counted and the percentage of occurrence calculated (Asare-Bediako et al. 2014). For assessing larvae infestation severity in a specific tree, five different categories were created based on the overall percentage of leaves that got infested: 0 = not infested, 1 = 1 < 25%, 2 = 25–50%, 3 = 50–5%, and 4 = > 75%. By applying the number of plants in each category in the formula below, the Damage Severity Index (DSI) (Lim et al. 1993) for each plantation was calculated:

$$DSI(\%) = \sum_{k=0}^{4} \frac{(n_0 x\ 0) + (n_1 x\ 1) + (n_2 x\ 2) + (n_3 x\ 3) + (n_4 x\ 4)}{n_t} \times \frac{100}{C}$$

where DSI = Damage Severity Index, n_o = number of trees in severity category 0, n_1 = number of trees in severity category 1, n_4 = number of trees in severity category 4, n_t = total number of responses and C = highest severity category assessed.

Laboratory diagnoses

For root and leaf disease, a portion of the infected area together with the bordering healthy tissue was cut into 1 × 1 cm pieces. The pieces were washed with sterile distilled water and immersed in 0.5% (v/v) sodium hypochlorite (commercial Clorox bleach) solution for 2 min, followed by

Table 2 Background information of the study locations and records on *Atteva sciodoxa* larvae occurrence and infestation

Planting regime	No	State	Location	Year of planting	Size (ha)	Tree height (m)	Fertiliser	Pesticide	In use	Planting distance (m x m)	Larvae occurrence (%)	Larvae infestation severity	Damage severity index (DSI = %)
Monoculture	1	Pahang	Felda Jengka 16	2005	2.02	5–6	C	Yes	x	1.0 x 1.0	16.7	1	
	2	Pahang	Felda Sg Tekam	2005	2.0	5–6	n/a	n/a	x	1.5 x1.5	86.7	4	
	3	Kuala Lumpur	FRIM, Kepong	2005	0.5	7–8	No	No	x	1.5 x 1.5	33.3	2	
	4	Pahang	FRIM, Maran	2005	2.0	4–5	No	No	y	1.5 x 1.5	33.3	2	58.3
	5	Kelantan	Kesedar Gua Musang	2000	2.5	4–5	No	Yes	y	1.0 x1.5	50.0	2	
	6	Negeri Sembilan	Sg Menyala FR	2010	2.5	1–2	O	Yes	y	3.0 x 1.5	83.3	4	
Polyculture	7	Perlis	Bukit Bintang	2000	4.5	1–5	O	No	y	2.0 x 4.0	16.7	1	
	8	Perak	Chikus FR	2002	8	6–8	No	No	x	3.0 x 3.0	6.7	1	
	9	Pahang	Felda Jengka 23	2004	2	6–7	O	n/a	x	1.5 x 1.5	10.0	1	
	10	Perlis	FRIM, Mata Ayer	2005	1.5	3–4	No	No	y	1.5 x 1.5	20.0	1	
	11	Kelantan	Kesedar Mengkebang	2000	5	5–6	O	Yes	y	3.0 x 3.0	16.7	1	33.3
	12	Kelantan	Kesedar Renok Baru	2002	1	4–5	O	No	x	1.0 x 1.5	3.3	1	
	13	Kelantan	Pahi FR	2007–2008	1.5	4–5	No	No	x	1.5 x 3.0	33.3	2	
	14	Kelantan	Sg Sam FR	2002	2	6–7	No	No	x	n/a	16.7	2	
	15	Melaka	Taman Impian Jati Dan Herba	1998	n/a	7–9	O	No	x	n/a	80.0	2	

Continued

Table 2 (Continued)

