

Effect of canopy cover on development of cedar (*Cedrela fissilis*) and aspects of damage caused by *Hypsipyla grandella* in agroforestry system

Efeito da cobertura sobre o desenvolvimento do cedro-rosa (*Cedrela fissilis*) e nos danos causados por *Hypsipyla grandella* em sistema agro florestal

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Abstract

Cedrela fissilis (Vell.) is an important wood species, native to South America. It is appreciated for its physical characteristics and, therefore, its native specimens are overexploited. Commercial cultivation initiatives have been continuously flawed as a result of the damage caused by mahogany shoot borer *Hypsipyla grandella* (Zeller, 1848). Planting under shaded sites has been one of the management methods used to reduce insect attacks. However, the reason why mahogany shoot borer does not attack shaded plants as often is still unknown. Therefore, the aim of this research was to find cultivation parameters that could combine proper plant development and low rate of attacks by *Hypsipyla grandella*. For this purpose, increases in height and shoot diameter of cedar seedlings, planted in agroforestry systems, were monitored for the two first years. Three canopy cover rates, namely, 0-20%, 20-40% and 40-60%, were tested for plant development and frequency of attacks by *Hypsipyla grandella*. The adult population of the insect was monitored with semiochemicals throughout the experimental period, and two pheromonal blends and one food bait were tested. Field results showed that one of the pheromone blends was efficient in identifying small variations in the population of adult specimens. Regarding to the plant development, the treatment with the highest cover rate showed the lowest parameters compared to the intermediate cover. The frequency of attacks by *Hypsipyla grandella* was greater in the treatment with the lowest cover (0-20%). The results suggest that in canopy cover, ranging from 20 to 40%, good rates of initial development of plants can be combined with low frequency of attack by *Hypsipyla grandella*.

Keywords: Photosynthetically active radiation; Ultraviolet radiation; Pheromone; Mahogany shoot borer

Resumo

Cedrela fissilis (Vell.) é uma importante espécie madeirável nativa da América do Sul que sofre frequente pressão do extrativismo ilegal. As iniciativas de cultivo comercial acumulam fracassos recorrentes pela ação da broca-do-cedro *Hypsipyla grandella* (Zeller, 1848). Um dos métodos de manejo utilizados para reduzir os ataques é o plantio em locais sombreados; entretanto, é desconhecido o fator que faz as plantas sombreadas serem menos atacadas. O estabelecimento dos parâmetros de cultivo em tal condição que alie desenvolvimento adequado das plantas e baixos índices de ataque de *Hypsipyla grandella* foi o objetivo central deste estudo. Foi acompanhado nos dois primeiros anos o crescimento em altura e diâmetro de coleto de mudas de cedro-rosa plantadas em sistemas agroflorestaís em que foram testados três níveis de cobertura 0-20%, 20-40% e 40-60% quanto ao efeito no desenvolvimento e frequência de ataque de *Hypsipyla grandella*. A população do inseto foi monitorada com semioquímicos durante todo o período de ensaios, e foram testadas duas misturas feromonais e um atrativo alimentar. Os resultados de campo indicaram que uma das misturas feromonais foi eficiente para identificação de pequenas variações populacionais de adultos. Quanto ao desenvolvimento das plantas, o tratamento com maior taxa de cobertura apresentou os menores parâmetros em comparação com a cobertura intermediária, e a frequência de ataque de *Hypsipyla grandella* foi maior no tratamento com menor cobertura (0-20%). Os resultados indicaram que, em cobertura variando de 20 a 40%, foi possível aliar boas taxas de desenvolvimento das plantas com baixa frequência de ataque da broca-do-cedro.

Palavras-chave: Radiação fotossinteticamente ativa; Radiação ultravioleta; Feromônio; Broca-do-cedro

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Introduction

Cedar *Cedrela fissilis* (Vell.) has been historically recognized as one of the major native timber trees in the southern portion of the American continent (GRIGNOLA et al., 2014). Wood from cedar has a high commercial value because of it has excellent characteristics (CUSATIS et al., 2013); thus, adult native trees have been overexploited for timber. For this reason, cedar has been listed as an endangered plant species in the Brazilian flora (CENTRO NACIONAL DE CONSERVAÇÃO DA FLORA, 2014).

The attempt to establish commercial areas with cedar trees has suffered several setbacks, especially shoot borer *Hypsipyla grandella* (Zeller, 1848) (Lepidoptera: Pyralidae) attacks in the first years after deployment. Therefore, this initiative has become unfeasible (BARBOZA et al., 2010) because shoot borer poses the greatest challenge to plant health during the cultivation of Meliaceae such as cedar (*Cedrela fissilis*) and mahogany (*Swietenia macrophylla* King.) (DE CASTRO et al., 2016; PEREIRA et al., 2016).

