

Article

Effect of Pasture Height on the Development of Free-Living Stages of *Haemonchus contortus* and *Haemonchus placei*

Cesar Cristiano Bassetto [†], Michelle Cardoso Santos [†], Natalia Mizuhira Magro
and Alessandro Francisco Talamini do Amarante ^{*}

Department of Biodiversity and Biostatistics, Institute of Biosciences, Sao Paulo State University (UNESP), Botucatu 18618-689, SP, Brazil; cesar.bassetto@unesp.br (C.C.B.); michelle.cardososantos@yahoo.com (M.C.S.); mizuhira.nmagro@gmail.com (N.M.M.)

^{*} Correspondence: alessandro.amarante@unesp.br

[†] These authors contributed equally to this work.

Simple Summary

Haemonchus contortus and *Haemonchus placei* are parasitic nematodes of sheep and goats and cattle, respectively, but can cross-infect different species of ruminants when they share the same pasture. Understanding the biology of both species is crucial, as it allows for the application of different management strategies in animal production. The development of *H. contortus* and *H. placei* from eggs to infective larvae was evaluated in two different environments. Different temperatures were recorded for the short grass and the tall grass; nonetheless, morphological development from eggs to infective larvae was similar for both species, but the tall grass favoured the development of *H. contortus* and *H. placei*.

Abstract

Haemonchus contortus and *Haemonchus placei* infect different species of ruminants, but when small ruminants and cattle share the same pasture, cross-infections can occur. Weather conditions and the herbage microenvironment influence the development and survival of larvae during the free-living stage. Development of free-living stages (eggs, L1, L2, and L3) for both nematode species in sheep faeces deposited on short grass (4 cm) and tall grass (60 cm) ground was evaluated during nine days at the beginning of the rainy season. Rainfall occurred during five of the nine days assessed, and the tall and short grass environments demonstrated different temperatures, with a maximum of 34.0 °C to 42.0 °C and 31.0 °C to 38.0 °C and a minimum of 12.0 °C to 17.0 °C and 10.0 °C to 24.5 °C for the short and tall grass, respectively. Due to the development of eggs into infective larvae (L3), decreased egg counts were observed over time in faecal samples from both species and environments. However, some eggs were still present in samples until eight days post-deposition among tall grass. In both environments, the development times for all larval stages were similar. Small numbers of *H. contortus* larvae were found in the soil and grass, whereas no *H. placei* larvae were found. In conclusion, the trend of development in different environments was similar for both nematode species; however, the tall grass environment provided better conditions for the development of larval stages of both *Haemonchus* species.

Keywords: epidemiology; nematode; ruminant; larval development; sheep; faeces



Academic Editor: Ceferino
Manuel López

Received: 17 July 2025

Revised: 5 September 2025

Accepted: 9 September 2025

Published: 10 September 2025

Citation: Bassetto, C.C.; Santos, M.C.; Magro, N.M.; Amarante, A.F.T.d. Effect of Pasture Height on the Development of Free-Living Stages of *Haemonchus contortus* and *Haemonchus placei*. *Ruminants* **2025**, *5*, 43. <https://doi.org/10.3390/ruminants5030043>

Copyright: © 2025 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article

distributed under the terms and

conditions of the Creative Commons

Attribution (CC BY) license

([https://creativecommons.org/](https://creativecommons.org/licenses/by/4.0/)

<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Haemonchus contortus and *H. placei* are preferential parasites of small ruminants and cattle, respectively, although cross-infections can occur when hosts share the same pasture [1–3]. *Haemonchus* spp. infections lead to losses in livestock production, and the growing issue of anthelmintic resistance jeopardises infection prophylaxis [4–6]. Infective larvae (third-stage larvae or L3) of *H. contortus* are present in sheep-grazed pastures year-round in Sao Paulo state, leading to high worm burdens and faecal egg counts (FECs) in animals at any time [7,8]. For this reason, it is imperative to adopt grazing strategies to minimise the risk of haemonchosis, which can cause anaemia, weight loss, and even the death of livestock. Such prophylactic strategies require knowledge about the biology of the free-living stages of the nematodes found in the pastures.

Haemonchus adult females are capable of producing thousands of eggs per day [9]. Such eggs are released to the environment in faeces, where the development of the pre-infective stages takes place. However, only a small percentage of the eggs of cattle and sheep nematodes give rise to the L3 in the environment [10,11]. Generally, the L3 with the double cuticle (sheath) is the most resistant stage to environmental conditions, followed by the embryonated egg, unembryonated egg, and first (L1) and second (L2) pre-infective larval stages [12].

Environmental conditions influence the successful development and survival of *Haemonchus* spp. in the free-living stages. The most favourable conditions for the development of the pre-infective stages are relatively high temperatures and adequate moisture in faeces, which is required to avoid desiccation before the L3 stage can be reached.