Planting regime	No	State	Location	Year of planting	Size (ha)	Tree height (m)	Fertiliser	Pesticide	In use	Planting distance (m x m)	Larvae occurrence (%)	Larvae infestation severity	Damage severity index (DSI = %)
Forest	16	Kedah	Bukit Perak FR	2005	0.5	7–8	No	No	x	1.5 x 1.0	16.7	1	
	17	Perak	Bubu FR	2010	1.5	< 1	No	No	x	1.5 x 3.0	13.3	1	
	18	Perlis	Bukit Bintang FR	1998	1	3–4	No	No	x	1.0 x 1.0	10.0	1	
	19	Kedah	Bukit Hijau RF	2004–2005	2	5–6	O	No	x	1.5 x 1.0	83.3	4	
	20	Johor	Gunung Arong FR	2007	1.5	1–2	No	No	x	4.0 x 4.0	10.0	1	32.7
	21	Negeri Sembilan	Lenggeng FR	2009	1	1–2	No	No	x	3.0 x 2.0	10.0	1	
	22	Johor	Panti FR	2006	1	1–2	No	No	y	4.0 x 4.0	10.0	1	
	23	Pahang	Paya Pasir FR	n/a	2	7–9	No	No	x	Random	3.3	1	
	24	Perak	Pengkalan Hulu FR	2010	1.5	1–2	No	No	x	1.5 x 3.0	30.0	2	
	25	Melaka	Sg Udang FR	2005	20	1–7	No	No	x	Random	3.3	1	
	26	Melaka	Sg Udang RF	2007	1	2–3	O	No	x	Random	6.7	1	
	27	Perak	Taman Herba Papan	2010	0.5	2–3	O	No	y	1.5 x 1.5	16.7	1	
	28	Terengganu	Tasik Kenyir	2002	15.8	1–10	No	Yes	y	1.0 x 1.5	13.3	1	

Fertiliser = type of fertiliser applied to the plantation in the form of organic (O), chemical (C) or no fertiliser (No), Pesticide = use of pesticide at the plantation, Condition = whether plantation was still in use (y) or abandoned (x) during the survey, Larvae infestation severity indicator on a scale of 1 (low) to 4 (high), n/a: data not available, FR = forest reserve

3 times washing in sterile distilled water. The surface sterilised tissues were then placed onto Potato Dextrose Agar (PDA) and incubated at 25 °C. When fungal colonies appeared, they were individually transferred onto fresh PDA and grown for 7 days at 25 °C. Cultures were subjected to morphological examination for species identification (Dugan 2006).

Statistical analysis

Statistical analyses were conducted using the general linear model procedure embedded in the Statistical Analysis System Studio release 3.5. The percentage of larvae occurrence and type of planting regimes (Table 2) were selected as data for statistical analysis. Both variables were subjected to a one-way analysis of variance (ANOVA) to determine significant differences in planting regime types towards percentage of larvae occurrence, using randomised complete block designs. Means were separated using Waller-Duncan's *T*-test (*k*-ratio = 100). Differences among means were considered significant at $\alpha = 0.05$ level (Waller & Duncan 1969).

RESULTS

General information on *Eurycoma longifolia* cultivation areas

In total, the study surveyed 28 fields planted with *E. longifolia* throughout Peninsular Malaysia. Of these, 13 were in natural forest areas, nine were polycultures and six were monoculture plantations. In the polyculture plantations, *E. longifolia* trees were inter-planted with other tree species such as *Acacia mangium*, *Tectona grandis*, *Cocos nucifera* and herbs such as *Cymbopogon nardus*. The cultivation areas ranged from 2 to 5 ha for monoculture, 1.5 to 12.5 ha for polyculture, and 0.5 to 2 ha for natural forest under the conservation of high value herbs efforts by the Forestry Department Penisular Malaysia (FDPM). Tree spacing varied from 1 m × 1 m to 4 m × 4 m. During the survey, many of the sites had already been abandoned. This was due to lack of knowledge on the planters side, as many of them had applied both contact and systemic chemical pesticides, such as deltametrin and carbofuran, and herbicides such as glyphosate to control pests and weeds, resulting with their plants being rejected by medicinal plant manufacturers upon food safety reasons. Some applied fertiliser and pesticide but only at the early stage of cultivation. The height of the trees was in the range of 1 to 10 m, and aged between 2 to 10 years (Table 2).

