Biology and dynamics *Hypsipyla robusta* (Moore) (Lepidoptera: Pyralidae)

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Abstract. *Hypsipyla* shoot borer (*Hypsipyla robusta* (Moore)) (Lepidoptera: Pyralidae) is the main pest of mahogany plants. This pest attacks the apical shoots and inhibits the growth of mahogany. This study observed the biology, damage, and attack patterns of *Hypsipyla* shoot borer attack on mahogany plants. The study was conducted for 1 yr by periodically monitoring per 2 mo of 3 blocks of mahogany plantation in KHDTK Haurbentes, Jawa Barat. Data collected included 1) observation of symptoms, signs, presence of pests, effects of attacks, and 2) number of attacks. The symptom of the shoot borer was the presence of a hole filled with powder from the secretion of pests; the sign of an attack was the appearance of shoot borer larvae in the stem hole of the shoot area; while the effects of attacks were the death of the shoot and the emergence of multishoots. Observation showed that shoot borer attacks were not influenced by the weather, with the highest attack occurred in March 2017. Various levels of instars could be found at one time, indicating that insect growth in the field was not uniform. One cycle takes 5 to 8 wk. The highest rate of repeated attacks founded was 7 times/tree/yr, the average attack occurred 2-4 times/tree/yr.

1. Introduction

*Hypsipyla* shoot borer (Lepidoptera: Pyralidae) attacks almost all species of subfamily Swietenioideae family Meliaceae, including *Cedrella odorata* [1, 2], *Toona ciliata* [3], *Khaya* spp [4], *Swietenia* (mahogany) to mangrove plant *Xylocarpus granatum*. *Hypsipyla* became a serious pest of mahogany plantation around the world; *H. Robusta* attacks mahogany plantation in Asia-Pacific region and Africa whereas *H. grandella* attacks mahogany plantation in American continent [5].

In Indonesia, *Hypsipyla* attacks *Swietenia macrophylla* King and *S. mahagoni* (L.) Jacq. This pest entered Indonesia in the late 1800s and attacked intensively in the mid-1920s [6, 7] with a widespread area covering Java, Sumatra, Kalimantan, Sulawesi and Maluku, from the low to highland (altitude of 1100 m asl). On Java Island, these pests attack young mahogany at 3-6 yr old with a height of about 2-8 m whereas older mahogany plants are not susceptible to *H. robusta* [6, 8]. Other paper reported that *H. robusta* attacks young plants with height between 1-4 m along Minahasa, Bitung and Bolaang Mongondow, Tomohon and Manado in Sulawesi Island [9].

*H. robusta* bores to the apical shoot and cause shoot death. In early instar, the larvae move along several locations causing sap droplets and withered shoots. Larger larvae usually move to older stem which inflict damage to the main stem; continuous damage cause stunted tree and branching [5].
The *H. robusta* pest problem is a challenge because the larvae lives in stem or apical shoot and regenerate continuously. This pest attack is a major cause of unsuccessful plantation and leads to serious ecological and commercial implications [10]. Therefore, information about the biology *H. robusta* is needed to estimate peak attacks and developing pest control techniques.

2. Methods

2.1. Time and location
Mahogany stand located in the Special Purpose Forest (KHDTK) Haurbentes, Bogor- Jawa Barat, Indonesia (06°32'880" S and 106°26'149" E) and altitude 274 m asl.

2.2. Material
Mahogany was planted in May 2016 and was attacked by *Hypsipyla* shoot borer in Oktober 2016 (5 mo after planting). Observation of the dynamics of *Hypsipyla* shoot borer was conducted for 1 yr, starting in Oct 2016 until Sept 2017.

The procedures included establishment of permanent observation plots, because the objects were constantly observed. The plots consisted of 3 blocks. Each block has different characteristics such as relatively flat, valley, and slope. One block consisted of 15 plots with 9 plants/plot, so the plants observed were 135 plants/blocks or a total of 405 plants.

2.3. Data collection
Observations included: (1) symptoms and plant the recovery after attack (2) biology of shoot borer (3) surveillance of symptoms, signs, the presence of pests, and the effects of attacks. All activities were conducted every 2 mo on the field whereas identification of the pest was conducted at Laboratory Forest Protection - Bogor Forest Research Center.

