Table S1. The minimum (Min.), maximum (Max.) and optimum temperature (in °C) for hatching of free-living parasitic nematodes with a direct life cycle in birds and terrestrial mammals under laboratory conditions. See Mkandawire *et al*., (2022), for an extensive review on the hatching processes and the involved intrinsic and extrinsic factors.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Host | Parasite | Min. °C | Max. °C | Optimum °C | Reference | Comment |
| Sheep | *Haemonchus contortus* | 9 | 36 |  | (Crofton, 1965) | Shortest hatching time at 36 °C. |
| Sheep | *Ostertagia circumcincta* | 4 | 34 |  | (Crofton, 1965) | Shortest hatching time at 34 °C. |
| Sheep | *Trichostrongylus axei, Trichostrongylus vitrinus* | 8-9 | 36 |  | (Crofton, 1965) | Shortest hatching time at 36 °C. |
| Sheep | *Cooperia curticei,*  *Cooperia oncophora, Bunostomum trigonocephalum* | 16 | 38 |  | (Crofton, 1965) | Shortest hatching time at 38 °C. |
| Sheep | *Chabertia ovina* | 6 | 36 |  | (Crofton, 1965) | Shortest hatching time at 36 °C. |
| Sheep, cattle, deer (Unspecified) | *Teladorsagia circumcincta, Ostertagia leptospicularis, Ostertagia ostertagi* |  |  | 23 | (C. Rossanigo & Gruner, 1995) | Optimum development temperature of 23 °C (with faecal moisture content FMC of 60%), within range of 5-33°C in faeces. |
| Sheep | *Trichostrongylus colubriformis* |  |  | 25-28 | (C. Rossanigo & Gruner, 1995) | Optimum development temperature at 25-28°C (with FMC of 60%), within range of 5-33°C in faeces. |
| Wombat | *Oesophagostomoides eppingensis* |  |  | 26 | (Smales *et al*., 2001) | Hatching occurred between 18 and 30 °C, with and optimum of 26 °C. Hatching did not occur at 4°C (with temperature of 4, 18, 22, 26 and 28 °C). |
| Sheep | *Nematodirus battus* | 11 | 17 | 13 | (van Dijk & Morgan, 2008) | Hatching was higher after a chill treatment at 4 °C. |
| Sheep (Lamb) | *Nematodirus filicollis* | 6 | 17-20 | 13 | (van Dijk & Morgan, 2009) | Hatching required chilling. |
| Reindeer | *Marshallagia marshalli* | 2 |  |  | (Carlsson *et al*., 2013) | Eggs didn't hatch at temperatures below 0 °C, or at mean temp of 0 °C. Hatching rate at 13 °C was quicker (11 days) than eggs at 8 °C (22 days). Eggs hatching at 2 °C took on average 113 days. |
| Sheep (Lamb) | *Nematodirus filicollis* |  |  |  | (Oliver *et al*., 2016) | Greater proportion of eggs hatched with chill accumulation. |
| Sheep | *Nematodirus battus* |  |  |  | (Melville *et al*., 2020) | In most populations, higher hatching proportion of larvated eggs that experienced chilling than at non-chilling, but for some populations hatching rate was higher at non-chilling than chilling conditions. |