Notable pests and diseases in *Eurycoma longifolia* plantation

From the survey, five pests were recorded, namely the tiger moth larvae (*A. sciodoxa*), scale insect, *Zeuzera* stem borer, termites (*Coptotermes* sp.) and spider mites. Occurrence of the tiger moth larvae was the highest (100%), followed by the scale insect (Homoptera: Coccidae) (93%) and the *Zeuzera* stem borer (46%) (Figure 2). The tiger moth larvae were especially destructive as they aggressively consumed all young foliage (Figure 3a). The *Zeuzera* stem borer was observed in several plantations and it can be recognised by the presence of powdery white frass at the tree base (Figure 3c), dropped from the holes bored by the larvae in the tree stem (Figure 3d). Damage by this pest can be deadly and symptoms of attack are often manifested as drying up of leaves, dieback and broken stem especially near the holes. Termites and spider mites were minor pests and were observed in only two plantations. Trees attacked by termites (Figure 3e) could be easily recognised by the presence of dried up leaves and/or death of the plant due to severe damage of the root system. In contrast, downward curling of leaves and the presence of a fine thin bronze crust on the lower leaflet surface were symptoms of spider mite attack (Figure 3f).

Four diseases were recorded in this survey namely algal leaf spot, *Colletotrichum* leaf disease, sooty mold and Sudden Death Syndrome. *Colletotrichum* leaf disease and sooty mold are the second records for *E. longifolia* in Peninsular Malaysia. Algal leaf spot was common and it was observed in almost all the plantations surveyed (97%) as well as in the forest (Figure 2). The disease can be recognised by the presence of circular spots with flattered or wavy edges, which are crusty gray-green to greenish brown, sometimes becoming red-brown due to the presence of spore-producing structures (Figure 4a). Algal leaf spot is not a major threat to the plant. Sudden Death Syndrome disease (Figure 4b) was found in KESEDAR Gua Musang and Felda Jengka 16. The disease is lethal and early detection is often difficult. *Fusarium* and *Lasiodiplodia* are two fungi genera that are often

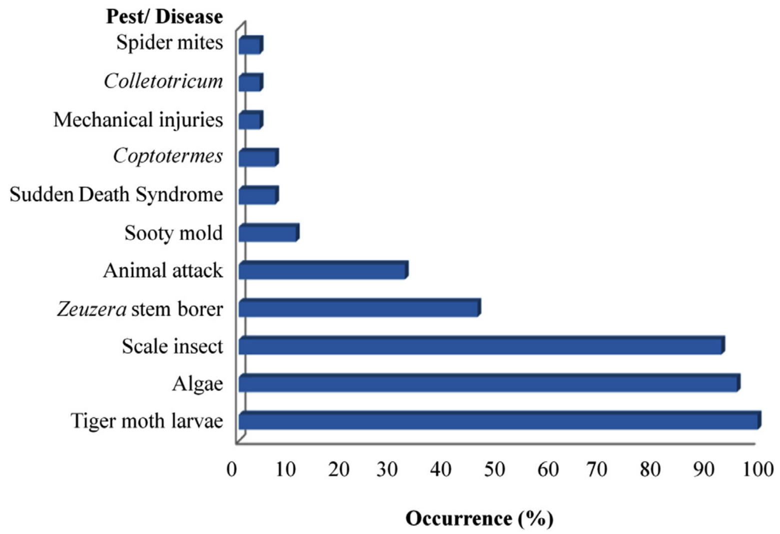

Figure 2 Occurrence of pests and diseases of *Eurycoma longifolia* plantations in PeninsularMalaysia based on percentage

associated with Sudden Death Syndrome trees, however, the causal agent is yet to be confirmed in our case. Mild sooty mold infection was also detected in several plantations especially in Bukit Bintang Forest Reserve, Taman Herba Papan and Chikus Forest Reserve. The sooty mold forms a velvety, gray-black, crust-like coating on the leaflet surface (Figure 4c). *Colletotrichum* leaf disease was found at FRIM's nursery only, where it seriously affected seedlings growing under conditions of excessive moisture and poor hygiene. Symptoms are yellow spots on the upper surface of leaflets, which later enlarged into dark necrotic lesions (Figure 4d). With time, heavy defoliation occurred in affected seedlings.

