Gastrointestinal nematodes in ruminants

Epidemiological principles
Integrated Parasite Management

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**Epidemiological principles**

- **Pasture contamination:**
  eggs passed by the animals with the feces onto pasture.
  Animals responsible for the contamination of pastures

- **Pasture infectivity:**
  infective larvae (L3) on pasture
  Environmental factors responsible for the development, transmission, and survival of L3 on pasture
Life cycle of gastrointestinal nematodes
Development time from egg to L3 *(inside feces)*

- **Spring**: 2-4 weeks
- **Summer**: 1-2 weeks
- **Autumn**: 4-6 weeks
Survival and dissemination of larvae on pasture

Protection of eggs and larvae from dessication for several weeks by crust of faecal pat.

Vertical migration by larvae

Horizontal migration by larvae

Protection by migration to lower herbage and soil to avoid dessication.
Pasture contamination and infectivity in 32 sheep flocks in Canada (May '06 – Apr '07)
Larval overwintering on pasture in Canadian flocks

(adapted from Pritchard et al, 1990)
Now what..?
Integrated Parasite Management

The crucial issue

“but, Doc, just give me a drug because what you suggest is too hard” syndrome

Ensure farmers (and vet advisors!) acceptance of IPM measures in contrast to dewormer treatments alone
Bioactive forages

Biological control

Immunity

Integrated Parasite Management

Monitoring

Anthelmintics (dewormers)

Grazing strategies

Nutrition

Genetics
What we don’t know, we cannot manage...

Monitoring (FEC) at times when the flock is at highest risk (e.g. ewes: lambing season; lambs and calves: mid-summer).
- will eventually allow for targeted selective treatments with indicators currently under study, i.e. FAMACHA, BCS, periodic weighing, milk yields.

Monitoring for AR every 3 years (or less!)
- if AR already suspected: FECRT (involving advisors & researchers)
Refugia: proportion of the parasite population that is not exposed to a given control measure (ATH), thus escaping selection for resistance.
Targeted selective treatments (TST): don’t treat the whole flock!
- ewes in good condition (BCS) and on a good nutritional level do not need treatment
- Target young ewes and/or those in poorer body condition
- Dependable indicators for TST are being studied (e.g. milk yield in goats)

Overdispersion: low numbers of individuals carry high parasite burdens while the majority of the population carries low burdens

Refugia: untreated animals will void eggs from unselected worms, compared to the few eggs from effectively dewormed animals.
2007: First confirmed (reported) case of AR in Canada

![Bar chart showing the effectiveness of anthelmintics](chart)

<table>
<thead>
<tr>
<th>Anthelmintic</th>
<th>Eggs per Gram of Feces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ivermectin (Ivomec®)</td>
<td>5550 (Pre) 3200 (Post)</td>
</tr>
<tr>
<td>Levamisole (UoG prep.)</td>
<td>4865 (Pre) 1565 (Post)</td>
</tr>
<tr>
<td>Albendazole (Valbazen®)</td>
<td>4517 (Pre) 2 (Post)</td>
</tr>
<tr>
<td>Moxidectin (Cydectin®)</td>
<td>4588 (Pre) 2 (Post)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>F1</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ivermectin</td>
<td>51.5</td>
<td>13.8</td>
</tr>
<tr>
<td>Levamisole</td>
<td>99.9</td>
<td>99.9</td>
</tr>
<tr>
<td>Albendazole</td>
<td>48.0</td>
<td>35.2</td>
</tr>
<tr>
<td>Moxidectin</td>
<td>99.9</td>
<td>99.9</td>
</tr>
</tbody>
</table>

1Coles et al., 1992; 2Dash et al., 1988
✓ **Safe (clean) pasture**: a pasture where the risk of accumulation of parasite larvae to pathogenic levels is minimal because the *pasture infectivity* is nil or very low when animals are introduced on the pasture.

