A new defoliating threat to eucalyptus plantations: Biology and foliar consumption of *Physocleora dukinfeldia* (Lepidoptera: Geometridae)

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Abstract

The defoliator *Physocleora dukinfeldia* Warren, 1897 (Lepidoptera: Geometridae) was recently reported attacking *Eucalyptus urograndis* (Myrtaceae) plantations in Brazil, raising concerns about its potential impact on commercial forestry. In this context, early characterization of pest biology plays a critical role in understanding host-use patterns and forecasting potential impacts on forest~~ry~~ ecosystems. This study aimed to characterize the biology and foliar consumption of *P. dukinfeldia* on *E. urograndis* and its native host, *Schinus terebinthifolia* (Anacardiaceae). Larval development, head capsule width, viability, pupal morphology, and leaf area consumed were assessed under controlled conditions. The insect completed its life cycle on both host plants, with significantly longer development time and reduced pupal viability observed on *E. urograndis*. Although larval survival was low on both host species, nearly one-third of the individuals successfully reached adulthood. No significant differences in leaf consumption were detected between the two eucalyptus species evaluated in this study. These findings indicate that *P. dukinfeldia* has the biological capacity to adapt to eucalyptus and should be closely monitored in forest production areas. This is the first report to detail the life cycle and feeding behavior of this species on eucalyptus, providing critical baseline information for future pest management strategies.

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Keywords: eucalyptus, forest pest, insect biology, host adaptation.

1. Introduction

Eucalyptus cultivation stands out in the Brazilian forestry sector due to its high economic viability and versatile applications (Barroso et al. 2004). Although the genus *Eucalyptus* comprises approximately ~~around~~ 730 species, only about 20 are commercially exploited, mainly to produce paper, pulp, timber, charcoal, essential oils, and biomass (Magaton et al. 2009; Penfold and Willis, 1954). Currently, eucalyptus plantations cover approximately 7.8 million hectares, accounting for 76% of all planted forests in the country (Ibá, 2024).

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The expansion of eucalyptus cultivation areas in Brazil has been accompanied by an increase in the occurrence of diseases and phytophagous insects, many of which are recognized as potential pests capable of causing serious damage to the crop (Pereira et al.~~,~~ 2001). The harm caused by these insect pests can compromise forest productivity directly in the field (Guo et al. 2023; Kog~~n~~an, 1998). Among the main groups responsible for such losses are defoliating caterpillars, which directly impact plant development by causing partial or even complete defoliation of the canopy, an effect that can severely hinder the growth and yield of commercial eucalyptus plantations (Poderoso et al. 2013; Zanuncio et al. 2018).

Among the colonization caterpillars, a species that has recently gained attention is *Physocleora dukinfeldia* (Lepidoptera: Geometridae) (Warren, 1897). Originally recorded in Brazil in the municipality of Castro, Paraná, Brazil (Schaus, 1897), this species was only recognized as a pest in 2021, following an outbreak in eucalyptus plantations that resulted in severe defoliation and economic losses. Similar to other geometrid caterpillars known to affect forest crops, *P. dukinfeldia* has demonstrated the potential to become a significant threat to commercial eucalyptus production (Silva et al. 2023; Pereira, 2012).

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The emergence of *P. dukinfeldia* as an eucalyptus pest highlights a broader ecological process: the colonization of new host plants by phytophagous insects and frequently precedes the emergence of pest outbreaks in managed ecosystems (Mass~~s~~elière et al. 2017). When a native herbivore shifts to a commercially important plant species, it may find favorable conditions for development due to reduced interspecific competition, lack of natural enemies, or continuous food availability, factors often present in large-scale monocultures. However, successful establishment in a novel host requires physiological and behavioral plasticity, which must be assessed through detailed biological studies (Agrawal, 2000; Schoonhoven et al. 2005).

Understanding the life cycle parameters of herbivorous insects on new hosts, including development time, survival rates, reproductive capacity, and feeding behavior, is essential to assess their establishment potential and predict future population dynamics (Gripenberg et al. 2010). Such data are crucial in forest production systems, where outbreaks of defoliators can lead to significant reductions in growth and wood yield. Moreover, early-stage studies on insect biology can reveal signs of host-use constraints or adaptive potential, guiding monitoring efforts and informing integrated pest management programs (Heidel-Fischer et al. 2019; Janz et al. 2006). In this context, the present study aimed to evaluate the biological performance of *P.* -*dukinfeldia* on *E. urograndis* compared to its native hosts, *Schinus terebinthifolia*, in order to assess this pest's its potential for adaptation and establishment in commercial eucalyptus plantations.