Weather data was obtained from the Meteorology, Climatology and Geophysics Agency (BMKG), Dramaga-Bogor. Data taken included rainfall and the number of rainy days from Jasinga Station, as the closest weather station to the research location.

2.4. Data analysis
Data analysis was carried out with descriptive and statical methods. Descriptive analysis was to observe attack symptoms in plants, pest biology, correlation between attack frequency and weather. Statistical analysis was used to find out the attack frequency and the correlation of plant age.

3. Results and discussion

3.1. Symptoms of attack and plants recovery
Early symptoms of attacked plant by *Hypsipyla* shoot borer were wilted plant and black apical shoots, as if the shoots were burned (Fig. 1a). Within 1 wk later colored translucent resin powder and dirt that are secreted by shoot borer were seen in the shoots (Fig. 1b). Plant recovery is showed by the appearance of multishoots, between 3 to five buds (Fig. 1c). Repeated attacks could occur in new shoots (Fig. 1d).
Figure 1. Observation of attacked mahogany plant by Hypsipryla shoot borer (a) initial symptoms; (b) advanced symptoms; (c) plant recovery; (d) repeated attack.

Top shoot borer on mahogany in Haurbentes-West Java KHDTK is destructive because it targets the shoot, an important organ for plant growth. One parameter of resistant-pest plants is the capacity to maintain apical shoots [11]. The initial symptoms of this pest attack are the appearance of clear sap and withering shoots; followed by the emergence of a hole filled with material secreted. The shoot that has been attacked can recover naturally, i.e: the emergence of new shoots that occur within 3-4 wk after the attack. The newly formed buds of recovery result in 3 to five shoots (multishoots) (Fig. 1c). Multishoots cause the emergence of new branches and it would reduce economic value of the stem.

Repeated attacks occur when no pest control is taken; new post-recovery shoots will be targeted by the pest again (Fig. 1d). According to [9] repeated attacks on plants produces multi shoots, which causes diminished growth rate and these multishoots became new targets of the attack. The effect of the attack caused the loss of apical buds, and plant responded by growing more than 1 lateral bud so that the growth of the mahogany shoots continued to resemble “brooms”. Another consequence of the attack led different growth of the mahogany stands. The plant which has several attacks will has growth disorders or will not produce wood as expected or even crop failure.
3.2. Biology of Hypsipyla shoot borer
In each field observation, different instars and cocoons could be found on observed plants (Fig. 2). Thirty larvae were collected from the field for observation and identification in Laboratorium.

![Figure 2. Hypsipyla robusta: (a) larva; (b) imago; (c) attack sign; (d) attack symptoms; (e) cocoon on leaf; and (f) cocoon on the stem.](image)

In field observation, eggs were not found on observed plants because eggs located in the stem. Early first instar larvae move into small stems. After 2-3 d the larvae attacks young leaves or shoots and return to the hole in the stem or branch. The remainder of the larvae stage is spent branching to the main stem or plant branch. If the shoots are not available, the larvae can eat subcortical tissue and the thick epidermis (Figs. 2c and 2d) [12, 13]. The terminal instar larvae have a dark body color (blackish brown) and a black head with a length of about 13 mm. One character unique of *H. robusta* larvae has black spots along his back (Fig. 2a). Cocoon can be formed in borer holes (Fig. 2f) or just stays in leaves (Fig. 2e) [14]. The duration of egg development to adult stage ranges between 26-40 d [13]. The color of *H. robusta* moth is brown with a body length of about 13-14 mm (Fig. 2b). Our observation showed that this pest completes its life cycle in 5-8 wk, and this data similar to results from Hadi & Mahfudz [15]. They stated that in Indonesia its life cycle lasts for approximately 7 wk on mahogany.

Insects continue to attack trees in wet areas throughout the year and switch from shoots to fruits in areas with dry season. Attacks usually occur more in the rainy season, when new shoots are produced [13].

3.3. The attack dynamics of Hypsipyla shoot borer
Within 1 yr of observation (Oct 2016 - Sept 2017) there was no death of mahogany in all observed blocks. This showed that the shoot borer attack in early stages of mahogany plant growth does not cause death. The same result was stated by Hossain *et al.*[16] that plant death due to shoot borer attack is rare. Of the 60% of plants affected by shoot borer, the plant naturally recovers after infestation.
3.3.1. Effect of blocks on the attack of shoot borer. Attack frequency for 1 yr of observation on mahogany plantations in Block I, II, and III are presented in Table 1. The frequency of attacks range from 0 (no attack) up to 7 attacks on 1 individual plant.