- e.g. safe pastures at turn-out in spring:
  - Pastures not grazed by sheep the year before (in sheep farms)
  - Newly sown pasture and never grazed

- e.g. safe pastures at mid-summer:
  - Pastures after the first cut for hay and not grazed by sheep the same year.
  - Pastures grazed by other species (e.g. cattle) the same year.
**Preventive grazing:** parasite-free animals onto parasite-free pastures
Prevents *pasture contamination*.
- Easier in cattle
- More difficult in sheep: effective deworming of adult ewes required before turn-out (which can select for AR)
- Alternation of different animals species (cattle/sheep; cattle/pigs; sheep/horses)

**Evasive grazing:** no prevention of *pasture contamination* as infected animals are turned-out to pasture; aims to move animals to “safe” pasture/s before it becomes dangerously infective.
- Viable dose & move strategy *only* in young animals (lambs/calves)

**Diluted grazing:** concurrent or alternate grazing of susceptible (young) animals with resistant/immune (older) animals of the same or different species; aims to reduce larval intake by susceptible animals
Nutrition

Effects of animal nutrition on GIN parasites

Changes in the parasite-gut environment
Changes in the animal defences

Good nutritional levels allow animals to increase their ability to withstand parasitic infections
Nutrition

Protein supplementation

Mineral nutrients (COWP)

Bioactive forages
### Effect of Animal Nutrition on GIN Parasites

<table>
<thead>
<tr>
<th>Diet Type</th>
<th># Adult Parasites</th>
<th>BW (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Protein diet + P</td>
<td>11,900</td>
<td>82.9</td>
</tr>
<tr>
<td>High Protein diet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(17 wks)</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>Low Protein diet + P</td>
<td>5,450</td>
<td>73.5</td>
</tr>
<tr>
<td>Low Protein diet</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>75.5</td>
<td></td>
</tr>
</tbody>
</table>

Louvandini et al. (2002)
Effect of animal nutrition on GIN parasites

Protein supplementation: 3 times/wk

- **Ewes**
  - Protein suppl.
  - 5 wks pre-lambing
  - FEC (43%)
  - The effect on FEC still present 8 weeks after supplementation ended.

- **Ewes**
  - Protein suppl.
  - 6 wks post-lambing
  - No FEC reduction

- **Ewes**
  - No Protein suppl.

Kahn et al. (2003)
COWP (Copper Oxide Wire Particles)

**Background:**

- Oxidized copper was developed for treatment of copper deficiency in sheep; also used in goats.

- COWP retained to the stomach (abomasum) → free Cu released → increases [Cu] in the abomasal digesta and is then stored in liver.

- Concentration of soluble Cu creates an environment in the stomach that cause the expulsion of parasites (mechanism?)
Dairy goats - Exp. infected; 2 or 4 g CON (= 3.4 g metallic Cu)

Worm burdens after 28 days of CON treatment

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<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>301</td>
<td>1083</td>
<td>1016</td>
</tr>
<tr>
<td>CON</td>
<td>74</td>
<td>780</td>
<td>862</td>
</tr>
<tr>
<td>Reduc. %</td>
<td>75.4</td>
<td>28</td>
<td>15.2</td>
</tr>
</tbody>
</table>

(Chartier et al, 2000)
**Sheep** - Naturally infected; 2 g COWP bolus at week 1 & week 6

**FEC Reduction:**
- **Weeks 1-4:** 68% – 99%
- **Weeks 7-10:** 47% – 72%

(Watkins, 2003)
Concepts

- **Resistance**: the animal’s ability to prevent the establishment and development of internal parasites
  - Moderate heritability
  - Lower pasture contamination

- **Resilience**: the animal’s ability to maintain its production levels while withstanding parasitic challenge
  - Lower heritability than resistance
  - Will not lower pasture contamination

- Three types of genetic variation:
  * Variation between breeds
  * Cross-breeding
  * Variation within breeds
Genetic resistance

Effects on parasites:

- Reduction of establishment of infective larvae (L3) in the animal’s gastrointestinal tract
- Reduction of development of L4 to adult parasites.
- Eliminates adult parasites
- Reduction of egg-laying capacity of adult female parasites
Genetic resistance

**Variation between breeds**

- Red Maassai > Dorper  (Baker *et al*, 1999)
- Gulf Coast Native > Suffolk  (Bahirathan *et al*, 2000)
- Texel > Suffolk  (Good *et al*, 2006)

**Cross-breeding**

- Border Leicester x Merino > Merino  (Donald *et al*, 1982)
- Texel x Romney > Romney  (Niezen *et al*, 1996)
**Indicator traits** - based on phenotypic measurements

- Fecal egg counts (FEC)
- Haematocrit (PCV)
- Plasmatic levels of pepsinogen
- Eosinophilia
- IgA activity

**Genetic markers** - based on genetic polymorphisms

- Major Histocompatibility Complex (MHC)
- Interferon gamma locus
Immunity

Vaccines

Potential for using vaccines has been studied for decades, the results are variable.