2. Materials and Methods

2.1 *Physocleora dukinfeldia* rearing

P.hysocleora dukinfeldia individuals were initially collected in a commercial eucalyptus area (Sylvamo do Brasil Ltda®), in Guatapará, SP, Brazil. Eggs and larvae were maintained in plastic containers (500 mL) covered with organza mesh, under controlled conditions (25 ± 2°C, 70 ± 10% relative humidity, and a 12-hour photoperiod). Larvae were fed with pure eucalyptus leaves (*Eucalyptus urophylla*), obtained from healthy plants. The pupae were kept in containers with soil substrate until complete sclerotization. Then, they were transferred to containers lined with moistened filter paper. Adults were kept in polyvinyl chloride (PVC) mesh cages, where a 20% honey solution and brown paper were available for adult feeding and female oviposition, respectively. Papers containing eggs were used to start new rearing cycles.

2.2 Life cycle assessment

The biology of *P. dukinfeldia* was assessed on two host plants, *Eucalyptus urograndis* (hybrid eucalyptus) and *Schinus terebinthifolia* (Brazilian peppertree), to better understand the developmental cycle of this defoliator species. The tree species used in the experiment were obtained from the Department of Crop Protection, São Paulo State University, Botucatu, SP, Brazil.

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Neonate larvae were individually placed in plastic containers (500 mL) containing leaves from each host plant. The leaves were inserted into Eppendorf tubes filled with water to maintain leaf turgor. Each container was considered an experimental unit, with 100 replicates per tree species, in a completely randomized design. The experiment was carried out in a climate-controlled room (25 ± 2°C, 70 ± 10% relative humidity, and a 12-hour photoperiod).

The insects were inspected ~~evaluated~~ daily ~~for~~ to measure larval head capsule width, pupal weight (24 hours post-pupation), dates of pupation and imago emergence, and viability in individual periods of development. Based on these records, the following parameters were determined: ~~the following parameters~~: duration of each larval instar, total larval period, duration of prepupal and pupal stages, and total development time (larva-adult); ~~head capsule width, total larval period,~~ larval and pupal viability (%), ~~duration of prepupal and pupal stages, pupal weight (24 hours pos-pupation),~~ morphological characteristics of the pupae~~, pupal~~ vi~~ability (%), and total development time (larva-adult)~~.

Head capsules were measured using an ocular micrometer attached to a stereomicroscope (Leica®), with 20 replicates. Pupal weights were obtained with an analytical balance (Shimadzu®, model ATY224), and pupal length and width were measured with a caliper. During inspection~~evaluations~~, excrements were~~eas~~ removed, and consumed leaves were replaced.

2.3 Leaf consumption

During the biological performance assay, consumed leaves of *E. urograndis* were photographed for subsequent assessment of leaf area consumption. In parallel, an independent assay was conducted using *E. urophylla* leaves to compare foliar consumption between this species and the eucalyptus hybrid (*E. urograndis*). The remaining leaf area after feeding was measured using ImageJ software (Ferreira *et al.* 2022). Leaves of *S. terebinthifolia* were not included in this analysis due to their morphology, which prevented accurate measurement of leaf area.

2.4 Statistical analysis

The data were subjected to analysis of variance, and the F-test was used to detect significant effects. The assumption of residual normality was assessed by the Shapiro-

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Wilk test, and the homogeneity of variances was verified using Levene's test (PROC UNIVARIATE, SAS). When significant differences among treatments were detected, the means were compared by the Tukey's test at a 5% significance level, using the PROC MIXED procedure (Sas, 2011).

3. Results

3.1 Life cycle determination

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The mean duration of the first instar larvae was 4.90 days on *E. urograndis* and 5.58 days on *S. terebinthifolia*, with no significant difference between host plants (F = 2.68; df = 1; *P* = 0.1054; Table 1). Similarly, development periods for the second and third instars showed no significant variation between host species (2^{nd} instar: F = 1.31; df = 1; *P* = 0.2559; 3^{rd} instar: F = 2.18; df = 1; *P* = 0.1441). Larvae fed with the eucalyptus hybrid completed the second and third instars in 4.38 and 4.97 days, respectively, while those reared on *S. terebinthifolia* completed the same stages in 4.00 and 4.20 days.