Table S2. The minimum (Min.), maximum (Max.) and optimum temperature (in °C) for development of free-living parasitic nematodes with a direct life cycle in birds and terrestrial mammals under laboratory conditions.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Host | Parasite | Min. °C | Max.°C | Optimum °C | Reference | Comment |
| Cattle | Multiple (5 species) | 6 | 32 | 25 | (Ciordia & Bizell, 1963) |  |
| Sheep, deer (Unspecified) | *Teladorsagia circumcincta, Ostertagia leptospicularis* |  |  | 23 | (C. Rossanigo & Gruner, 1995) | At faecal moisture content of 60% and in a temperature range between 5 and 33 °C. |
| Cattle | *Ostertagia ostertagi* |  |  | 23 | (C. Rossanigo & Gruner, 1995) | At faecal moisture content of 60% and in a temperature range between 5 and 33 °C (in sheep and cow faeces). |
| Sheep | *Trichostrongylus colubriformis* |  |  | 25-28 | (C. Rossanigo & Gruner, 1995) | At faecal moisture content of 60% and in a temperature range between 5 and 33 °C. |
| Possum | *Parastrongyloides trichosuri* |  |  |  | (Stankiewicz, 1996) | Infective larvae were only observed at incubation at room temperature (20-23°C) and 26 °C (vs. incubation at 4, 10 °C). |
| Sheep, cattle, deer (Unspecified) | Multiple (four species) |  |  |  | (C. E. Rossanigo & Gruner, 1996) | L3 were longer at optimal development temperatures. This had no consequence for survival. |
| Sheep | *Haemonchus contortus* |  |  | 15 (vs. 5 and fluct -1 and 15) | (Troell *et al*., 2005) | Eggs did not develop at 5 °C or at fluctuating temperatures between -1 °C and 15°C |
| Sheep | *Nematodirus battus* | 11,5 | ~28 | 15 | (van Dijk & Morgan, 2008) |  |
| Sheep (Lamb) | *Nematodirus filicollis* | 12 | 25 |  | (van Dijk & Morgan, 2009) | Optimum temperature was at lower end of temperature range. |
| Reindeer | *Ostertagia gruehneri* | < 5 | 30-35 |  | (B. Hoar, 2012) | Development rate increased with increasing temperature, but with lower rate of increase for development from L2-L3 than the other stage transitions. Also, developmental stage duration (time spent in that specific stage), decreased with increasing temperature, but was longer for L2 than for the other stages. |
| Chicken (Hens) | *Ascaridia galli* | > 15 | < 35 | 20-30 | (Tarbiat *et al*., 2015) |  |
| Horse | *Strongyloides westeri* |  |  | 25 | (Gugosyan *et al*., 2018) | The optimum temperature for embryonic development was 25 °C with less optimal culture circumstances at the lower and higher temperatures. |
| Cattle | *Trichuris globulosa* |  |  | 25 | (V. O. Yevstafieva, Melnychuk, *et al*., 2020) | Temperature of 20 °C and 30 °C resulted in lower viability of eggs. |
| Horse | *Oxyuris equi Schrank* |  |  | 25 | (V. O. Yevstafieva, Prykhodko, *et al*., 2020) | Optimal temperature of embryogenesis was 25 °C, while survival decreased at 15 and 20 °C. 25 °C also resulted in fastest development. |
| Rabbits | *Passalurus ambiguus* |  |  | 35 (within range of 20-35) | (V. Yevstafieva *et al*., 2022) | At lower temperatures, development time increased and egg viability decreased. |
| Sheep | *Trichostrongylus* *vitrinus* | 9 | 39 | 23 | (Gyeltshen *et al*., 2022) | From egg to intra-pellet infective larvae. |
| Sheep | *Teladorsagia circumcincta* | 10 | 39 | 23 | (Gyeltshen *et al*., 2022) | From egg to intra-pellet infective larvae. |
| Sheep | *Trichostrongylus* *colubriformis* | 10 | 38 | 20 | (Gyeltshen *et al*., 2022) | From egg to intra-pellet infective larvae. |
| Sheep | *Trichostrongylus* *vitrinus* | 9 | 44 | 24 | (Gyeltshen *et al*., 2022) | Development from egg to pre-infective larvae. |
| Sheep | *Teladorsagia circumcincta* | 7 | 44 | 23 | (Gyeltshen *et al*., 2022) | Development from egg to pre-infective larvae. |
| Sheep | *Trichostrongylus* *colubriformis* | 9 | 47 | 28 | (Gyeltshen *et al*., 2022) | Development from egg to pre-infective larvae. |