Temperature and moisture predominantly influence the free-living stages, whereas pasture conditions modulate these effects. The length and success of the development cycle are dependent largely on temperature, with the development rate increasing at warmer temperatures, e.g., *H. contortus* are most susceptible to cold temperatures, followed by *Trichostrongylus colubriformis* and then *Teladorsagia circumcincta*. There has been somewhat less research assessing the impact of moisture on free-living development; however, it is evident that *H. contortus* is most vulnerable to desiccation during the pre-infective stages. While a substantial amount of data exists regarding temperature thresholds for development, information on the impact of temperature on the rate of development is rather scarce. The creation of functions, informed by current temperatures, that delineate the duration from egg deposition to each free-living stage, as well as the success rate of development, would provide essential data for forecasting the probability of pasture infectivity at a specific time after a grazing event [13]. In addition, larval development and survival rate increase during the period of the year with high temperatures associated with rainfall [14–16], which also contributes to the migration of *H. contortus* L3 from faeces to the upper herbage strata, facilitating larvae ingestion by the host [17,18].

The height of the forage plays an important role in the microenvironment. The retrieval of *H. contortus* and *T. colubriformis* L3 was insignificant when sheep faeces were deposited on shorter herbage grounds, whereas higher rates of development were observed when faeces were protected by taller forages [10,19]. Thus, this study aimed to evaluate the influence of the herbage height on the development of the free-living stages of *H. contortus* and *H. placei* and to compare the development rate of both species in sheep faeces. We hypothesised that because sheep faecal pellets contain less moisture than cattle faeces, *H. placei* might have a lower rate of development in sheep faeces compared to *H. contortus*. It is possible that, during the process of speciation, *H. placei* became adapted to developing in cattle dung that contains higher levels of moisture than sheep faeces.

2. Materials and Methods

2.1. Experimental Site

This study was carried out at the beginning of the rainy season (November 2011) in a paddock located at S 22° 53.268' W 48° 29.236' at an altitude of 876 m asl in the Sao Paulo State University (UNESP), Botucatu, Sao Paulo State, Brazil. Rainfall and temperature information was obtained daily on the study site. The rainfall was measured using a rain gauge (Multitec®; São Leopoldo, Brazil), and the maximum and minimum temperatures at ground level were measured using a thermometer (J Prolab®, Curitiba, Brazil). It was decided to conduct the trial during a warm and rainy period of the year, which is considered suitable for the *Haemonchus* spp. free-living stage migration previously observed at our study site [17,18]. The total rainfall during the experiment was 35 mm, and the average maximum and minimum temperatures were 27.7 °C and 15.7 °C, respectively. These data and the relative humidity (RH) and solar isolation (SI) during the trial period were obtained from the Meteorological Station of the Rural Engineering and Socioeconomics, School of Agricultural Sciences, São Paulo State University (UNESP, Botucatu, São Paulo State, Brazil), located 8 km from the experimental site.

2.2. Experimental Animals and Collection of Faecal Samples

The *H. contortus* isolate was donated by Dr F.A.M. Echevarria in 2001. Infective larvae produced from housed sheep were kept frozen since that year until they were used in this trial [20]. *H. placei* was isolated from a bovine naturally infected with gastrointestinal nematodes in 2005 and was used to infect donor calves on two different occasions, the last one in 2009. Two lambs were infected with *H. contortus* and two calves with *H. placei*; they served as donors of faeces for faecal composites and produced fresh larvae to infect the lambs used in this trial [20].

Two Santa Ines crossbred male lambs (*Ovis aries*), around six months old, were dewormed and maintained indoors to avoid any other infections with gastrointestinal nematodes and used as faecal donors. One lamb was infected with *H. contortus* (4000 L3), and the other one received *H. placei* (4000 L3). The lambs' worm-free status as well as the *Haemonchus* isolates used have been described previously [20].

On 21 November 2011 (day 0), each donor lamb was harnessed from 8 a.m. until 4 p.m. for faecal collection. After removing the collection bag, five samples of each donor animal (infected with either *H. contortus* or *H. placei*) were taken at random to estimate the faecal egg counts using a modified McMaster technique [21].

Fifteen faecal samples, each with 50 intact faecal pellets, were prepared for each *Haemonchus* species: five to be used as a control, five to be placed among short grass (4 cm), and five to be placed among tall grass (60 cm). The control samples were placed in pre-labelled Petri dishes and maintained in a BOD incubator (Eletrolab® EL101/3, São Paulo, Brazil) at 26 °C; in these Petri dishes, moistened filter paper was attached to the upper plate to provide a controlled environment for larval development.

The experimental area was planted with *Urochloa decumbens* grass, which had not been grazed by animals, so it was free of gastrointestinal nematode larvae. The faecal deposition sites had been previously chosen and marked with stakes to indicate the deposition of the samples. The faecal samples were deposited on the soil next to each stake and among the herbage (Figure 1).