When the larvae attack apical branches, they cause intense sprouting, which impairs the production of trees with erect stems, thereby reducing plant development. In severe and recurring cases, they may cause the plant death (LUNZ et al., 2010).

Some methods of management and control have been proposed, e.g., insecticide application (KULKARNI, 2017) and the pruning of re-sprouts (CORNELIUS, 2009); however, they were shown to be economically unfeasible or not very efficient. One alternative used by the farmers to reduce insect attacks is to keep young plants under the shade of older tree species in intercropped systems (OPUNI-FRIMPONG et al., 2008). For this reason, the option of planting cedar trees in agroforestry systems is recommended by Pérez-Salicrup and Esquivel (2008). However, little is known about the impact of the shade management on plant development and frequency of attacks by *Hypsipyla grandella*.

Therefore, the objective of the present study was to assess the influence of canopy cover on the development of cedar plants and on the frequency of the damage caused by *Hypsipyla grandella* as well as to determine the levels of canopy cover that combine adequate development rates and low damage rates.

Material and methods

The experiment was conducted between 2013 and 2016 in an agroforestry system (AFS) in the town of Fraiburgo, in the west of Santa Catarina state, with dimensions of 2.2 hectares. Average rainfall in the region is 1,500 mm per year and average annual temperature is 15.3°C. The weather is classified as Cfb, according to the Köppen classification (TRABAQUINI; VIEIRA, 2017).

The AFS was deployed in August 2013 in an area previously planted with pioneer species, such as bracatinga (*Mimosa scabrella*, Benth), sigua (*Ocotea puberula*, Rich. Nees) and ear leaf nightshade (*Solanum mauritianum*, Scop). Cedar seedlings with 15 ± 2 cm in height and 0.5 ± 0.2 cm in shoot diameter were selected. They were planted at the density of 50 plants per hectare with 20 m x 10 m spacing. Neither fertilizer at planting nor topdressing fertilization was used.

Cultural treatments consisted in crowning and mowing seedlings in the months of October and November and mowing them again in the months of February and March. These procedures were repeated on a yearly basis. Throughout the first year, original tree vegetation was preserved in order to reduce the effect of frost. For this reason, the treatments with different levels of coverage were not set up until the month of August, 2014.

In the first cycle, in 2013-2014 (prior setup), plant development was monitored by the selection of five rows spaced at 20 meters, in which four plants were marked (n=20). The height was measured using a tape measure while shoot diameter was measured with a pachymeter (Starrett Brasil, model 125 MEBT-8/200). The measurements were made in the months of January

and August, 2014.

In the second year (2014-2015), between August and October, six experimental blocks were set up with a randomized block design with three treatments and six replicates. The minimum distances were 10 meters between blocks and 5 meters between plots, respectively. Each plot was 10 m wide and 20m long and contained a cedar plant positioned at the center.

The treatments were randomly selected in the block: 0 to 20%, 20-40% and 40-60% canopy cover. To achieve the established level of cover, the pioneer plants were cut or pruned until the desired level was visually achieved. The correct level of cover was measured with photographs of the canopy above the plots, made with a Sony Cyber-Shot DSC-HX1 camera, fitted with Pixco fisheye lens, model FC-67E25 0.25X, mounted on a tripod and using two bull's eye levels and one tubular level. The equipment was installed at one meter from the ground, and the level was then adjusted in order to capture images of the existing vegetation cover. The images were treated with the software HemiView (Delta-T Devices Ltd), and cover percentage was determined at four different points of each plot using a methodology adapted from the study of Chianucci and Cutini (2013).

In the spring of the last cycle of the trial, an assessment was made of the influence of the treatments on solar radiation interception, in the range of 300 to 750 nm. Five measurements were made per plot using a Li-cor Inc. spectroradiometer (model LI-1800), thus enabling the assessment of ultraviolet radiation (UV), photosynthetically active radiation (PAR) and red to far-red ratio (R:FR) in comparison to open sky conditions (Table 1).

Table 1 – Mean percentage of ultraviolet radiation (UV), photosynthetically active radiation (PAR) and red to far-red ratio (R:FR) interception in three different classes of cover in THE agroforestry system in Fraiburgo, SC state, 2017.

Tabela 1 – Percentual médio de interceptação das radiações ultravioleta (UV) e fotossinteticamente ativa (PAR) e relação vermelho:vermelho-distante (V:VD) nas três diferentes classes de cobertura em sistema agroflorestal em Fraiburgo - SC, 2017.