Table S3. The optimum temperature (in °C) for survival of free-living parasitic nematodes with a direct life cycle in birds and terrestrial mammals under laboratory conditions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Host | Parasite | Optimum °C | Reference | Comment |
| Rat | *Strongyloides ratti* |  | (Gardner *et al*., 2004) | Optimum life span (mean and maximum) of virgin free-living females reduced significantly with increasing temperatures from 10 to 30 °C. |
| Sheep | *Haemonchus contortus* |  | (Troell *et al*., 2005) | Long term survival of infective larvae decreased especially at 15 °C (in comparison with 5 and fluctuating -1 and 15°C). |
| Sheep | *Ostertagia(Teladorsagia) circumcincta* |  | (Walker *et al*., 2007) | L3 larvae survived at 45 °C for at least 90 minutes, but were inactivated with higher temperatures. |
| Sheep | *Nematodirus battus* |  | (van Dijk & Morgan, 2008) | Larval death rate increased towards and above hatching threshold. For chilled L3 larvae, mortality rates decreased above 17 °C. For non-chilled L3 larvae, mortality rates were higher at 13, 15 and 17 °C than for chilled L3 larvae, and mortality increased with increasing temperatures. |
| Sheep (Lamb) | *Nematodirus filicollis* | 9-11 (vs. 9-30) | (van Dijk & Morgan, 2009) | Mortality of L3 was significantly lower at 9 and 11 °C than other temperatures within a range of 9 to 30 °C. Larvae survived longer at 13 °C than at 17 °C, and mortality increased quickly above 20 °C. |
| Reindeer | *Ostertagia gruehneri* |  | (B. Hoar, 2012) | Maximum recovery of larvae occurred at 5 °C and 20 °C, which suggested a trade-off between survival and development in which respectively slow and high development was compensated by high and lower survival. |
| Unspecified (Cattle) | *Cooperia oncophora* |  | (Knapp-Lawitzke *et al*., 2016) | Higher temperature (20-33 °C vs. 17-22.6 °C) and exposure duration negatively affected the overall recovery of L3 (proxy for survival). L3 recovery in soil was negatively affected by temperature, while recovery of L3 on grass was negatively affected by time. |
| Horse | *Oxyuris equi Schrank* | 25 | (V. O. Yevstafieva, Prykhodko, *et al*., 2020) | Highest survival rate of infectious eggs. |
| Sheep | *Marshallagia marshalli* |  | (Aleuy *et al*., 2020) | Survival decreased with increased freezing temperature (from -9 to -20 and -35 °C) and freeze duration. At low temperatures (-9 and -20 °C) survival rates of L3 and eggs were higher than for L1. Survival of unhatched L1 was higher than of hatched L1. |
| Barren-ground caribou | *Ostertagia gruehneri (pre-infective stage)* |  | (Peacock *et al*., 2022) | Mortality was lowest at 5 °C and highest at 30 °C (within range of 5-40 °C) . |
| Barren-ground caribou | *Ostertagia gruehneri (infective stage)* |  | (Peacock *et al*., 2022) | No consistent pattern (within range of 5-40 °C) with lowest mortality at 25 °C and highest at 30 °C. Mortality of infective larvae was lower than for pre-infective stages. |
| Chicken | *Ascaridia galli* |  | (Shifaw *et al*., 2022) | Overall treatment storage of eggs at 4 °C had higher percentage of total viable eggs than those stored at 26 °C, but viability depended strongly on storage condition and medium with optimal storage at 4 °C with anaerobic conditions and at 26 °C and aerobic conditions. |
| Sheep | *Teladorsagia circumcincta* |  | (Hamilton *et al*., 2022) | Recovery of L3 decreased after storage at 4 °C, but no comparison with other temperatures. |
| Cattle (Beef) | *Ostertagia ostertagi* |  | (Wang *et al*., 2022) | L3 survival was high between 0 and 30 °C (within tested range of -15 until 30 °C) in soil and faeces. |
| Cattle (Beef) | *Cooperia oncophora* |  | (Wang *et al*., 2022) | L3 survival was high between 0 and 30 °C (within tested range of -15 until 30 °C) but, mortality was higher in faeces than in soil. |
| Sheep | *Trichostrongylus* *vitrinus* | 23 | (Gyeltshen *et al*., 2022) | Predicted decrease of egg survival with increasing temperature. Survival of pre-infective larvae was largely insensitive to temperature and survival of infective larvae was predicted to increase with increasing temperatures and had temperature optimum. |
| Sheep | *Teladorsagia circumcincta* | 34 | (Gyeltshen *et al*., 2022) | ‘’ |
| Sheep | Trichostrongylus *colubriformis* | 27 | (Gyeltshen *et al*., 2022) | ‘’ |
| Cattle | *Dictyocaulus viviparus* |  | (McCarthy *et al*., 2022) | Mortality of parasitic larvae increased below 0 °C (in range of - 4 until 30 °C). |

Table S4. The effect of temperature on the development path of free-living parasitic nematodes with a direct life cycle in birds and terrestrial mammals under laboratory conditions.