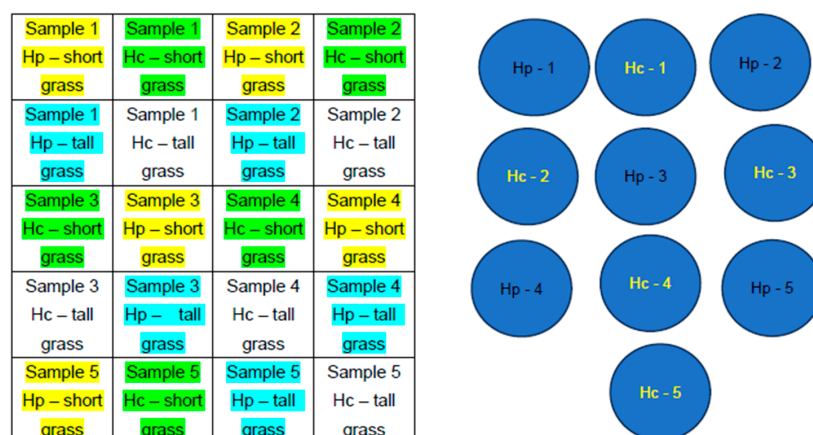


Figure 1. Schematic representation of the distribution of the faecal samples among the herbage. Each sample consisted of 50 intact faecal pellets containing either *Haemonchus contortus* (Hc) or *Haemonchus placei* (Hp) eggs. In the field, samples were placed among short grass (4 cm) and among tall grass (60 cm). The control samples were placed in Petri dishes and maintained in an incubator at 26 °C.

2.3. Sample Collection and Laboratory Analysis

Faecal samples from the incubator (control group) and those deposited on pasture were processed in the same way. Starting 24 h after faecal deposition (day 1), samples were collected at 4 p.m. (for larvae and egg examinations), and these procedures were repeated on each consecutive day from day 1 until day 9. At each sampling time, four faecal pellets were recovered from each deposition. The pellet samples were stored separately for subsequent processing in the laboratory. On the last day of the trial (day 9), the grass, from 10 cm from the centre of the pellet deposition, and the superficial layer of soil, to a depth of approximately 1 cm, from beneath the pellets, were also collected. The samples were stored separately in pre-labelled plastic bags for further processing in the laboratory.

Laboratory analysis consisted of faecal pellet processing to determine FEC using two of the four collected pellets. The volume of the flotation solution was adjusted according to the weight of the faecal pellets, always maintaining the same proportion (1 g of faeces in 29 mL of flotation solution). Faecal egg counts were performed daily until day 8. The other two pellets were processed by the Baermann technique for larvae recovery [21]. The soil and pasture larvae were recovered according to techniques previously described [17,22].

The L1, L2, and L3 stages (Figure 2) were identified according to [23,24]. The L1 were identified after egg hatching based on size, oesophagus rhabditoid appearance, and bulb presence. The L2 were differentiated by size and the constriction of the oesophagus as it became less marked or lost its rhabditoid form. Finally, larvae with a double cuticle (sheath) were identified as L3. *Haemonchus* larvae were distinguished from free-living nematodes following the descriptions of [25].



Figure 2. Free-living larvae of *Haemonchus* spp.: (A) first-stage larvae (L1); (B) second-stage larvae (L2); (C) third-stage larvae (L3).

2.4. Statistical Analysis

Data were analysed by a general linear model with the programme Statistical Analysis System[®], version 9.2 (SAS Institute, Inc., Cary, NC, USA). Means were compared by a Student's *t*-test at a 5% significance level. The results were analysed following a logarithmic transformation ($\text{Log}_{10}(x + 1)$), and they are presented as the arithmetic mean ($\pm$ standard error) of untransformed data.

3. Results

3.1. Experimental Site and Meteorological Conditions

Precipitation occurred at 1, 2, 6, 8, and 9 days post-deposition, with accumulations of 7, 10, 7.5, 2.5, and 8 mm, respectively (Table 1). The average relative humidity during the trial period was 67.4%, and the average solar insolation was 6.3 kWh/m²/d (Table 1). Due to frequent rains, faecal samples began to degrade after seven days of deposition.

Table 1. Maximum, minimum, and mean daily temperature (measured at ground level), rainfall, relative humidity (RH) and solar insolation (SI) during the trial. Sheep faecal pellets containing eggs with *H. contortus* or *H. placei* were deposited on day 0 on the ground covered by *Urochloa decumbens* grass.

Days	Temperature (°C) at Short Grass Level (4 cm)			Temperature (°C) at Tall Grass Level (60 cm)			Rainfall (mm)	RH ** (%)	SI ** (kWh/m ² /d)
	Maximum	Minimum	Mean	Maximum	Minimum	Mean			
1	34.0	*	*	32.0	10.0	21.0	7.0	63.8	7.4
2	36.0	12.0	24.0	31.0	13.0	22.0	10.0	65.6	7.5
3	36.0	12.0	24.0	34.0	15.0	24.5	0	50.5	7.2
4	42.0	13.0	27.5	38.0	15.0	26.5	0	63.9	2.6
5	40.5	17.0	28.8	36.0	17.5	26.8	0	70.6	6.2
6	39.0	12.5	25.8	31.0	24.5	27.8	7.5	63.9	6.8
7	39.0	15.0	27.0	32.5	18.0	25.3	0	74.9	5.9
8	36.0	15.0	25.5	32.5	18.0	25.3	2.5	78.7	5.7
9	35.5	17.0	26.3	35.0	19.5	27.3	8.0	74.8	7.3

* Data was not recovered. ** Source: Rural Engineering and Socioeconomics, School of Agricultural Sciences, São Paulo State University (UNESP, Botucatu, São Paulo State, Brazil), located 8 km from the study site.