Table 1. The attack frequency of *Hypsipyla* shoot borer.

| Frequency | Attack number | Percentage |
|-----------|---------------|------------|
|           | Block I | Block II | Block III | Block I | Block II | Block III | Total |
| 0         | 13      | 25       | 25        | 9.63    | 18.52    | 18.52     | 15.56 |
| 1         | 34      | 33       | 44        | 25.19   | 24.44    | 32.59     | 27.41 |
| 2         | 39      | 37       | 31        | 28.89   | 27.41    | 22.96     | 26.42 |
| 3         | 25      | 26       | 27        | 18.52   | 19.26    | 20.00     | 19.26 |
| 4         | 10      | 11       | 5         | 7.41    | 8.15     | 3.70      | 6.42  |
| 5         | 5       | 1        | 2         | 3.70    | 0.74     | 1.48      | 1.98  |
| 6         | 3       | 0        | 0         | 2.22    | 0.00     | 0.00      | 0.74  |
| 7         | 0       | 1        | 0         | 0.00    | 0.74     | 0.00      | 0.25  |

Fluctuate attack percentages of *Hypsipyla* shoot borer in blocks I, II and III (Table 2). In Block I the percentage of pest attacks occurred between 22.22% to 40.47%, in block II between 8.15% to 59.26% while in Block III between 11.11% to 48.89%.

Mahogany stands were attacked by *Hypsipyla* shoot borer with a frequency of 1-7 times during 1 yr observation period (Table 1), with attacks more than once in individual mahogany trees occurring in all observation plots. The percentage of mahogany plants that were attacked once during 1 yr observation period in block I were 25.19%; block II is 24.44% and in block III is 32.59% (mean 27.41%). The percentage of mahogany plants that were attacked twice in 1 yr observation period in I, II and III blocks were 28.89%, 27.24%, and 22.96% (mean 26.42%). The percentage of mahogany plants being attacked 3 times in plots I, II, and III were respectively 18.52%, 19.26%, and 20.00% (mean 19.26%). Four and 5 times attack frequencies occurred in the 3 observation blocks but in low percentage. Six times attacks frequencies occurred only in block I and the frequency of 7 times occurred only in the second block. Whereas mahogany plants that have never experienced shoot borer pests in blocks I, II and II respectively amounted to 9.63%; 18.52% and 18.52% (mean 15.56%).

Table 2. Attack percentage of *Hypsipyla* shoot borer.

| Months    | Block I | Block II | Block III | CH<sup>b</sup> | HH<sup>b</sup> |
|-----------|---------|----------|-----------|----------------|---------------|
| Oct 2016  | 35.56   | 9.63     | 11.11     | 267            | 14            |
| Nov 2016  | 29.63   | 8.15     | 18.52     | 180            | 13            |
| Jan 2017  | 17.04   | 8.89     | 20.00     | 260            | 18            |
| March 2017| 40.00   | 59.26    | 48.89     | 179            | 16            |
| May 2017  | 37.04   | 42.96    | 24.44     | 241            | 12            |
| Jul 2017  | 22.22   | 26.67    | 14.07     | 238            | 9             |
| Sept 2017 | 40.74   | 31.85    | 40.74     | 191            | 8             |

<sup>a</sup>Data in percentages.

<sup>b</sup>Remarks: CH = rainfall; HH = sum of rainy day.

The results of the analysis of variance (ANOVA) percentage of pest attacks in Blocks I, II, and III are presented in table 3 with a P-Value value of 0.967273.
Table 3. Analysis of variance.

| Source of Variation | SS     | df | MS          | F        | P-value  | F crit     |
|---------------------|--------|----|-------------|----------|----------|------------|
| Between Groups      | 26,7778| 2  | 13,38888889 | 0.033348093 | 0.967273 | 3.68232    |
| Within Groups       | 6022,333 | 15 | 401,4888889 |          |          |            |
| Total               | 6049,111 | 17 |             |          |          |            |

Based on observations the attack percentage of trees by *Hypsipyla* shoot borer in block I was higher than block II and block III (Table 2), but analysis of variance (ANOVA) showed no significance from *P*-Value 0.967273 (Table 3). This mean that the difference in site contours (relatively flat, valley, and slope) did not affect the rate of attack of *Hypsipyla* shoot borer.