|  |  |  |  |
| --- | --- | --- | --- |
| Host | Parasite | Reference | Comment |
| Rats | *Strongyloides ratti* | (Viney, 1996) | Homogonic development (development until L3 stage in which larvae are infective to hosts again) occurred mostly at 13 °C while at 30 °C heterogonic development (development to adult stage outside the host) occurred more often. |
| Rats | *Strongyloides ratti* | (Harvey *et al*., 2000) | Incubation temperature only affected the developmental pathway of females and not of males. Developmental path was also affected by host immune status (and by the interaction between temperature and host immune status for females). |
| Horse | *Strongyloides westeri* | (Gugosyan *et al*., 2018) | Optimal development temperature for the form of the free-living adults was 20 °C, while 30 °C for filariform larvae (that can infect host). |
| Sheep | *Marshallagia marshalli* | (Aleuy *et al*., 2019) | The larval stage at hatching depended on incubation temperature; above 20 °C larvae hatched as L3 (in contrary to as L1), with higher L3 hatching proportions at higher temperatures. |

Table S5. The effect of fluctuating versus constant temperatures on life history traits of free-living parasitic nematodes with a direct life cycle in birds and terrestrial mammals under laboratory conditions.

|  |  |  |  |
| --- | --- | --- | --- |
| Host | Species | Reference | Comment |
| Pheasants | *Heterakis gallinarum* | (Saunders *et al*., 2000b) | Faster egg development under fluctuating temperatures between 12°C and 22°C than at constant 17 °C, but slower than under constant 22 °C. |
| Pheasants | *Heterakis gallinarum* | (Saunders *et al*., 2002) | Earlier embryonation in stochastic daily cycles (12 °C and 17 °C) than in deterministic cycles (with similar mean temperature). |
| Sheep | *Nematodirus battus* | (van Dijk & Morgan, 2008) | Proportion of hatched eggs did not differ between fluctuating 11-15 °C and 14-20 °C from constant 15 °C. Development was less and slower at constant 20 and 25 °C than at constant 11, 13 and 15 °C and fluctuation between 14 – 20 °C (which did not differ from each other). Larva survival was higher at fluctuation of -5 and 6 than at 6 °C. At fluctuating 14-20 °C chilled larvae became hyperactive and died quicker than at 17 °C, while there was no difference for non-chilled larvae. |
| Sheep (Lamb) | *Nematodirus filicollis* | (van Dijk & Morgan, 2009) | Hatching percentage was similar between fluctuating 7-13 °C and constant 11 °C, and between 14-20 °C versus constant 13 °C. L3 mortality increased above 20 °C, and L3 survival at fluctuating temperatures of 14-20 °C was similar low to constant 20 °C and 25 °C. |
| Rabbit (European rabbit) | *Graphidium strigosum, Trichostrongylus retortaeformis* | (Hernandez *et al*., 2013) | Higher hatching rate at constant temperatures than cycle or stochastic temperatures, but more eggs hatched in stochastic than cycle trials and at the warm than cold temperatures due to higher thermal energy accumulation. |

Table S6. The effect of temperature on life history traits of free-living parasitic nematodes with a direct life cycle in birds and terrestrial mammals under field conditions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Host | Parasite | Reference | Stage | Comment |
| Reindeer | *Ostertagia gruehneri* | (B. M. Hoar *et al*., 2012) | L3 | Broad thermal range and upper threshold for development to L3 was suggested. However, there was no difference in abundance found between the different plots, as recovery rates were low. |
| Rabbit (European rabbit) | *Graphidium strigosum, Trichostrongylus retortaeformis* | (Hernandez *et al*., 2013) | L3 | More L3 larvae were recovered from faeces with eggs placed in the turf-grass within open top chamber OTC (with higher thermal energy accumulation) than plot without OTC, while the pattern was driven by recovery of *T.retortaeformis*. |