The difference between mean temperatures above the soil of the short and tall grass areas was about 3.0 °C. In the short grass, the average maximum and minimum temperatures were 37.6 °C and 14.2 °C, respectively, and the highest maximum temperature (42.0 °C) was observed in this location at day 4 (Table 1). In the tall grass, the average maximum and minimum temperatures were 33.6 °C and 16.7 °C, respectively.

3.2. Development of Eggs to Third-Stage Larvae

The initial (Day 0) mean FEC of the samples containing *H. contortus* and *H. placei* eggs were 3560 ± 386.78 epg and 2240 ± 248.19 epg, respectively (Figure 3A,B). Free-living stages of *H. contortus* developed in the short grass, L1 were present on Day 1 post-deposition, and L2 and L3 on the following days (Figure 4); 45 L3 were recovered on the last day (Day 9), corresponding to 0.06% of the total eggs deposited. *H. placei* also showed the presence of L1 on Day 1 post-deposition, demonstrating that the eggs developed and hatched (Figure 4).

In tall grass and in the control group (incubator), similar patterns of larval development was observed for both *Haemonchus* species in the tall grass and incubator (control) environments. The FEC decreased over time due to egg hatching associated with the appearance of L1 (Figure 4A,B). L1 started to appear on Day 1 post-deposition, followed by the presence of L2 (Figure 4C,D) from Day 2 post-deposition, which continued to be recovered until the last day of sampling. The recovery of *H. contortus* and *H. placei* L3 started on Day 3 post-deposition, on the control for *H. contortus* and on tall grass and

control of *H. placei* (Figure 4E and 4F, respectively). High numbers of L3 were observed until the last day of the trial. In the tall grass, some eggs did not hatch during the initial days of the trial and were still detected 8 days after faecal deposition (160 ± 160 *H. contortus* and 60 ± 40 *H. placei* epg (Figure 3).

The highest recovery of *H. contortus* L3 from control cultures occurred in the last five days of the trial (Days 5–9), with an overall mean of 805 L3 during this period (Figure 4E). In the tall grass samples, the highest means were recorded in the last three days (Day 7–9), with an overall mean of 54 L3 (recovered from the faecal pellets), a value that corresponds to 6.7% of that recorded in the control cultures. In relation to *H. placei*, the highest yield of L3 in the control cultures occurred in the last three days of the trial (Days 7–9), with an overall mean of 199 L3 (Figure 4F), while in the tall grass, an overall mean of 14.5 L3 was recorded in the last two days (recovered from the faecal pellets), corresponding to 7.3% of the control group. L3 means differed between the tall and short grass on days 5, 6, 7, 8, and 9 due to an absence of L3 in the short grass faecal samples ($p < 0.05$).