Radiation	λ	0-20%	20-40%	40-60%
UV	300-390 nm	65.9%	87.4%	95.6%
PAR	400-700 nm	57.0%	84.7%	95.9%
R:FR ratio		2.20	2.05	1.40

The plant development in the plots was monitored during the months of January and July 2015 and January 2016 with new measurements of plant height and shoot diameter, using the same method described above. Canopy cover rate in the plots was measured in the month of April 2015, according to the above-mentioned method.

The plants were inspected on a weekly basis to identify initial damage caused by mahogany shoot borer (*Hypsipyla grandella*). Because the attacks occurred most often between November and February, the number of attacks per plant could not be assessed; rather, the plants were classified as affected or not affected. Such procedure had an influence on the statistical analysis of the data, which used Cochran's non-parametric Q test.

The population of adult mahogany shoot borer was monitored with sex pheromones (BLASSIOLI-MORAES et al., 2017) impregnated in rubber septa, which were placed in plastic Delta traps kept in the field between September and April from 2013 through 2016. Six traps (one per experimental block) were positioned at fixed points at 1.80 meters from the ground. Weekly sampling was performed.

Results and discussion

The cedar plants developed differently among the tested treatments only in the last round of assessments, as shown in Table 2. Seventeen months after the experiment had been set up, plants under an intermediate cover rate (20-40%) showed greater height and shoot diameter than those which developed under more intense cover (40-60%). The two treatments did not differ from the treatment with 0-20% cover (Table 2).

Table 2 – Mean height ± standard deviation (cm) and shoot diameter ± standard deviation (cm) of cedar (*Cedrela fissilis*) plants in the first three years of development in an agroforestry system, under three rates of natural cover (0-20%, 20-40% and 40-60%) in Fraiburgo, SC state, 2017.

Tabela 2 – Média da altura ± desvio padrão (cm) e diâmetro do coleto ± desvio padrão (cm) de plantas de cedro *Cedrela fissilis* nos três primeiros anos de desenvolvimento em sistema agroflorestal, submetidas a três classes de cobertura natural (0-20%, 20-40% e 40-60%) em Fraiburgo - SC, 2017.

		Prior setup								
		January				August				
2014	Height (cm)	20.96	±	5.03		32.74	±	19.05		
	Shoot diameter (cm)	0.73	±	0.17		2.09	±	1.15		
		0-20%		20-40%		40-60%		CV(%)		
January 2015	Height (cm)	55.50	±	30.73	ns	43.53	±	9.34	49.28 ± 11.94	37.82
	Shoot diameter (cm)	1.95	±	1.47	ns	1.09	±	0.12	1.42 ± 0.60	66.11
August 2015	Height (cm)	59.77	±	32.23	ns	51.70	±	22.44	55.97 ± 17.76	29.74
	Shoot diameter (cm)	2.26	±	1.85	ns	1.96	±	1.53	1.56 ± 0.99	39.96
January 2016	Height (cm)	83.00	±	62.39	*ab	116.92	±	88.71	a 58.87 ± 25.68	b 44.12
	Shoot diameter (cm)	2.83	±	2.11	*ab	3.36	±	2.91	a 1.78 ± 0.79	b 41.58

*Means followed by the same letter on the row do not differ by Tukey's test ($p < 0.05$)

ns = non-significant

The findings for plant development in terms of height, in the first cycle (prior setup), were similar to those reported by Linzmeier (2011) at nine months after planting, with average height of 27.94 cm. Mean shoot diameter, as found by the author, was 0.72 cm, which is lower than the value found in the present study.

As far as the effect of cover is concerned, Souza (2008) concluded that plants under 29% artificial cover grew taller than those under 55% of coverage or in full sunlight, after 33-month exposure. These findings are similar to those reported in the present experiment, in which plants under intermediate cover had greater development than those under 40-60% cover. This behavior was explained by Ballaré (2014); it occurs through the action of the phyB photoreceptor and a series of physiological phenomena known as Shade-avoidance Syndrome (SAS).

This effect of shade which leads to SAS is referred to by Hideg et al. (2013) as “good stress”. However, development is impaired when particular limits are exceeded. Further studies should clarify whether development achieved under a 20-40% canopy cover continues until the plants grow taller than pioneer species, or if this behavior is restricted to the first months of plant growth.

SAS is expressed under intense shading, but growth becomes progressively lower as plant reserves are depleted and photosynthetic rates are insufficient to support the demand for energy (SANCHES; MARZINEK; BRAGIOLA, 2017). Such limitation explains the lower development of plants exposed to 40-60% cover.