Table S7. Effect of moisture and precipitation on life history traits of free-living parasitic nematodes with a direct life cycle in birds and terrestrial mammals under laboratory conditions. FMC: Faecal moisture content.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Host | Species | Reference | Factor | Comment |
| Sheep, cattle, deer (Unspecified) | Gastrointestinal nematode (8 species) | (C. Rossanigo & Gruner, 1995) | FMC | Optimal FMC for development was between 60 and 70% at 23 °C. |
| Sheep, cattle, deer (Unspecified) | Multiple (8 species) | (C. E. Rossanigo & Gruner, 1996) | Moisture | L3 body length increased with faecal moisture content. This had no consequence on survival. |
| Sheep | *Haemonchus contortus* | (O’Connor *et al*., 2007) | Moisture requirement | Positive relation between rainfall amount and recovery of L3 from the soil, higher recovery after single rain event than split event and positive relation between larvae recovery and FMC and precipitation/evaporation ratio. |
| Sheep | *Haemonchus contortus* | (O’Connor *et al*., 2008) | Evaporation | Evaporation had a regulatory role on the influence of rainfall on L3 recovery/transmission, but no difference in L3 recovery between single and split rain events. |
| Sheep (Lamb) | *Nematodirus battus* | (van Dijk & Morgan, 2012) | Desiccation | Eggs kept in salt solution resulting in 95% and 70% RH at 20 °C showed accelerated hatch when put at 15 °C, while eggs at higher osmotic pressure (55% and 33% RH) died. |
| Sheep | *Haemonchus contortus, Trichostrongylus colubriformis* | (Khadijah, Kahn, Walkden-Brown, *et al*., 2013a) | Rainfall timing | Recovery of L3 in soil (extra-pellet) was highest when rain fall on the day of deposition (only for *Haemonchus* *contortus*). Recovery of L3 intra-pellet was highest with rain on day 0 and 1 of deposition (for both species). |
| Sheep | *Haemonchus contortus, Trichostrongylus colubriformis* | (Khadijah, Kahn, Walkden-Brown, *et al*., 2013c) | Soil moisture | Total recovery of L3 was affected by soil moisture (which modulated the effect of rainfall), rainfall timing and their interaction, but not by rainfall amount. |
| Sheep | *Haemonchus contortus, Trichostrongylus colubriformis* | (Khadijah, Kahn, Walkden-Brown, *et al*., 2013b) | Soil moisture | L3 recovery increased with rainfall, but benefit of rain decreased with increasing soil moisture. Recovery of L3 was higher with rain on day of deposition than rain during other days. |
| Unspecified (Cattle) | *Cooperia oncophora* | (Knapp-Lawitzke *et al*., 2016) | Drought | Drought stress had smaller (and non-significant) impact on recovery of L3 (proxy for survival) than temperature and duration, for both overall recovery, recovery of L3 in soil and in grass. |
| Sheep | *Trichostrongylus* *vitrinus* | (Gyeltshen *et al*., 2022) | FMC | Extensive results and prediction on effect of FWC on recovery of larvae stages, for example development of eggs to intra-pellet infective larvae were observed at 20% FMC, increasing development with increasing FWC up to 60% FMC and predicted minimum of 17 %. |
| Sheep | *Teladorsagia circumcincta* | (Gyeltshen *et al*., 2022) | FMC | Extensive results and prediction on effect of FWC on recovery of larvae stages, for example development of eggs to intra-pellet infective larvae were observed at 20% FMC, increasing development with increasing FWC up to 60% FMC, predicted minimum of 13 %. |
| Sheep | *Trichostrongylus* *colubriformis* | (Gyeltshen *et al*., 2022) | FMC | Extensive results and prediction on effect of FWC on recovery of larvae stages, for example development of eggs to intra-pellet infective larvae were observed at 20% FMC, increasing development with increasing FWC up to 60% FMC, predicted minimum of 16 %. |

Table S8. Effect of moisture and precipitation on life history traits of free-living parasitic nematodes with a direct life cycle in birds and terrestrial mammals under field conditions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Host | Species | Reference | Factor | Comment |
| Sheep | *Haemonchus contortus, Trichostrongylus colubriformis* | (Khadijah, Kahn, Walkden-Brown, *et al*., 2013) | Soil moisture | The importance of soil moisture for translation was suggested, since rainfall timing (on day -1, 0, 3 relative to faecal contamination), rainfall amount (0, 12 or 24 mm) and herbage height (4 or 12 cm) did not influence translation of *H.contortus* and *T.colubriformis* in sheep under the conditions of high soil moisture. |
| Racoon | *Baylisascaris procyonis* (but can have a direct and indirect lifecycle) | (Ogdee *et al*., 2016) | Soil characteristics | Viability of eggs was high (> 92 %) regardless of soil texture, moisture, and sun exposure. |
| Cattle and sheep | Endoparasites ( strongyles and non-nematodes Eimeria spp and Fasciola hepatica) | (May *et al*., 2022) | Wetting of pasture | Rewetting of the pasture did not have long term effect on infection of endoparasites (gastrointestinal strongyles, *Eimeria* *spp* or *F.hepatica*) in host. |