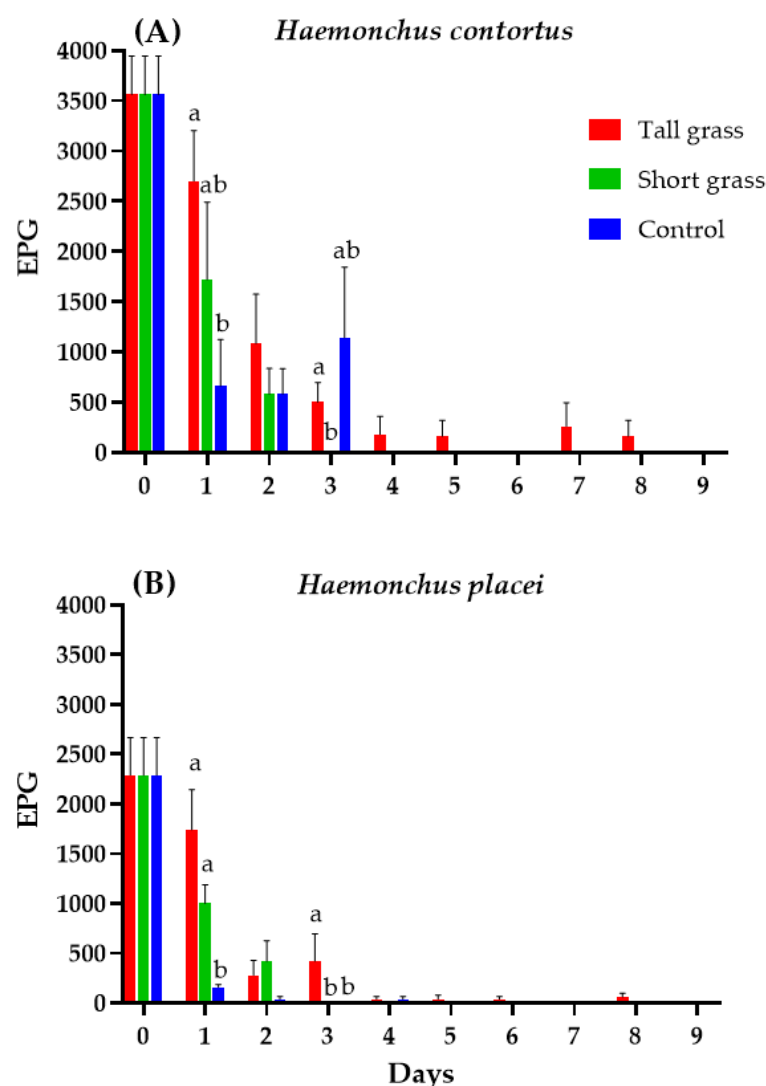


Figure 3. Mean faecal egg counts (expressed as eggs per gram, epg) of *H. contortus* (A) and *H. placei* (B) in different study environments (tall grass, short grass, and control (incubator)). Significant differences ($p < 0.05$) between the groups on each sampling day are indicated by different letters. Each bar represents the mean of five samples and its standard error.

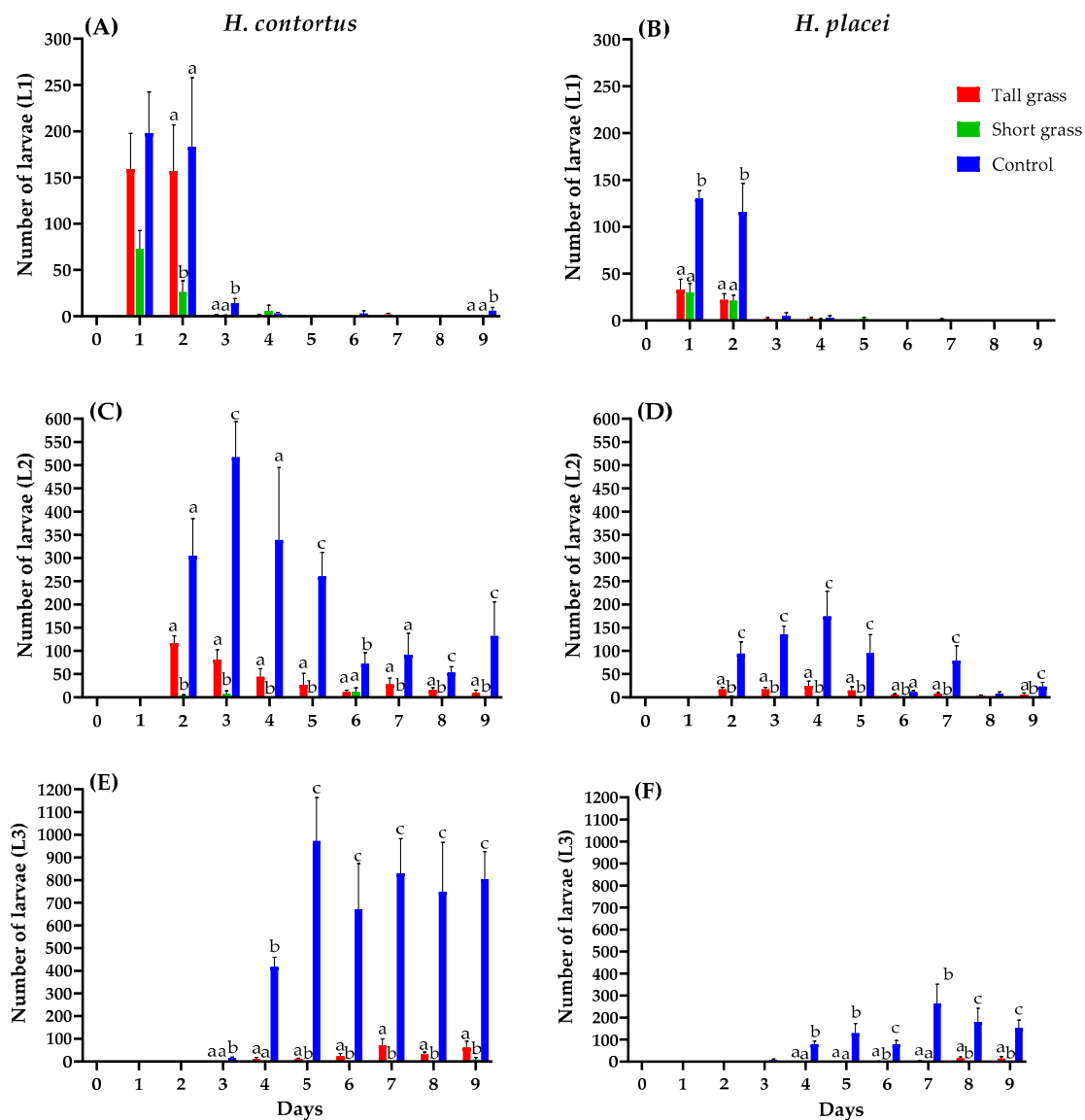


Figure 4. Mean numbers of *H. contortus* and *H. placei* larvae recovered from faecal pellets as L1 (A,B), L2 (C,D) and L3 (E,F) in three different environments: tall grass, short grass, and control (incubator). Significant differences ($p < 0.05$) between the groups on each sampling day are indicated by different letters. Each bar represents the mean of five samples and its standard error.

