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ScienceDirect
Veterinary Parasitology 146 (2007) 90–101
veterinary parasitology
www.elsevier.com/locate/vetpar

# The effects of amount, timing and distribution of simulated rainfall on the development of *Haemonchus contortus* to the infective larval stage

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Received 12 October 2006; received in revised form 22 January 2007; accepted 7 February 2007

**Abstract**

Three studies were undertaken to determine the effects of amount, timing and distribution of simulated rainfall on the developmental success of *Haemonchus contortus*. Faeces containing *H. contortus* eggs were deposited onto pasture plots under a rainfall-activated retractable roof which eliminated incident rainfall. In October (spring) 2004 and January (summer) 2005, the effects of amount (6, 12, 18 or 24 mm) and timing (1, 4, 8 or 15 days post-faecal deposition) of a single simulated rainfall event was investigated via manual application of water to plots. More *H. contortus* pre-infective larvae (L1 and L2) developed under the d 1 simulated rainfall treatment than later treatments. There was no effect of rainfall amount on development in either experiment, and negligible development to infective larvae (L3). In February (summer) 2006, the effects of amount (12, 24 or 32 mm) and distribution (single event or three smaller but equal split events over 32 h) of simulated rainfall events was investigated with water applied via sprinkler. In this experiment L3 were recovered from the herbage in one-third of the plots harvested, however recovery was low (0.08% of eggs deposited) and there were no treatment effects. Recovery of L1 and L2 from faeces increased with simulated rainfall amount at d 4, and more L1 and L2 were recovered from the split distribution treatment at d 4. The results indicate that moisture conditions soon after faecal deposition are key determinants of *H. contortus* development success, with significant penalties on development when simulated rainfall was applied 7 days or more post-deposition, and when the duration of simulated rainfall was short. High rates of evaporation during both summer experiments resulted in rapid drying of the micro-environment and this appears to have limited development to L3.


*Keywords:* *Haemonchus contortus*; Ecology; Free-living stages; Rainfall; Moisture

## 1. Introduction

The ecology of the free-living stages of *Haemonchus contortus* has been studied extensively under both laboratory and field conditions (reviewed by Levine, 1963; Michel, 1969; O'Connor et al., 2006), providing a thorough understanding of the temperature requirements for development to infective larvae (L3). However, our knowledge of the quantitative relationships between moisture, temperature and *H. contortus* development remains incomplete, limiting our ability to exploit the natural processes controlling free-living development for control of gastrointestinal nematodiasis. With the increasing popularity of intensive rotational grazing systems for sheep, and the demonstrated efficacy of these

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doi:10.1016/j.vetpar.2007.02.002

systems in controlling *H. contortus* (Healey et al., 2004), comes the opportunity to accurately determine the infective status of individual paddocks based on rainfall and temperature conditions. This information could be readily used in grazing systems with short (2–5 days) but intensive periods of grazing to delay re-stocking with sheep to a time when sufficient mortality of *H. contortus* infective larvae has occurred. In intensive rotational grazing systems with a large number of paddocks, it is probable that only a limited number of paddocks will become significantly infective following each grazing event, and the ability to determine and avoid this based on current climatic information will further facilitate integrated worm control.

The susceptibility of *H. contortus* pre-infective stages to desiccation (Rose, 1963; Waller and Donald, 1970; Rossanigo and Gruner, 1995) is highly characteristic of the species, limiting its distribution to areas with warm, moist summers and creating a natural barrier to development that results in sporadic development of the free-living stages. The sporadic nature of development is compensated for by the fecundity of *H. contortus* (Gordon, 1948) which means that under continuous stocking of pasture, short periods of favourable conditions for development generally produce significant numbers of L3. Rotational grazing systems disrupt this compensatory mechanism by disassociating areas of recent faecal deposition with areas grazed, both spatially and temporally.

Bioclimatographs developed by early researchers attempted to identify the rainfall conditions required for *H. contortus* development under continuous grazing conditions, defining approximately 50 mm as the minimum monthly rainfall required for outbreaks of haemonchosis (Gordon, 1948; Levine, 1963). More recently, attempts at modelling the free-living phase of *H. contortus* (Barger et al., 1972; R. Dobson, unpublished data) have used the ratio of, or difference between, cumulative precipitation and evaporation to describe the moisture conditions influencing development success. The former reported that 90% of hatched eggs would reach L3 stage if the cumulative P/E ratio exceeded 1 after 1 week, and 50% if it took 3 weeks to exceed 1. However, Besier and Dunsmore (1993) identified rainfall distribution following faecal deposition and the proportion of green herbage as better indicators of *H. contortus* development than total rainfall and evaporation post-deposition, observing that L3 recovery from pasture plots was higher following 8 mm of rainfall over 4 consecutive days compared to 26 mm on 1 day. Rossanigo and Gruner (1995) investigated faecal moisture content (FMC) as a predictor of *H. contortus* development, reporting optimal development of *H. contortus* eggs to L3 at 23 °C and FMC of 70%. O'Connor et al. (2006) signalled the potential to simplify the multitude of moisture influences on the free-living environment through determination of the relationship between macroclimate moisture variables and FMC, combined with the defining of the effects of FMC on each free-living developmental stage.

Although this current knowledge is valuable for predicting trends in field-scale development to L3 under continuous grazing, it does not provide detailed information on the effects of a given rainfall event on eggs recently deposited in faeces. As yet we cannot accurately correlate faecal moisture, or the amount, distribution and timing of rainfall relative to faecal deposition, with the development and success rates of *H. contortus* eggs. The maximum time allowable between faecal deposition and rainfall in order for transmission to occur has been poorly quantified, and, given the short lifespan of *H. contortus* pre-infective stages, the 50 mm threshold for monthly rainfall defined by Gordon (1948) and Levine (1963) is of limited value for predicting pasture infectivity following a particular climatic or grazing event. The effect of rainfall distribution remains unknown, beyond the observational reports of Besier and Dunsmore (1993), and considerable research is required to determine the effects of rainfall variables, pasture conditions and prevailing temperatures on faecal moisture content before knowledge of its effects on development can be utilised in a practical manner.

Three studies were undertaken in order to address these deficiencies, testing *H. contortus* transmission on pasture in the Northern Tablelands of NSW under a controlled rainfall environment. Experiments were conducted using pasture plots under a rainfall-activated retractable roof to assess the effect of simulated rainfall events on free-living stages. Whereas earlier studies have relied on incidental rainfall to evaluate moisture effects on development (Gordon, 1948; Barger et al., 1972; Besier and Dunsmore, 1993), the current study was designed to explicitly measure the impact of a given amount, timing and distribution of rain applied under controlled conditions. The purpose of measuring *H. contortus* development at simulated rainfall increments, under otherwise naturally occurring climatic conditions, was to determine: (a) how soon after faecal deposition a rainfall event is required for pre-infective stages to remain capable of development, (b) whether a quantitative relationship existed between rainfall amount and *H. contortus* development, and (c) whether