Table S9. Effect of moisture and temperature on life history traits of free-living parasitic nematodes with a direct life cycle in birds and terrestrial mammals under laboratory conditions. FMC: faecal moisture content.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Host | Species | Reference | Factor | Comment |
| Sheep, cattle, deer (Unspecified) | Gastrointestinal nematode (four species) | (C. Rossanigo & Gruner, 1995) | Temperature x moisture | Optimal FMC for development was between 57 and 68 %, at 18, 23 and 28 °C in faeces. The optimal faecal moisture content for development was not temperature dependent (three temperatures). |
| Cattle | *Dictyocaulus viviparus* | (McCarthy *et al*., 2022) | Temperature x moisture | No difference in L3 mortality under wet and dry treatments at 15, 20 and 25 °C in soil. |

Table S10. Effect of temperature on the behaviour of free-living parasitic nematodes with a direct life cycle in birds and terrestrial mammals under laboratory / greenhouse conditions.

|  |  |  |  |
| --- | --- | --- | --- |
| Host | Species | Reference | Comment |
| Red grouse | *Trichostrongylus tenuis* | (Saunders *et al*., 2000a) | L3 recovery on heather was higher at 10 than at 20 °C. There was an interaction between light and temperature and between light conditions and vegetation type. |
| Unspecified (Cattle) | *Cooperia oncophora* | (Knapp-Lawitzke *et al*., 2016) | L3 migrated more (but not significantly) into the soil than on the grass in the higher temperature regime (20 °C -33 °C and 26 %-64 % humidity) than the lower temperature regime (17 °C -22.6 °C, humidity between 33.9 and 38; in climate chamber). Individuals recovered from soil were considered as more fit than the individuals recovered from the grass (measured with a migration assay). |
| Sheep | *Haemonchus contortus* | (Wang *et al*., 2018) | In a controlled environment without moisture limitations, migration rate of L3 larvae out of faeces by using a sieve was lowest at the high and low end of the temperature range (7 °C-33 °C, and predicted maximum at 15 °C ) with RH of 95%. However, in a greenhouse setting 3 °C difference (mean temperature of 19.4 °C and 22.5 °C ) did not result in difference in faecal moisture content and did not affect L3 migration out of faeces. |
| Cattle | *Dictyocaulus viviparus* | (McCarthy *et al*., 2022) | Minimum, maximum and optimum temperature for migration due to fungus (*Pilobolus spp*) was estimated at 8.8, 30.7 and 20 °C. |
| Sheep | Trichostrongylus *vitrinus* | (Gyeltshen *et al*., 2022) | Predicted optimum temperature for infective larvae to migrate out of faeces was 33 °C. |
| Sheep | *Teladorsagia circumcincta* | (Gyeltshen *et al*., 2022) | Predicted optimum temperature for infective larvae to migrate out of faeces was 19 °C. |
| Sheep | *Trichostrongylus* *colubriformis* | (Gyeltshen *et al*., 2022) | Predicted optimum temperature for infective larvae to migrate out of faeces was 27 °C. |
| Sheep | *Teladorsagia circumcincta* | (Hamilton *et al*., 2022) | Migration proportion of L3 (through sieve under lab conditions) declined with duration of incubation at 30 °C, possibly due to high use of energy supplies at high temperatures. |

Table S11. The effect of temperature on skin penetrating nematodes under laboratory conditions.