Occurrence and severity of *Atteva sciodoxa* infestation in Peninsular Malaysia

Infestation by *A. sciodoxa* larvae is the most common when compared to other insect pests (Figure 2). It occurred in all plantations surveyed, with occurrence ranging from 3.3% to 86.7% (Table 2). The mean larvae occurrence (%) is significantly higher in monoculture planting regime (Waller-Duncan *T*-test, $p \leq 0.05$) when compared to the other two, while there is no difference between forest-planted and polyculture plantation (Figure 5). For monoculture plantations, Felda Sungai Tekam (86.7%) and Sungai Menyala Forest Reserve (83.3%), recorded the highest occurrence, while three others had moderate (30–50%) and one had low occurrence (Felda Jengka 16 at 16.7%). For polyculture, the highest occurrence was recorded at Taman Impian Jati dan Herba (80%), three plantations fell under moderate occurrence (25% to 50%) and the remaining five recorded less than 20%, of which Kesedar Renok Baru had only 3.3% larvae occurrence. A majority of *E. longifolia* trees planted in the forested areas recorded low larvae occurrence. Only one area, Bukit Hijau Forest Reserve (83.3%) was reported high, followed by Pengkalan Hulu Forest Reserve (30%) as moderate, and the remaining 11 sites had less than 16.7% occurrence, of which two had only 3.3% occurrence (Paya Pasir Forest Reserve and Sungai Udang Forest Reserve). The severity of the infestation was scored based on the percentage of infested leaves on 30 trees in a plantation, from which the DSI for each planting regime was derived. The highest DSI from *A. sciodoxa* infestation was recorded for monoculture (58.3%). Polyculture and forest-planted area had similar DSI of 33% and 32.7%, respectively.

DISCUSSION

Tiger moth larvae (*Atteva sciodoxa*)

At present, there is no known records of *A. sciodoxa* attacks on other hosts other than *E. longifolia*. We confirmed *A. sciodoxa* infestation in every field we surveyed similar to reports by Mohd-Noh (2000), Patahayah et al. (2011) and Mohd-Farid et al. (2014). Generally, *A. sciodoxa* outbreaks are related to the flushing of new shoots in *E. longifolia* after the rainy season.