The development time for the fourth instar differed significantly between host plants (F = 15.56; df = 1; *P* = 0.0002), being longer on *E. urograndis* (5.86 days) compared to *S. terebinthifolia* (4.21 days). In contrast, no significant differences were observed for the fifth and sixth instars (5^{th} instar: F = 0.70; df = 1; *P* = 0.4054; 6^{th} instar: F = 3.92; df = 1; *P* = 0.0524). In the fifth instar, larvae fed with the hybrid eucalyptus and *S. -terebinthifolia* exhibited mean durations of 4.97 and 5.35 days, respectively. In the sixth instar, the mean durations were 11.43 days for *E. urograndis* and 9.22 days for *S. terebinthifolia*.

Considering the total larval period, larvae fed with the hybrid eucalyptus exhibited a significantly longer duration (35.07 days) compared to those fed with *S. terebinthifolia* (31.56 days) (F = 5.93; df = 1; *P* = 0.0180). The durations of the prepupal and pupal stages did not differ significantly between hosts (prepupa: F = 3.28; df = 1; *P* = 0.0755; pupa: F = 0.96; df = 1; *P* = 0.3313). The longest larva-adult development cycle was recorded on *E. urograndis* (52.00 days), which differed significantly from that observed on *S. terebinthifolia* (48.13 days) (F = 6.18; df = 1; *P* = 0.0160).

3.2 Cephalic capsule measurements

The mean head capsule width of *P. dukinfeldia* larvae differed significantly between host plants during the second instar (F = 5.73; df = 1; *P* = 0,0217; Table 2), with values

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of 0.28 mm on *E. urograndis* and 0.26 mm on *S. terebinthifolia*. However, no significant differences were observed for the third (F = 3.81; df = 1; *P* = 0.0583), fourth (F = 1.42; df = 1; *P* = 0.2408), fifth (F = 3.66; df = 1; *P* = 0.0633), and sixth instars (F = 3.84; df = 1; *P* = 0.0574).

3.3 Larval and pupal viability

Larval viability of *P. dukinfeldia* was low on both host plants, with 28.00% on *E. urograndis* and 32.00% on *S. terebinthifolia*, with no statistical difference between treatments (F = 0.38; df = 1; *P* = 0.5395; Figure 1). However, pupal viability was significantly lower in larvae fed on *E. urograndis* (85.71%) compared to those reared on *S. terebinthifolia* (100.00%) (F = 5.16; df = 1; *P* = 0.0269).

The morphological characteristics of *P. dukinfeldia* pupae, including weight, length, and width, showed no statistically significant differences between host plants for either sex. Among males, mean values were similar between treatments with *E. urograndis* (0.0713 mg; 10.90 mm in length; 3.32 mm in width) and *S. terebinthifolia* (0.0722 mg; 11.09 mm in length; 3.37 mm in width) (weight: F = 0.04; df = 1; *P* = 0.8527; length: F = 0.40; df = 1; *P* = 0.5301; width: F = 0.18; df = 1; *P* = 0.6724; Table 2). Similarly, female pupae exhibited comparable measurements across host plants (weight: 0.0747 mg in *E. urograndis* and 0.0863 mg in *S. terebinthifolia*; length: 11.57 mm and 11.7 mm; width: 3.44 mm and 3.56 mm, respectively) (weight: F = 3.40; df = 1; *P* = 0.0755; length: F = 0.84; df = 1; *P* = 0.3668; width: F = 1.91; df = 1; *P* = 0.1772).

3.4 Foliar consumption

No significant differences were observed for total leaf consumption among the eucalyptus species evaluated in this study (F = 0.01; df = 1; *P* = 0.9514; Figure 2). The consumption of *P. dukinfeldia* was 0.7309 cm^2/larva and 0.7173 cm^2/larva in *E. urophylla* and *E. urograndis*, respectively.