The presence of larvae was assessed in samples of herbage and soil collected on the last day of the trial (Day 9) to estimate the L3 migration from faecal pellets to herbage and soil. In the herbage, only 5 and 11 *H. contortus* L3 were recovered from the tall grass and short grass, respectively. A single *H. contortus* L2 and three L3 were recovered from the five soil samples of the short grass environment, whereas a total of five L3 were isolated from the soil in the tall grass environment. No *H. placei* larvae were recovered from herbage or soil samples in both environments (tall and short grass).

4. Discussion

An interesting finding of the present study was that in late spring, with moderate rainfall and mild temperatures, there was almost a complete disappearance of the free-living stages when faeces were deposited among short herbage and that the moisture provided by frequent rains during the trial was insufficient to prevent the deleterious effects of the direct solar radiation associated with high thermal amplitude (22.9 °C).

Such adverse conditions possibly had a negative impact, especially in the initial free-living stages that are very vulnerable and may be destroyed when direct solar radiation causes faecal dryness [26]. Due to the double sheath, L3 are considered more resistant than other free-living stages regarding desiccation and ultraviolet light exposure [27,28].

The decrease in the number of eggs at Day 1 is predictably explained by the hatching of the eggs and the emergence of L1, which is not possible to observe from Day 2 onwards. It is also observed that the number of recovered L1 and L2, mainly for *H. contortus*, does not correspond to the number of L3. These results are not just from the field samples, but they are confirmed with the control samples from the incubator.

Another important finding was that in a suitable microenvironment provided by the tall pasture (60 cm), the L3 start to appear three days after faecal deposition in the environment, i.e., only faeces protected from the sun at the base of the tall grass yielded L3. The same was also observed in Botucatu, Brazil, where the highest recoveries of larvae were observed in the tall grass (30 cm) environment, which was more favourable to the development and survival of larvae than was short grass 5 cm in height [10,19]. Therefore, the microclimate provided by herbage with high height helped to prevent desiccation and protected faeces from solar radiation, which favoured the L3 survival. However, it is important to emphasise that the number of L3 in this environment was significantly lower than that observed under controlled conditions in the laboratory. Based on the present results, it is possible to infer that an intensive rotational grazing system that reduces herbage height to less than 5 cm, along with moving animals to a new paddock in less than four days, might drastically reduce the risk of high infections during the “rainy season”, corroborating previous studies [13,19].

In the tropical environment of the Pacific Island of Tongatapu, [29] observed that hatching and development for all nematode species were rapid and continuous, with a short survival period on the pasture (3–7 weeks) for the resulting L3. Their results indicated that a rotational grazing system consisting of ten paddocks, grazed in sequence for 3.5 days at a time, favoured the control of gastrointestinal nematodes in goats. The results of the present study demonstrated that 3 days would be sufficient for L3 development under climatic conditions similar to the ones recorded in the present study, i.e., if the animals stayed in the same pasture for more than three days, they were at risk of acquiring infective larvae derived from their own faeces. It is also important to consider that with rotational grazing, it is possible to increase the stocking rates, which may have an adverse effect due to an increase in environmental contamination by free-living stages of nematodes [30].

Similarly to *H. contortus*, the free-living stages of the cattle parasite *H. placei* developed well in sheep faeces kept in the incubator. The trends in the development were like those observed with *H. contortus* in the different environments. This finding reinforces the concept that the host–parasite specificity is basically due to the host immune response [20], and it is not related to poor development of *H. placei* free-living stages in sheep faeces. These results indicate that sheep infected only with *H. placei* may be used as donors of infective larvae of that species. It is much easier and cheaper to use a sheep as a donor than cattle.

5. Conclusions

H. placei and *H. contortus* present a similar rate of development in faeces, with the L3 starting to appear after three days in the environment during the rainy season. The results indicate that intensive grazing of paddocks that reduces grass height, thereby allowing direct solar exposure to the faeces, associated with a short time of grazing (no longer than three days), might contribute to the prophylaxis of haemonchosis in sheep during the rainy season (from late spring to early autumn) in the studied area.

Author Contributions: Conceptualization, C.C.B., M.C.S., N.M.M. and A.F.T.d.A.; methodology, C.C.B., M.C.S., N.M.M. and A.F.T.d.A.; validation, C.C.B., M.C.S., N.M.M. and A.F.T.d.A.; formal analysis, C.C.B. and M.C.S.; investigation, C.C.B., M.C.S. and N.M.M.; resources, C.C.B., M.C.S. and A.F.T.d.A.; data curation, C.C.B. and M.C.S.; writing—original draft preparation, C.C.B. and M.C.S.; writing—review and editing, C.C.B., M.C.S., N.M.M. and A.F.T.d.A.; visualisation, C.C.B. and M.C.S.; supervision, A.F.T.d.A.; project administration, A.F.T.d.A.; funding acquisition, C.C.B., M.C.S. and A.F.T.d.A. All authors have read and agreed to the published version of the manuscript.