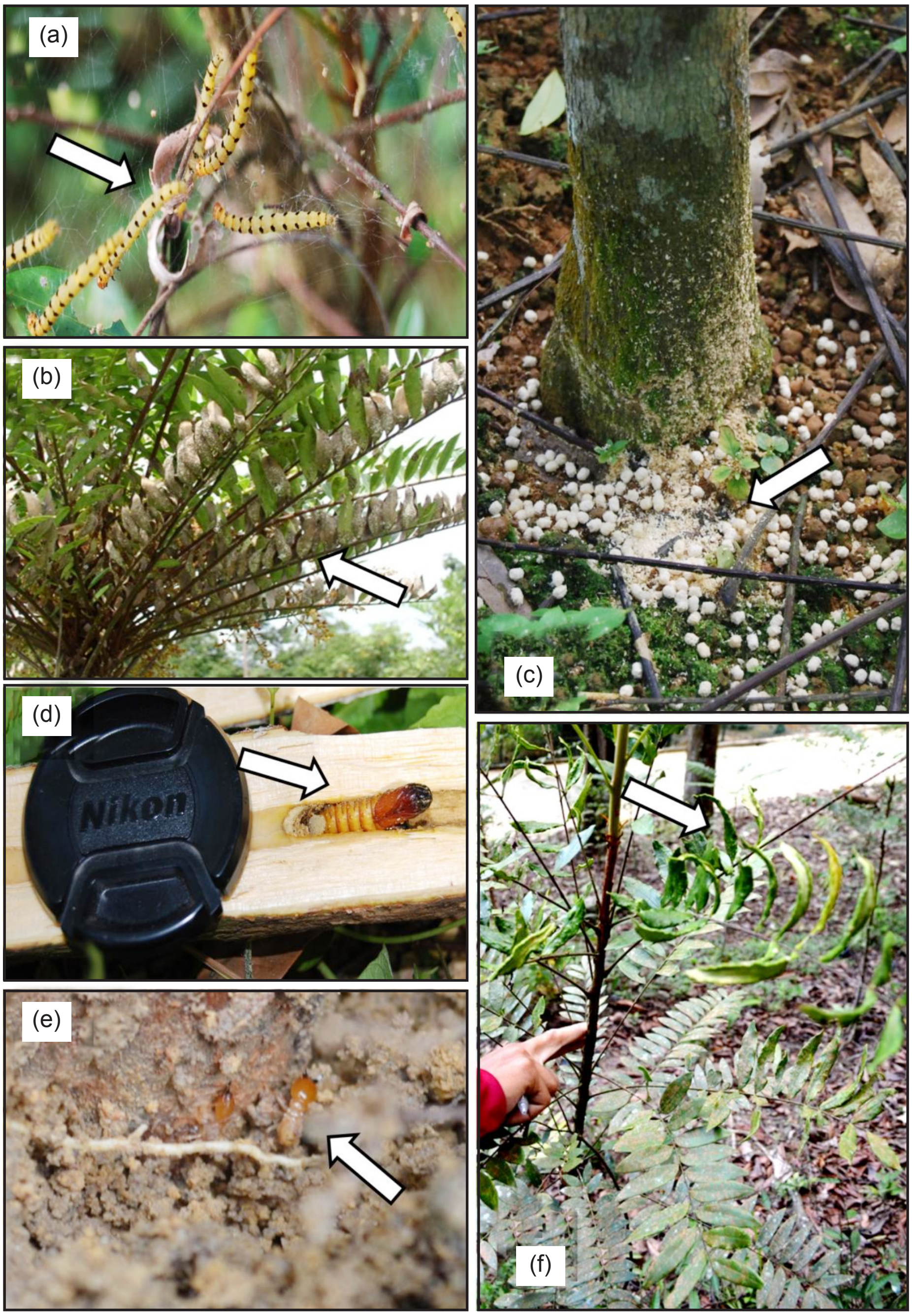

Figure 3 Insect pests of *Eurycoma longifolia* recorded during the survey. (a) *Atteva sciodoxa* larvae infesting the leaves, (b) dead leaves caused by sap sucking scale insects, (c) white frass on the ground due to *Zeuzera* stem borer, (d) *Zeuzera* pupae hiding in the stem, (e) a collar root damaged by *Coptotermes* sp. and (f) downward curling of leaflets due to spider mite infestation

However, it was also observed that the larvae are present throughout the year and can withstand hot sunlight, but gradually decrease when leaf supply is restricted, or when there is long periods of rain or drought (Mohd-Farid et al. 2014). During observation, dead trees were not found because the trees were mature and thus, could withstand the damage caused by *A. sciodoxa*. A previous study reported high mortality up to 80% in young *E. longifolia* trees (Mohd-Noh 2000). It was observed that the first instar larvae were generally confined to one or two leaflet and freshly sprouted tender leaves, while damages extended to older leaves when second instar larvae appear. A complete life cycle of *A. sciodoxa* consists of five instar larva stage, and stays alive

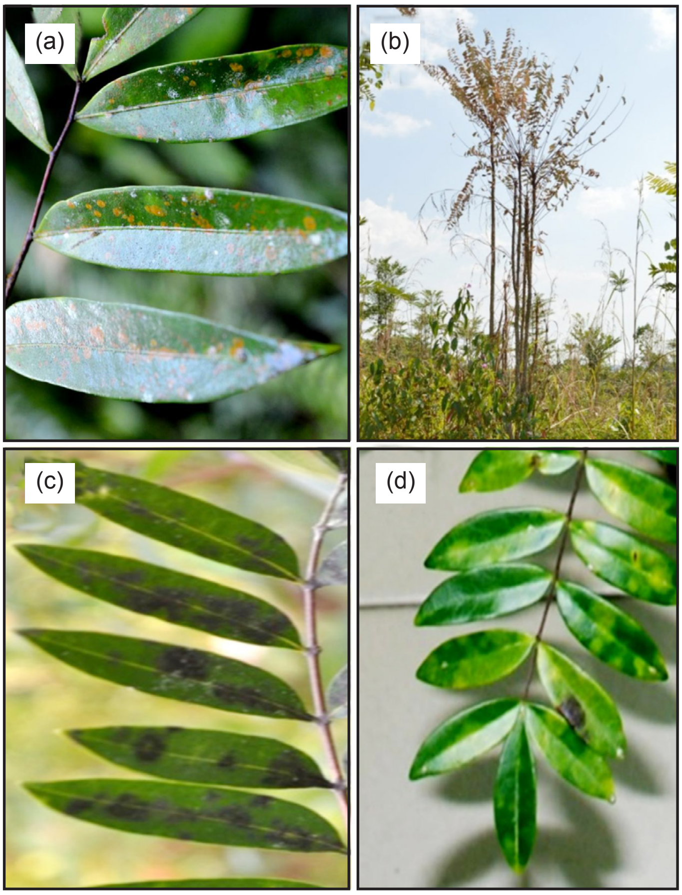

Figure 4 Diseases of *Eurycoma longifolia* recorded during the survey. (a) algal leaf spot, (b) dried up leaves and dead plants due to Sudden Death Syndrome, (c) sooty mold and (d) *Collectotrichum* leaf spot