4. Discussion

The results demonstrated that *P. dukinfeldia* is capable of completing its life cycle on *E. urograndis*, although with a significantly prolonged larval development time and life cycle (larva-adult) compared to its native host, *S. terebinthifolia*. The observed extension, particularly during the fourth instar and the total larval period, suggests that eucalyptus may impose physiological or nutritional challenges to the development of

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this species, which is consistent with patterns reported for other insect herbivores (Campos et al. 2022).

The increase in developmental time from the fourth instar onward may indicate a delayed adaptive response to secondary compounds present in *E. urograndis*, such as monoterpenes and sesquiterpenes, which are commonly associated with the chemical defense of *Eucalyptus* species (Araújo et al. 2010; Cheng et al. 2009; Elangovan and Poonam, 2023). However, the ability to complete development on *E. urograndis* demonstrates that *P. dukinfeldia* has the potential to establish and adapt to this crop, which justifies special attention in monitoring its occurrence in commercial eucalyptus plantations. Furthermore, the longer life cycle observed on the eucalyptus hybrid (52 days) is consistent with that of other defoliator species, such as *Thyrinteina arnobia* (Stoll, 1782) and *Iridopsis panopla* *Prout, 1932*, whose developmental duration may also range from 40 to 60 days depending on environmental conditions and host plant (Jesus et al. 2015; Oliveira et al. 2005; Santos et al. 1996).

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The mean head capsule width of *P. dukinfeldia* increased progressively across the six instars on both host plant species, reflecting the typical larval growth pattern observed in Lepidoptera. The consistent increment in head capsule width throughout the instars indicates a stable growth rate, possibly associated with the larva's physiological adaptation to the host plant (Calvo and Molina, 2008; Castañeda-Vildózola et al. 2016; Panzavolta, 2007).

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The low survival rate during the larval stage may reflect the species' intrinsic sensitivity to host plant defenses (Araújo et al. 2010; Carneiro et al. 2024). However, nearly one-third of the larvae successfully completed development, demonstrating the pest's potential to establish in commercial eucalyptus plantations. Pupal viability was significantly lower in larvae fed on *E. urograndis*, suggesting that sublethal effects of feeding on the alternative host may accumulate and impact the final transition to adulthood. This reduction in performance is characteristic of early stages of host range expansion, during which the pest is still undergoing adaptation to the novel host (Agrawal, 2003). Over time, *P. dukinfeldia* populations may experience selection and adapt to eucalyptus, potentially increasing host-use efficiency and reducing observed mortality rates.

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Despite the variations in development time and viability rates observed between host plants, *P. dukinfeldia* maintained a stable phenotypic pattern during the pupal stage. The absence of morphometric differences also suggests that although *E. urograndis* may pose challenges during larval development, the surviving individuals do not exhibit visible impairments in final growth. This pattern is common in cases of compensatory ontogenetic selection, ~~in~~ where ~~ich~~ individuals with greater ability to utilize the host offset early developmental deficits with more efficient growth rates during the later stages (Maino and Kearney, 2015). Furthermore, pupal size is directly related to the reproductive potential of adults, especially females, with direct implications for fecundity and population viability (Lee et al. 2023; Santos et al. 2023).

From a nutritional standpoint, both eucalyptus species tested in this study provide similar conditions for leaf consumption by the pest. *P. dukinfeldia* appears to feed with comparable efficiency across different eucalyptus species, reinforcing its potential generalist behavior regarding host plant use. Although individual foliar consumption was relatively low in this study (less than 1 cm^2 throughout development), this may be offset by population outbreaks if environmental conditions favor pest density increases. Therefore, even species with low individual consumption can cause significant damage at the population level, particularly during the early stages of infestation and in the absence of effective management strategies (Speight et al. 2008).

5. Conclusion

The emergence of *P. dukinfeldia* as a defoliator of *E. urograndis* highlights the need for proactive biological studies on newly observed pest species in forest plantations. Although this insect exhibited extended development times and reduced viability on eucalyptus compared to its native host, *S. terebinthifolia*, it was capable of completing its life cycle, indicating its potential to establish and adapt to commercial eucalyptus systems. This pioneering study provides essential baseline data on the biology, development, and feeding behavior of *P. dukinfeldia* under controlled conditions. The results underscore the pest's capacity to exploit eucalyptus as a viable host, even in the early stages of host adaptation. Given that individual foliar consumption was relatively low, but survival to adulthood was achievable, future outbreaks cannot be ruled out. The data generated here serve as a valuable reference for integrated pest

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Отформатировано: междустрочный, множитель 1,08 ин

Table 1 – Means lengthnumber (± SE) of 1st, 2nd, 3rd, 4th, 5th, and 6th instar periods, larval period, prepupal period, pupal period and larva-adult development cycle of *Physocleora dukinfeldia* in two forest species.