Funding: Michelle C. Santos (grant # 2012/23941-2) and César C. Bassetto (grant # 2010/18678-5) received financial support from FAPESP (São Paulo Research Foundation). Natalia M. Magro received support from CAPES (Federal Agency for the Support and Improvement of Higher Education), and Alessandro F.T. Amarante received financial support from CNPq (National Council for Scientific and Technological Development).

Institutional Review Board Statement: The animal study protocol was approved by the Institutional Ethics Committee of the Institute of Biosciences (protocol code 274-CEEA, approved on 4 March 2011).

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Amarante, A.F.T.; Bagnola, J., Jr.; Amarante, M.R.V.; Barbosa, M.A. Host specificity of sheep and cattle nematodes in São Paulo State, Brazil. *Vet. Parasitol.* **1997**, *73*, 89–104. [\[CrossRef\]](#) [\[PubMed\]](#)
2. Jacquet, P.; Cabaret, J.; Thiam, E.; Cheikh, D. Host range and the maintenance of *Haemonchus* spp. in an adverse arid climate. *Int. J. Parasitol.* **1998**, *28*, 253–261. [\[CrossRef\]](#)
3. Achi, Y.L.; Zinsstag, J.; Yao, K.; Yeo, N.; Dorchie, P.; Jacquet, P. Host specificity of *Haemonchus* spp. for domestic ruminants in the savanna in northern Ivory Coast. *Vet. Parasitol.* **2003**, *116*, 151–158. [\[CrossRef\]](#) [\[PubMed\]](#)
4. Torres-Acosta, J.F.J.; Mendoza-de-Gives, P.; Aguilar-Caballero, A.J.; Cuéllar-Ordaz, J.A. Anthelmintic resistance in sheep farms: Update of the situation in the American continent. *Vet. Parasitol.* **2012**, *189*, 89–96. [\[CrossRef\]](#)
5. Bassetto, C.C.; Albuquerque, A.C.A.; Lins, J.G.G.; Marinho-Silva, N.M.; Chocobar, M.L.E.; Bello, H.J.S.; Mena, M.O.; Niciura, S.C.M.; Amarante, A.F.T.; Chagas, A.C.S. Revisiting anthelmintic resistance in sheep flocks from São Paulo State, Brazil. *Int. J. Parasitol.* **2024**, *24*, 100527. [\[CrossRef\]](#)
6. Borges, F.A.; Amarante, A.F.T.; Lopes, W.D.Z.; Canton, C.; Alvarez, L.; Lifschitz, A. Anthelmintic resistance of gastrointestinal nematodes in cattle in Brazil and Argentina-current status and global perspectives. *Braz. J. Vet. Parasitol.* **2024**, *33*, e010524. [\[CrossRef\]](#)
7. Rocha, R.A.; Bresciani, K.D.S.; Barros, T.F.M.; Fernandes, L.H.; Silva, M.B.; Amarante, A.F.T. Sheep and cattle grazing alternately: Nematode parasitism and pasture decontamination. *Small Rumin. Res.* **2008**, *75*, 135–143. [\[CrossRef\]](#)
8. Wilmsen, M.O.; Silva, B.F.; Bassetto, C.C.; do Amarante, A.F.T. Gastrointestinal nematode infections in sheep raised in Botucatu, State of São Paulo, Brazil. *Braz. J. Vet. Parasitol.* **2014**, *23*, 348–354. [\[CrossRef\]](#)
9. Coyne, M.J.; Smith, G.; Johnstone, C. Fecundity of gastrointestinal trichostrongylid nematodes of sheep in the field. *Am. J. Vet. Res.* **1991**, *52*, 1182–1188. [\[CrossRef\]](#)
10. Carneiro, R.D.; Amarante, A.F.T. Seasonal effect of three pasture plants species on the free-living stages of *Haemonchus contortus*. *Arq. Bras. Med. Vet. Zootec.* **2008**, *60*, 864–872. [\[CrossRef\]](#)
11. Fabiyi, J.P.; Copeman, D.B.; Hutchinson, G.W. Abundance and survival of infective larvae of the cattle nematodes *Cooperia punctata*, *Haemonchus placei* and *Oesophagostomum radiatum* from faecal pats in a wet tropical climate. *Aust. Vet. J.* **1988**, *65*, 229–231. [\[CrossRef\]](#)
12. Levine, N.D.; Todd, K.S., Jr. Micrometeorological factors involved in development and survival of free-living stages of the sheep nematodes *Haemonchus contortus* and *Trichostrongylus colubriformis*. A review. *Int. J. Biometeorol.* **1975**, *19*, 174–183. [\[CrossRef\]](#)
13. O'Connor, L.J.; Walkden-Brown, S.W.; Kahn, L.P. Ecology of the free-living stages of major Trichostrongylid parasites of sheep. *Vet. Parasitol.* **2006**, *142*, 1–15. [\[CrossRef\]](#) [\[PubMed\]](#)
14. Banks, D.J.D.; Singh, R.; Barger, I.A.; Pratap, B.; Le Jambre, L.F. Development and survival of infective larvae of *Haemonchus contortus* and *Trichostrongylus colubriformis* on pasture in a tropical environment. *Int. J. Parasitol.* **1990**, *20*, 155–160. [\[CrossRef\]](#)