3.3.2. Effect of weather on pest attacks *H.* robusta. The weather at the observation location, both rainfall and the number of rainy days, did not affect the percentage of pest attacks (Fig. 3 and 4).

The attack evidences of *Hypsipyla* shoot borer in mahogany plants in KHDTK Haurbentes-West Java were fluctuated for each mo. Data observation showed the highest attacks occurred in March 2017 and the lowest occurred in July 2017 (Fig. 1 and 2). These 2 graphs showed no correlation between the percentage of trees infested and weather factors such as rainfall and number of rainy days. Preliminary attack occurred 5 mo after planting (October 2016) to 8% of mahogany stands and reached its highest, 40-59%, in March 2017. Subsequent observations in May 2017 showed decreased attack percentage to 24-42% followed by 14-26% in July 2017. Observation in Sept 2017 showed raised attack percentage to 31-40%. Our result showed that none of the blocks were free from *Hypsipyla* shoot borer attacks.

**Figure 3.** The correlation between rain fall to *Hypsipyla* shoot borer attack.

Information about seasonal abundance and current patterns of attack is rarely available, even though this knowledge could lead to predicting the peak of attacks, design the sampling techniques, and particularly management of pest controlling. According to Taveras *et al.* [12] *Hypsipyla* is active throughout the year, and its population is influenced by abiotic factors (humidity, rainfall, temperature) and biotic factors (availability of mahogany shoots and natural enemies). Based on some studies, the availability of shoots is mainly related to the rainy season so the abundance of *H.* robusta is related to the rainy season [17, 18]. In this research, the research location was located in Haurbentes.
KHDTK, and based on weather data, rainfall was distributed throughout the year. Rainfall below 60 mm occurred only in 1 mo and the rest eleven mo had higher than 60 mm. The smallest number of rainy days occurred in Jul 2017 and was indicated by the low percentage attacks in blocks I, II, and III respectively 22.22%, 26.67%, and 14.07%. Percent attack < 25% consider as low level of pest attack, then it is still on the range of tolerant to the presence of the Hypsipyla shoot borer.

3.3.3. Effect of accumulated attack rates on age. Accumulation levels of shoot borer attacks against age is presented in Fig. 5. The accumulation of attack rate is defined as adding shoot borer attacks occurring every 2 mo to the total amount of attacks and correlating it with the age of mahogany plants throughout the year.

The effect of the accumulated level of infestation on plant age showed an expIntial graph. It means the higher the age of the plant, the higher the level of attack with the value $R^2 = 0.6854$ (Fig. 5). The effect of this accumulated level of attack is still in the process of observation so that the age of mahogany plant, when pest infestation of H. robusta would no longer happen, could be known.
Observation of the level of attack on age still needs to be continued so that the age of plants that are safe against this pest attack can be known.

The challenges of shoot borer are because: the larvae live in shoots; they continuously regenerate; and mahogany’s characteristic to create multiple branches as a response to shoot damage [19]. No adequate technique has been found to control *Hypispyla* shoot borer [20]. Control of *H. robusta* has been carried out through various approaches, including the silvicultural approach, but its success is still low. Intensive silviculture is carried to reduce the suitability of host plants by planting resistant plant, planting border plants to resist insects, or planting interfering plants to disrupt the ability of insects to look for hosts [21]. Chemical control is generally not needed from an environmental point of view or attacks are considered not exceeding the economical threshold. The use of systemic insecticides cannot kill larvae fast enough to prevent shoot damage, thus chemical insecticides can be carried out in limited use as part of integrated pest management [22].

4. Conclusion

Mahogany shoot borer attack in KHDTK Haurbentes occurred throughout the year with fluctuating attack patterns. Attack frequency ranges from 1-7 times in 1 yr. The average attack occurred 2-4 times/tree/yr. Both blocks and weather did not affect the attack percentage. The accumulated level of attack on plant age showed that the higher the plant age, the higher the level of attack.

All 3 observation blocks experienced of shoot borer attack, with the highest attack rate occurring in the month of March 2017, which was around 40-59%.

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