|  |  |  |  |
| --- | --- | --- | --- |
| Host | Species | Reference | Comment |
| Possum | *Parastronglyoides trichosuri* | (Stankiewicz, 1996) | Movement towards higher temperatures (in form of metal stick warmed to 39 °C). |
| Rat | *Strongyloides ratti* | (Tobata-Kudo *et al*., 2000) | Thermokinetic behaviour and thermotaxis depended on the temperature individuals developed in and placed in at the start of the migration assay. |
| Human | *Necator americanus, Ancylostoma duodenale* | (Haas *et al*., 2005) | Larvae migrated towards warm end in thermal gradient but turned back and accumulated at different temperatures. |
| Rat | *Strongyloides ratti* | (Sakura & Uga, 2010) | Thermokinetic behaviour and thermotaxis of L3 larvae depended on the skin temperature of host. |
| Dogs | *Ancylostoma caninum* | (Franke *et al*., 2011) | Rate of migration increased with increasing temperatures, with maximum migration levels at temperature of 32°C and 37°C. |
| Rat | *Strongyloides ratti* | (Lee *et al*., 2016) | Incubation temperature also impacted olfactory responses. |
| Diverse | Multiple (5 species) | (Bryant *et al*., 2018) | Larvae responded to thermal gradients, showed positive and negative thermotaxis, and thermosensory behaviour could overcome attraction to odorants. |
| Human | *Strongyloides stercoralis* | (Pan *et al*., 2022) | Heat-seeking was context dependent, based on cultivation temperature and starting temperatures. |
| Human | *Strongyloides stercoralis* | (Bryant *et al*., 2022) | Larvae were able to reverse their path encountering heat sources that are not from the host. |
| Various | *Strongyloidoidea* | (Dulovic *et al*., 2022) | Species differed in response to temperatures and chemotactic responses. |

Table S12. The effect of rain and moisture on the behaviour of free-living parasitic nematodes with a direct life cycle in birds and terrestrial mammals under laboratory /greenhouse conditions. FMC: Faecal moisture content.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Host | Species | Reference | Factor | Comment |
| Sheep, cattle, deer | Multiple (8 species) | (C. E. Rossanigo & Gruner, 1996) | Moisture | Moisture positively affected body length of L3. Short L3 (collected from dry faeces) migrated slower on agar gel than long L3's (collected from wet faeces). For one species, establishment rate within host was lower for short L3 than for long L3. |
| Sheep | *Haemonchus contortus* | (O’Connor *et al*., 2008) | Evaporation / rain | Averaged over all (rain and evaporation) treatments, most of extra-pellet L3 were recovered from the upper stratum of soil, but proportion of L3 recovery in lower strata increased over time. Recovery of L3 from lower strata was higher with lower evaporation rates and with increasing amount of rain. |
| Sheep | *Nematodirus battus, Haemonchus contortus, Teladorsagia circumcincta* | (van Dijk & Morgan, 2011) | Water | Under constant temperature of 20 °C – 24 °C larvae only needed water to migrate out of faeces but did not need water (wetting of grass leaves) to move into herbage. |
| Sheep (Lamb) | *Haemonchus contortus* | (Wang *et al*., 2014) | Rain | At temperature of 25 °C to 27 °C L3 larvae needed water to migrate out of faeces through a sieve in a funnel. Rainfall amount and temporal distribution and relative humidity and hence faecal moisture content were of importance for migration out of faeces. |
| Unspecified (Cattle) | *Cooperia oncophora* | (Knapp-Lawitzke *et al*., 2016) | Drought | Drought stress had negative but non-significant effect on migration of L3 into soil. |
| Sheep | *Trichostrongylus* *vitrinus* | (Gyeltshen *et al*., 2022) | FMC | Predicted minimum and optimum FWC for infective larvae to migrate out of faeces pellet were 35% and 97%. |
| Sheep | *Teladorsagia circumcincta* | (Gyeltshen *et al*., 2022) | FMC | Predicted minimum and optimum FWC for infective larvae to migrate out of faeces pellet were 30% and 69%. |
| Sheep | *Trichostrongylus* *colubriformis* | (Gyeltshen *et al*., 2022) | FMC | Predicted minimum and optimum FWC for infective larvae to migrate out of faeces pellet were 52% and 93%. |
| Cattle (Beef) | *Ostertagia ostertagi,*  *Cooperia oncophora* | (Wang *et al*., 2022) | Rain | Estimated rainfall threshold for horizontal migration of L3 out of faeces (in greenhouse at 20 °C ) was estimated at 5.8 mm (*O.ostertagi*) and 6.7 mm (*C.oncophora*), and migration increased with increasing rainfall amount. |

Table S13. The effect of rain and moisture on the behaviour of free-living parasitic nematodes with a direct life cycle in birds and terrestrial mammals under field conditions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Host | Species | Reference | Factor | Description |
| Racoon | *Baylisascaris procyonis* (but can have a direct and indirect lifecycle) | (Ogdee *et al*., 2016) | Dry-wet soil | Eggs remained on surface of dry soils, and on sandy wet (most permeable) soils it took 1 year for 60% of the eggs to move from the surface to the next soil layer. |

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