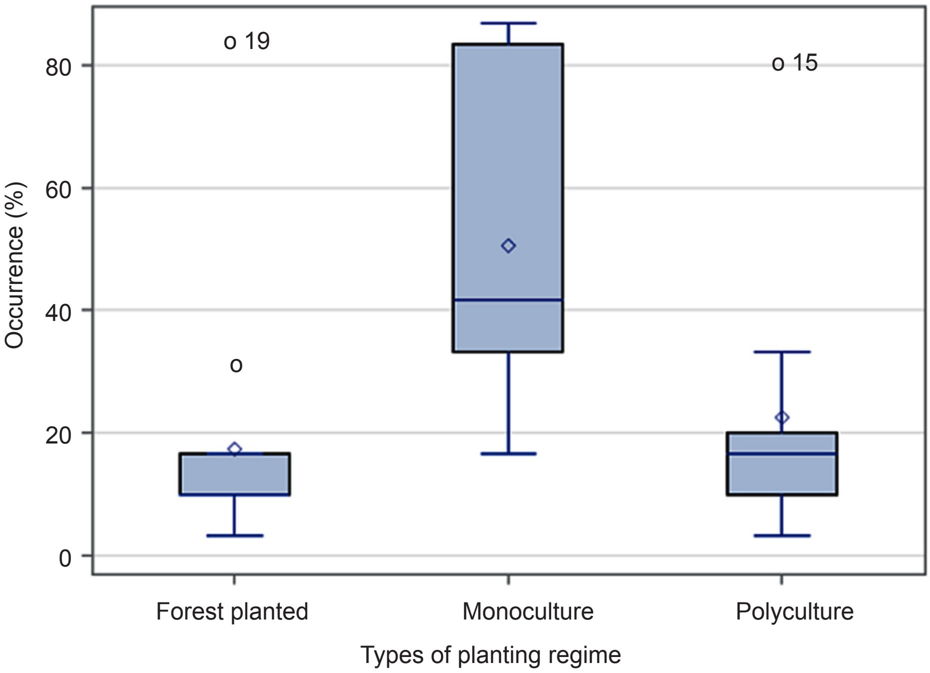

Figure 5 Distribution of *Atteva sciodoxa* larvae occurrence (%) in forest-planted, monoculture and polyculture planting regimes surveyed in the 28 different *Eurycoma longifolia* planting sites in Peninsular Malaysia, using the general linear method (GLM)

for 34 to 52 days, with an average of 20.7 days for larval, 6.2 days for pupal and 13.32 days for adult periods (Abood et al. 2010). In the field, the female moth would lay eggs on the lower leaflet surface, particularly along the midrib towards the tips of leaflets (Mohd-Farid et al. 2014). The tiger moth larvae display negative geotropic behaviour, whereby neonates would crawl upwards and congregate on freshly spouted leaves (Abood et al. 2011). Occurrence of *A. sciodoxa* in *E. longifolia* planted underneath forest trees revealed that the pest is not just a problem to plantations but also to natural forest albeit at lower levels. The only forest area with high occurrence and infestation was Bukit Hijau Forest Reserve, Kedah. The larvae were present in more than 50% of the trees surveyed and caused heavy infestation. It was predicted that the infestation had happened at an earlier stage when the trees had just been planted, but poor management in controlling the pest and later abandonment had given rise to pest breeding in the area.