Specie	1st instar	2nd instar	3rd instar	4th instar	5th instar	6th instar	Larval period
Eucaliptus urograndis	4.90 ± 0.17	4.38 ± 0.16	4.97 ± 0.26	5.86 ± 0.23 a	4.97 ± 0.17	11.43 ± 0.39	35.07 ± 0.54 a
Schinus terebinthifolia	5.58 ± 0.21	4.00 ± 0.14	4.20 ± 0.19	4.21 ± 0.11 b	5.35 ± 0.21	9.22 ± 0.45	31.56 ± 0.56 b
P	0.1054	0.2559	0.1441	0.0002	0.4054	0.0524	0.0180

	Prepupal period	Pupal period	Larva-adult period
Eucaliptus urograndis	2.33 ± 0.12	15.04 ± 0.20	52.00 ± 0.53 a
Schinus terebinthifolia	1.88 ± 0.06	14.38 ± 0.28	48.13 ± 0.60 b
P	0.0755	0.3313	0.0160

[1]Means followed by the same lowercase letter per column do not differ from each other by the LS-Means adjusted by Tukey's test (*P* ≤ 0.05).

Отформатировано: По ширине, интервал Перед: 12 пт, после: 0 пт, междустрочный, одинарный

Table 2 – Means (± SE) head capsule width (mm) of *Physocleora dukinfeldia* larvae fed on two forest tree species.

Specie	2nd instar	3rd instar	4th instar	5th instar	6th instar
Eucaliptus urograndis	0.28 ± 0.01 a	0.46 ± 0.01	0.74 ± 0.02	1.15 ± 0.03	1.65 ± 0.05
Schinus terebinthifolia	0.26 ± 0.00 b	0.43 ± 0.00	0.71 ± 0.01	1.07 ± 0.02	1.53 ± 0.03
P	0.0217	0.0583	0.2408	0.0633	0.0574

[1]Means followed by the different lowercase letters per column differ from each other by the LS-Means adjusted by Tukey's test (*P* ≤ 0.05).

Table 3 – Mean ~~s~~ number (± SE) of weight, length, and width of male and female pupae of *Physocleora dukenfildea* from larvae fed with two forest species.

Specie	**Males**		
	Weight (mg)	**Length (mm)**	**Width (mm)**
Eucaliptus urograndis	0.07~~13~~ ± 0.00	10.90 ± 0.25	3.32 ± 0.06
Schinus terebinthifolia	0.07~~22~~ ± 0.00	11.09 ± 0.13	3.37 ± 0.06
P	0.085~~27~~	0.53~~01~~	0.67~~24~~
	Females		
Eucaliptus urograndis	0.0747 ± 0.00	11.57 ± 0.12	3.44 ± 0.04
Schinus terebinthifolia	0.0863 ± 0.00	11.77 ± 0.15	3.56 ± 0.05
P	0.076~~55~~	0.37~~668~~	0.18~~772~~