Research is being conducted into the mechanisms of naturally-acquired immunity to GIN.
*Nutraceuticals:*

- Foods thought to have beneficial effects on health;
- Individual chemicals present in common foods and, therefore, may be delivered in a non-drug form
Bioactive forages

Legumes:

- Sulla (*Hedysarium coronarium*)
- Lotus or Greater birdsfoot trefoil (*L. pedunculatus*)
- Sainfoin (*Onobrychis viciifolia*)
- White clover (*Trifolium repens*)
- Birdsfoot trefoil (*Lotus corniculatus*)
- Chicory (*Cichorium intybus*)

CT: secondary plant metabolites, closely associated with plant defence mechanisms towards insects and mammalian herbivores.
(1) CT may have direct ATH properties;

(2) Consumption of CT also related to indirect effects of tannins: reduced ruminal degradation of diet proteins $\rightarrow$ increased flow of digestible proteins in the small intestine (protein supplementation, therefore nutritional impact of CT)
Sheep with reduced parasite egg excretion and decreased parasite burdens.

- Effect on intestinal parasites but not abomasal (sainfoin, quebracho)
- Effect on abomasal parasites but not intestinal (chicory, sulla)

* exp. from turn-out to weaning (July)

- Lambs on chicory pasture: 262 g/d …plus reduced FEC until 13 wk-old
- Lambs on grass/clover pasture: 219 g/d

The strategic use of CT forages in grazing management could appear as a promising contribution to the control of GIN

Considerations !!

* Different plant metabolites seems to affect differently the parasites in stomach and intestine > problem in mixed parasites infections.

* Agronomical > choosing plant species or varieties well-adapted to the various local environmental conditions in different climatic regions

* Metabolical > most plant metabolites have also anti-nutritional properties if consumed in excess; need to clearly assess the balance between positive effects and potential negative consequences
Biological control

“An ecological method designed by man to lower a pest or parasite population to keep these populations at a non-harmful level using natural living antagonists”

(Grønvold et al. 1996)
Biological control

*Duddingtonia flagrans*: nematophagous microfungus

- Efficacy studies
- Environmental studies

Lab and field studies
Europe, Australia, Asia, N.Am. & S.Am.

- cattle, sheep, goats, horses, pigs
Duddingtonia flagrans

Adhesive hypha

Fungal net

Chlamydomspore (resting spore)

Conidia and chlamydospores

Trapped larva
Administration of chlamydospores

Chlamydospores in feces

Germination & growth = fungal network → nematophagous action on nematode larvae

L2, L1, L3
Biological control by means of nematophagous fungi targets the free-living stages of parasitic nematodes in animal faeces, with the purpose of lowering the larval parasitic population on pasture.
Field studies - two locations

(Jackson et al, 2005)
Pasture infectivity ($L_3$) around faecal pats and reduction effect of *D. flagrans*

<table>
<thead>
<tr>
<th>Season</th>
<th>Control</th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>Control</td>
<td>11</td>
<td>1017</td>
</tr>
<tr>
<td></td>
<td>CI3</td>
<td>5</td>
<td>122 (88%) **</td>
</tr>
<tr>
<td></td>
<td>TA</td>
<td>--</td>
<td>212 (79%) **</td>
</tr>
<tr>
<td>Summer</td>
<td>Control</td>
<td>296</td>
<td>1548</td>
</tr>
<tr>
<td></td>
<td>CI3</td>
<td>44 (85%) **</td>
<td>360 (77%) **</td>
</tr>
<tr>
<td></td>
<td>TA</td>
<td>--</td>
<td>361 (77%) **</td>
</tr>
<tr>
<td>Early autumn</td>
<td>Control</td>
<td>301</td>
<td>2140</td>
</tr>
<tr>
<td></td>
<td>CI3</td>
<td>35 (85%) **</td>
<td>427 (80%) **</td>
</tr>
<tr>
<td></td>
<td>TA</td>
<td>--</td>
<td>456 (79%) **</td>
</tr>
</tbody>
</table>

**P<0.01**

(Fernández et al. 1999)
Oscillations in the population density of parasitic nematodes
“The important point... is not that any specific control method may be unsustainable when considered in isolation, but that the more choices there are and the more that different controls are used in combination rather than relying almost solely on anthelmintics, the longer can we eke out the continued effectiveness of all of them”

(Barger, 1997)