From the DSI value, the monoculture plantation fell under severe infestation (> 50%), while the other planting regimes were moderately infested (33%). This could be explained by the mixture of different species in the polyculture and forest-planted areas, which reduces the risk of tree mortality or poor growth resulted by the spatially spreading agent, the tiger moth. Perhaps, tiger moth may be one of the pests that requires proximity to host trees for successful attacks, and cannot infect trees surrounded by non-host trees, which are insusceptible toward infestation (Larjavaar 2008). In general, insect herbivory is expected to reduce with increased tree diversity. In a region where there is a mixture of taxonomically distant tree species, where the proportion of non-host trees is greater than host trees, insect attack is reportedly more effectively controlled, compared to a host tree-rich region (Jactel and Brockerhoff 2007, Vehvilainen et al. 2007). Other speculation included the conservation level of natural enemies which may be higher in forest area compared to monoculture and polyculture plantations. These biological control agents could facilitate aerial pests and may disrupt the pests' temporal cycle, offering a lower attack rate in cultivated crops in forest areas (Ratnadass et al. 2012). At present, planters are often encouraged to establish mixed-species or polyculture plantations over single species (monoculture) plantations. Common successful outcomes such as increased growth rates, better quality in stem structure and reduction in risk damage by pests and diseases have been complementary toward this practice. While infestation of *A. sciodoxa* mainly occurs in young leaves, it is believed that the quality structure of stem and crown in *E. longifolia,* due to the effect from mixed-species or polyculture plantation practice, also seems to be contributing toward reducing *A. sciodoxa* infestation indirectly (West 2014).

Intercropping practice in polyculture or mixed-species plantations are known to give effect in changing the composition of neighboring plants, microclimatic conditions and host plant quality, including its morphology and chemical content (Langer et al. 2007). These factors attribute to reduction of pests in plantation caused by the increase of difficulty in locating the host plant, or introduction of greater amount of natural enemies. It is believed that the volatile compounds from the host plant play a major role in attracting the female moths' antennal and behavioural response, which is similar to the incident recorded for *Heortia vitessoides* on cultivated *Aquilaria* tree (Qiao et al. 2012). Herbivorous insects, such as *A. sciodoxa*, are known to respond upon different chemical signals emitted from the plants, thus guiding them to the host plants (Bruce et al. 2005). However, polyculture or mixed-species practice may interfere with the attractiveness of focal plants with non-host plants, resulting in olfactory masking (Koschier 2006). The diversity of olfactory stimuli emanating from polycultures might mask the olfactory cues used by monophagous herbivores like *A. sciodoxa* to locate their host plants, or otherwise confuse or repel these herbivores (Andow 1991). On the other hand, higher plant species diversity in intercropped plantations support diversity, abundance and activity of natural enemies (Haddad et al. 2001), whereby additional resources such as food and shelter, enhance abundance and effectiveness of natural enemies in the region (Mensah 1999). This could be explained from a study of maize intercropped with the non-host molasses grass, *Melinis minutiflora,* reported significant decrease in levels of infestation by stem borers *Chilo partellus* Swinhoe, from 39.2% to 4.6%, and at the same time, increased *Cotesia sesamiae* larval parasitism in 451 stem borers (Khan et al. 1997, Khan et al. 2001).

In future, for new *E. longifolia* cultivation efforts, planters should opt for planting sites within forest-planted area or adopt polyculture planting method, to avoid potential severe damage due to *A. sciodaxa* infestation. Monoculture is possible if pest control can be performed successfully using non-pesticides approaches, such as the usage of nettings, trap lights or biocontrol agents. Examples of biocontrol agents are microbes *Bacillus thuringiensis, Metarhizium anisopliae, Isaria fumosorosae* and *Beauveria bassiana,* predator *Sucanus* sp. (Heteoptera: Reduviidae) and parasitoids *Oozymus* sp. (Hymenoptera: Eylophidae), *Brachymera* sp. (Hymenoptera: Chalchidae) and *Drino* sp. (Diptera: Tachinidae) (Mohd Anuar 2003, Abood et al. 2010, Sajap et al. 2014).

Scale insect

Scale insect was the second major pest in *E. longifolia* cultivation area (93% occurrence). This pest is regularly recognised as a common pest in cultivation area with a wide host range mostly vascular plants (Miller 2005). However, the severity was low during this survey when compared to a previous report of 80% mortality in 4- to 6-month-old plants (Mohd-Noh et al. 2004). The study concluded that scale insect caused little damage to *E. longifolia* aged above 1-year-old.