While the trial was conducted, the plants from the 0-20% treatment were frequently attacked by mahogany shoot borer (*Hypsipyla grandella*), as shown in Table 3. Especially in the 2015/2016 cycle, there was a greater percentage of attacks in the 0-20% treatment compared to the 20-40% and 40-60% treatments (Table 3).

Tabela 3 – Percentage of cedar (*Cedrela fissilis*) plants attacked by mahogany shoot borer (*Hypsipyla grandella*) in three different rates of natural cover in agroforestry system in Fraiburgo, SC state, 2017.

Tabela 3 – Porcentagem de plantas de cedro-rosa *Cedrela fissilis* atacadas pela broca-do-cedro *Hypsipyla grandella* nas três diferentes classes de cobertura natural em sistema agroflorestal em Fraiburgo - SC, 2017.

Cycle	Prior setup					
	0-20%		20-40%	40-60%	CV%	
2013/2014					0%	
2014/2015	50%	ns	50%	0%	136.93	
2015/2016	50%	*a	16%	b	0%	129.54

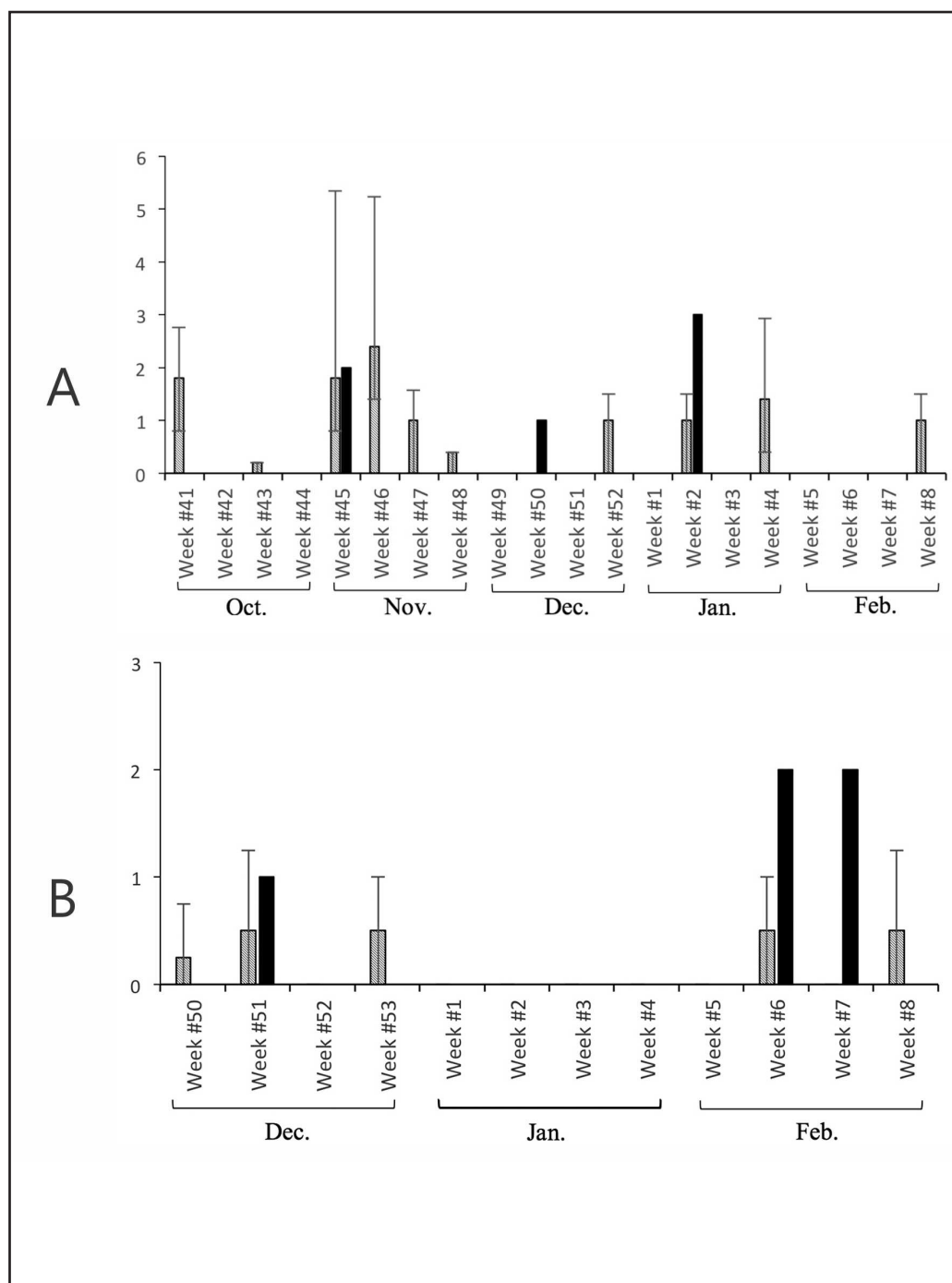
*Data followed by the same letter do not differ by Cochran's Q-test ($p < 0.05$)