15. Fernández-Ruvalcaba, M.; Vázquez-Prats, V.; Liebano-Hernández, E. Development and recovery of *Haemonchus contortus* first larval stages on experimental plots in Mexico. *Vet. Parasitol.* **1994**, *51*, 263–269. [[CrossRef](#)]
16. Ndamukong, K.J.N.; Ngone, M.M. Development and survival of *Haemonchus contortus* and *Trichostrongylus* sp. on pasture in Cameroon. *Trop. Anim. Health Prod.* **1996**, *28*, 193–198. [[CrossRef](#)] [[PubMed](#)]
17. Silva, B.F.; Amarante, M.R.V.; Kadri, S.M.; Carrijo-Mauad, J.R.; Amarante, A.F.T. Vertical migration of *Haemonchus contortus* third stage larvae on *Brachiaria decumbens* grass. *Vet. Parasitol.* **2008**, *158*, 85–92. [[CrossRef](#)] [[PubMed](#)]
18. Santos, M.C.; Silva, B.F.; Amarante, A.F.T. Environmental factors influencing the transmission of *Haemonchus contortus*. *Vet. Parasitol.* **2012**, *188*, 277–284. [[CrossRef](#)]
19. Rocha, R.A.; Rocha, G.P.; Bricarello, P.A.; Amarante, A.F.T. Recuperação de larvas infectantes de *Trichostrongylus colubriformis* em três espécies de gramíneas contaminadas no verão. *Braz. J. Vet. Parasitol.* **2008**, *17*, 227–234. [[CrossRef](#)]
20. Santos, M.C.; Xavier, J.K.; Amarante, M.R.V.; Bassetto, C.C.; Amarante, A.F.T. Immune response to *Haemonchus contortus* and *Haemonchus placei* in sheep and its role on parasite specificity. *Vet. Parasitol.* **2014**, *203*, 127–138. [[CrossRef](#)]
21. Ueno, H.; Gonçalves, P.C. *Manual Para Diagnóstico das Helmintoses de Ruminantes*, 4th ed.; Japan International Cooperation Agency: Tokyo, Japan, 1998.
22. Niezen, J.H.; Waghorn, G.C.; Charleston, W.A.G. Establishment and fecundity of *Ostertagia circumcincta* and *Trichostrongylus colubriformis* in lambs fed lotus (*Lotus pedunculatus*) or perennial ryegrass (*Lolium perenne*). *Vet. Parasitol.* **1998**, *78*, 13–21. [[CrossRef](#)] [[PubMed](#)]
23. Veglia, F. The anatomy and life history of the *Haemonchus contortus* (Rud). In *Third and Fourth Reports of the Director of Veterinary Research*; Government Printer and Stationery Office: Pretoria, South Africa, 1916; pp. 347–500.
24. van Wyk, J.A.; Mayhew, E. Morphological identification of parasitic nematode infective larvae of small ruminants and cattle: A practical lab guide. *Onderstepoort J. Vet. Res.* **2013**, *80*, 539. [[CrossRef](#)] [[PubMed](#)]
25. van Wyk, J.A.; Cabaret, J.; Michael, L.M. Morphological identification of nematode larvae of small ruminants and cattle simplified. *Vet. Parasitol.* **2004**, *119*, 277–306. [[CrossRef](#)]
26. Dinnik, J.A.; Dinnik, N.N. Observations on the longevity of *Haemonchus contortus* larvae on pasture herbage in the Kenya highlands. *Bull. Epizoot. Dis. Afr.* **1961**, *9*, 193–208.
27. Chylinski, C.; Lherminé, E.; Coquille, M.; Cabaret, J. Desiccation tolerance of gastrointestinal nematode third-stage larvae: Exploring the effects on survival and fitness. *Parasitol. Res.* **2014**, *113*, 2789–2796. [[CrossRef](#)] [[PubMed](#)]
28. van Dijk, J.; Louw, M.D.E.; Kalis, L.P.A.; Morgan, E.R. Ultraviolet light increases mortality of nematode larvae and can explain patterns of larval availability at pasture. *Int. J. Parasitol.* **2009**, *39*, 1151–1156. [[CrossRef](#)]
29. Barger, I.A.; Siale, K.; Banks, D.J.D.; Le Jambre, L.F. Rotational grazing for control of gastrointestinal nematodes of goats in a wet tropical environment. *Vet. Parasitol.* **1994**, *53*, 109–116. [[CrossRef](#)]
30. Colvin, A.F.; Walkden-Brown, S.W.; Knox, M.R.; Scott, J.M. Intensive rotational grazing assists control of gastrointestinal nematodosis of sheep in a cool temperate environment with summer-dominant rainfall. *Vet. Parasitol.* **2008**, *153*, 108–120. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.