Zeuzera stem borer and termites

Zeuzera stem borer was reported as a pest of *E. longifolia* for the first time in 2002 (Mohd-Noh et al. 2004). Over the years, its occurrence has increased from less than 5% in 2004 to 46% recently (Wan-Muhd-Azrul et al. 2014). *Eurycoma longifolia* is one of the favorite hosts for this pest. In this field survey, other nearby tree species were rarely attacked except for *Aquilaria* sp. Even though the infestation is still low, early management and control should be taken as it can cause damage and mortality to the tree. Termites from the genus *Coptotermes* is another pest that attacks and causes mortality to *E. longifolia* (Patahayah et al. 2011). *Coptotermes* is a termite species that is capable of killing living tree or plant (Tho 1974, Lai et al. 1983). Termite infestation in Taman Herba Papan occurred randomly and other tree species planted nearby were also affected. Infestation often happened at the root collars making it hard for early detection and control. Thus, a thorough land clearing by removing or treating infested trees, trunks or large branches, are possible approaches to overcome this problem (Thistleton et al. 2013). Termite infestation is frequently attributed to poor land preparation including incomplete clearing of timber residues (Rassmussen et al. 1982) and poor drainage system (Chew 1975).

Sooty mold leaf and algal leaf spot disease

Sooty mold leaf disease is often associated with the presence of honeydew secreted by sap sucking insects by interaction among sap-feeding insects and non-parasitic fungi (Hughes et al. 2012). Algal leaf spot is caused by parasitic *Cephaleuros* alga, which can be found on an extremely wide range of hosts extending from dicotyledonous trees and shrubs to palms (Nelson 2008). It can infest both twigs and leaves (Old et al. 2000). Both diseases do not infect the plant tissues, classified as cosmetic diseases. However, serious infection by sooty mold and alga could be a threat to the plant by blocking the photosynthesis process. Frequent rainfall and wet conditions favor disease development. Removing spotted leaves or infected area and selective pruning of surrounding plants will encourage dry leaves by improving air movement between and among plants. Controlling the phloem feeding insect using soapy water, neem oil, or horticultural oil can prevent from initiating sooty mold development.

Sudden Death Syndrome

To date, Sudden Death Syndrome is recorded as a minor disease of *E. longifolia* but it can cause mortality among young saplings. In total, three cultivation areas had this disease: KESEDAR Gua Musang, Felda Jengka 16 from the present survey and MARDI Kluang, Johor (Patahayah et al. 2011). The infection occurs at the collar root zone and blocks nutrient transportation system in the plant (Khuhro et al. 2005). Late symptom apparent and random infection make this disease hard to control. No pathogenic agent has been proved until now. Patahayah et al. (2011) discovered white sporodothia on the infected root and obtained a *Fusarium* isolate. This fungus has been reported as a Sudden Death Syndrome agent in soy plant (Westphal et al. 2006). Another agent is the fungus *Lasiodiplodia theobroma* that causes mild symptoms of Sudden Death Syndrome in mango tree. The disease becomes more virulent in combination with other fungi especially C*eratocystis fimbriata* (Al-Adawi et al. 2006). Due to lack of information on causal agent, the management of SDS incidence on *E. longifolia* is very difficult to be carried out in plantations. It is vital to conduct further investigation and correctly identify the pathogen first, prior to recommendation of control measures. This approach would help planters from applying incorrect, expensive and toxic fungicides to treat the symptomatic trees, thus reducing management cost as well as environment pollution. Mean time, planters are also advised to continuously monitor their plantations. This activity would help them to detect early stages of the disease incidence and thus avoid it from spreading to adjacent healthy trees.

CONCLUSION

Survey is an important exercise to gather information on major insect pests and diseases for a plant species or plantation area. This information can be used to construct pest management program to control the agents. The study indicated that *E. longifolia* pests and diseases developed over time, evidently from the emergence of new diseases. Among these observed attacks, it was found that the leaf defoliator, *A. sciodoxa* larvae, poised a great threat toward *E. longifolia* in Peninsular Malaysia. This was attributed to poor management to control the disease at initial stage. Pests and diseases monitoring could aid in early detection of disease outbreak and timely control of pest problems before they become severe. Proper land preparation, material selection and plantation maintenance could reduce chances of crop becoming stressed and vulnerable to attacks by pests or diseases. For a robust and aggressive insect pest like *A. sciodoxa*, a management program that is continuous is needed to keep the pest under control. Integrated pest management using biological control is considered a promising alternative in substitution of hazardous chemical pesticides, and is necessary to ensure healthy growth of this plant at plantation level, as severity of infestation may worsen if left unattended.

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