ns = non-significant

Many studies have reported higher frequency of attacks by *Hypsipyla grandella* to other species of the family Meliaceae exposed to high levels of solar radiation (SÁNCHEZ-SOTO; DOMÍNGUEZ DOMÍNGUEZ; CORTÉS MADRIGAL, 2009; RUIZ et al., 2016). Our results have shown the same behavior for *Cedrela fissilis* and indicate that mahogany shoot borer attacks impaired the development of plants exposed to 0-20% cover, despite the higher levels of photosynthetically active radiation (PAR) observed under such conditions.

Figure 1 – Mean percentage of weekly catches of *Hypsipyla grandella* in Delta traps baited with sex pheromone (striped columns) and amount of damage identified on a weekly basis in cedar (*Cedrela fissilis*) plants (black columns) in the 2014/15 (A) and the 2015/2016 (B) cycles in an agroforestry system in Fraiburgo, SC state, 2017.

Figura 1 – Dados semanais (apresentados em sequência ordinal) de capturas de *Hypsipyla grandella* em armadilhas Delta iscadas com feromônio sexual (colunas listradas) e número de danos identificados em plantas de cedro *Cedrela fissilis* (colunas negras) nos ciclos 2014/2015 (A) e 2015/2016 (B), em sistema agroflorestal em Fraiburgo - SC, 2017.



Source: Authors (2019)

Newton et al. (1998) correlate the attacks of mahogany shoot borer in *Cedrela odorata* L. and *S. macrophylla* to the larger volume of young leaves present in plants at an early stage of development, this may also be related to nutritional conditions according to the authors. Abraham et al. (2014) suggest that the dynamics of attacks observed in *Entandrophragma* and *Khaya* mahogany by *Hypsipyla robusta* (Moore) (Lepidoptera, Pyralidae) are guided by volatiles emitted by plants and vary according to the phenological stage.

There were variations in the population of *Hypsipyla grandella* in the area between October and February in the 2014/15 cycle while in the 2015/2016 cycle, catches occurred mostly between December and February (Figure 1A). It should be noticed that the pheromone traps indicated small fluctuations in insect population, which often had no impact on the increase of plant damage, as observed, for example, at weeks 41, 46, 47 and 4 of the 2014/2015 cycle and week 53 of the 2015/2016 cycle (Figure 1B).

There is evidence that this behavior is the result of the change in volatile compounds released by shaded plants, which are used by females of *Hypsipyla grandella* for locating oviposition sites (BORGES, 2017). These temporal variations of the arrangement of volatile secondary compounds emitted may explain the fluctuations in the adult population of *Hypsipyla grandella*, which did not result in visible damage to the sampled plants.

As far as the behavior of the insect population is concerned, the low catch rates found in the 2015/2016 cycle, in comparison to the previous cycle, may be due to extreme climate events which occurred in the winter months and early spring of 2015 (SILVA, 2016), i.e., excess rainfall in that period may have compromised the viability of pupae or the longevity of adults (KRAMS et al., 2015). Future research, while using longer sampling periods, could associate data on catches with pheromone traps with the occurrence of damage; thus, a level of control can be established for the species.

The data collected in this study suggest a positive effect of cover up to 40% in the early development of the cedar plants, not only because it did not compromise the increase in height and shoot diameter, but especially because it reduced the frequency of attacks by mahogany shoot borer.

Conclusions

Young plants of *Cedrela fissilis* under canopy cover varying between 20% and 40% have higher development, either because of the solar radiation that support the plant growth, either by the reduced rates of attack of the mahogany shoot borer.

There is an inversely proportional relationship between coverage increase above *C. fissilis* plants and mahogany shoot borer attack level. Plants located in environments with low coverage and greater solar radiation have more growth resources, but this condition is obliterated by the attack of mahogany shoot borer, which has a preference in attacking these plants. The facts that guide the damage dynamics of *H. grandella* in *C. fissilis* plants should be investigated in future works.

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