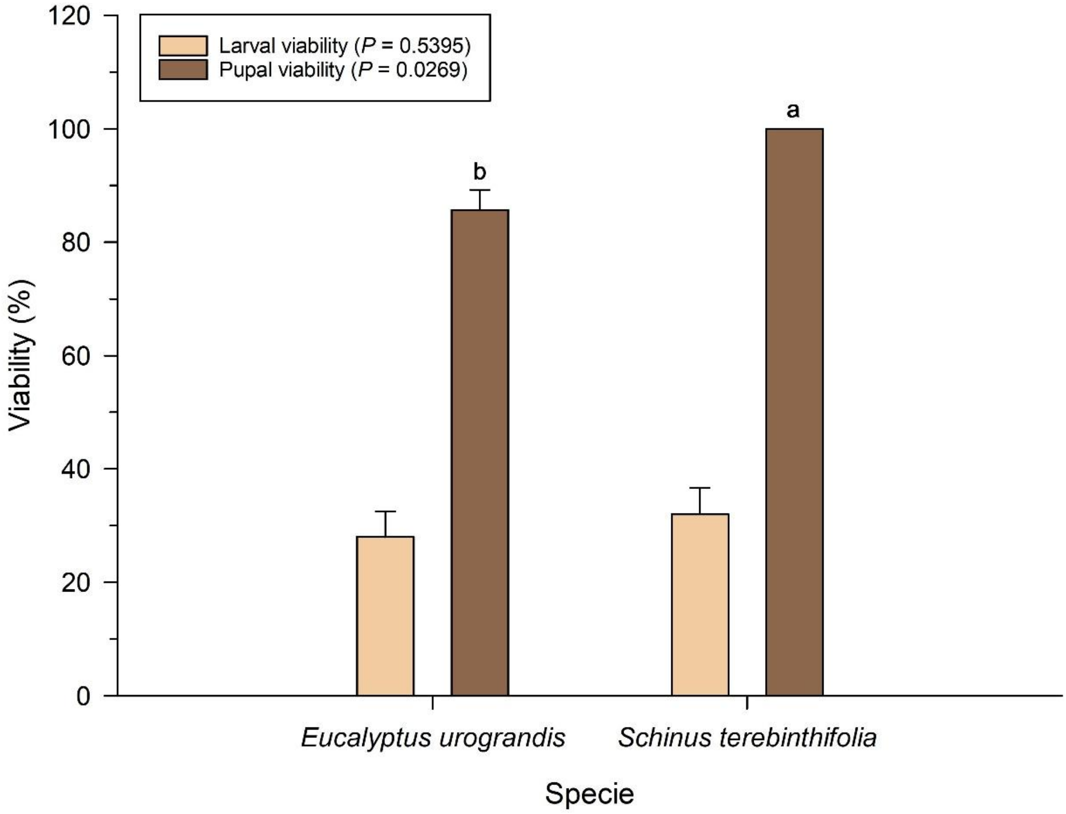

Figure 1 - Means (± SE) of larval and pupal viability of *Physocleora dukinfeldia* in forest species. Means followed by the same lowercase letter do not differ from each other by the LS-Means adjusted by Tukey's test ($P \leq 0.05$).

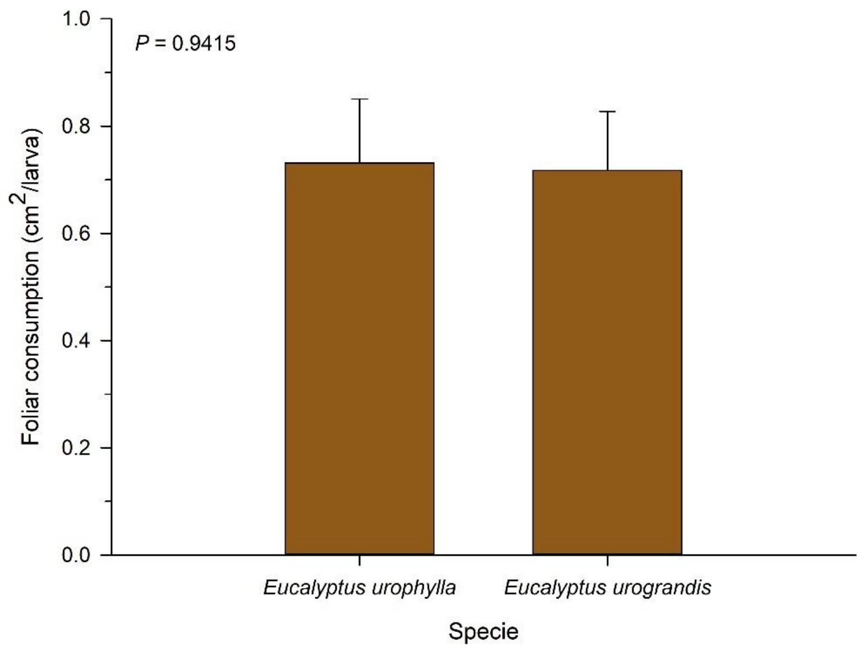

Figure 2 – Total leaf consumption (± SE) of *Physocleora dukinfeldia* larvae fed with leaves of forest species. Total leaf consumption considers the total consumed by the individual until its death or passage to the prepupal phase.