Innovations in Goat & Sheep Parasite Management

Slides contributed by Steve Hart, Betsy Hodge, Diane Hoffelder, Katherine Petersson, Susan Schoenian, Mary Smith DVM, James Weber DVM and tatiana Stanton
The Northeast US has an abundance of land ideal for pasturing goats and sheep. HOWEVER →

The management of parasites, particularly internal parasites, is a major challenge for pasture based Northeast sheep and goat farms.
Traditional parasite control:
Maximize parasite control to
Maximize production and health

Included deworming the entire herd regularly to meet needs of the most susceptible, and other practices that exposed a lot of worms to a lot of chemical dewormers frequently.

In order for chemical dewormers to be effective, the worm population on your farm has to be vulnerable.

-> However, repeated exposure leads to the survival of worms with genetic resistance ->

GENETIC SELECTION FOR DEWORMER RESISTANCE

NOW A MAJOR PROBLEM THROUGHOUT THE US
Comparison of fecal egg counts before and 10 days after deworming with Fenbendazole in NY and PA goat herds

Fenbendazole resistance in worm populations of goat herds

- severe resistance, 55%
- moderate resistance, 27%
- low or no resistance, 18%

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<th>Dewormer efficacy (%)</th>
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</table>
Comparison of fecal egg counts before and 7 days after deworming with ivermectin in NY and PA goat herds

Ivermectin resistance in worm populations of goat herds

- **Blue** = severe resistance, 38%
- **Yellow** = moderate resistance, 15%
- **Red** = low or no resistance, 47%

Dewormer efficacy (%) vs Herd:

- Herd 1: 10%
- Herd 2: 30%
- Herd 3: 40%
- Herd 4: 50%
- Herd 5: 60%
- Herd 6: 70%
- Herd 7: 80%
- Herd 8: 90%
- Herd 9: 100%
- Herd 10: 100%
- Herd 11: 100%
- Herd 12: 100%
- Herd 13: 100%
Traditional destroys the "Refugia"

- The proportion of the population that has not been exposed to the dewormer treatment – In "refuge" from dewormer
- Refugia includes the worms in untreated animals, and the eggs and larvae on pasture before treatment
- Provides a gene pool that is sensitive to the dewormer – Dilutes genes resistant to dewormer
Tools to slow the rate of dewormer resistance include:

- Selective treatment
- Evasive grazing
- And other activities such as boosting the immune system, breeding for parasite resistance, etc.
- COWP?
- Forages high in condensed tannins?
Targeted Selective Deworming

- Prolongs dewormer efficacy, also very important for farms that cannot use dewormers except for emergencies
- Parasites are not equally distributed to all individuals
- Resistance of animals to parasites such as barber pole worm differs
  - 20-30% of animals harbor 80% of worms, responsible for most of egg output and pasture contamination
  - Just need to deworm these animals, not the entire herd or flock
Distribution of FEC in Goat Herds

Treating high 33% greatly reduces daily pasture contamination with eggs.

- 33% of goats
- 80% of eggs

Treating 1/3 of herd gives just as good control as treating the entire herd.
What Happens If We Treat Only the High 33%?

Treating high 33% with a drug that causes a 99% FECR reduces daily pasture contamination with eggs by 80%.

33% of Goats < 5% of Eggs

Following treatment > 95% of eggs are being shed by untreated goats = REFUGIA and will crossbreed with the “resistant” eggs, thus diluting the “resistant” population.
How do you determine who to deworm?

- Fecal egg counts – costly, time consuming, does not identify animals with low tolerance to worms that are not shedding a lot of eggs

- Visual cues? Production records?
Brown Stomach Worm (Ostertagia circumcincta)

- Used to be considered the most serious parasite of sheep in cool climates
- Worm develops in gastric glands of stomach (abomasum) and destroys the glands as they grow
- Affects appetite, digestion and nutrient utilization

Other important strongyle worms included Cooperia spp., Nematodirus spp. (thin-necked or thread-necked worm), Oesophagostomum spp. (nodular worm), Trichostrongylus spp. (black scours worm).
These worms disrupt digestion and the absorption of nutrients by damaging gastric glands in the abomasum or damaging the small intestines. Clinical signs

Clinical signs are fairly obvious –
- Diarrhea (scours),
- Weight loss,
- Rough hair coat
**Haemonchus contortus** — now considered most dangerous

**The Barber Pole Worm**

A blood-sucking parasite that pierces the mucosa of the abomasum (ruminant “stomach”), causing blood plasma and protein loss to the sheep or goat.

- Originally a parasite of warm climates, but has spread throughout the world
- Short generation time (<3 wks, heavy egg producer; 5,000-10,000 eggs/worm/day)
- Each worm can consume 0.05 ml blood per day (lamb can lose as much as 1/5th of its blood volume in a day)
- Can infest and kill host in 4 weeks

Haemonchus contortus

video courtesy of Dr. Scott Bowdridge (WVU)

https://www.youtube.com/watch?v=-rDRo8HG_oA&feature=youtu.be

click anywhere on page to view video
Clinical signs of barber pole worm infection

- Visual signs are subtle -> animal can look terrific and be dying of barber pole worm

- Primary symptom is ANEMIA

- May develop a bottle jaw (hypoproteinemianemia) as a loss of protein from the blood serum results in fluid leaking from the blood and collecting between the mandibles
Five Point Check — a practical method for selective deworming

1. Body condition, weight gain
2. Diarrhea, dag score
3. Fleece or hair coat
4. Bottle jaw, moves slowly
5. FAMACHA

Check needs include FAMACHA to monitor for barber pole worm as well as worms that cause things that are easy to observe such as diarrhea and poor growth.
**FAMACHA©**

- Need to do at least every two weeks during the grazing season
- Only screens for barber pole worm not other strongyles

Treat adults at scores 4 and 5*

Treat lambs, kids and milking or late pregnancy ewes and does at categories 3, 4, and 5

If >10% of flock/herd in categories 4 & 5, consider treating 3’s as well and start checking weekly

<table>
<thead>
<tr>
<th>Clinical Category</th>
<th>Eye Lid Color</th>
<th>Packed Cell Volume</th>
<th>Treat?</th>
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<tbody>
<tr>
<td>1</td>
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<td>No</td>
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<tr>
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<td>3</td>
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<td>5</td>
<td>White</td>
<td>≤ 12</td>
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[Image of FAMACHA test being performed on a sheep]
Haemonchus (Barber pole worm) and other strongyles

- pasture and barnyard problem - especially if pasture is small and damp
- few larvae picked up in barn – ammonia gas from bedding pack discourages larvae survival
- infective larvae in dewdrops on grass
Parasite Evasive Grazing

- Move animals fast enough to prevent infection from feces deposited during current grazing period (autoinfection). Takes 3-5 days for barber pole worm to hatch at 77-79°F, 15-30 days to hatch at 50-52°F. Often ~5 to 14 days from egg to L3.

- Play it safe with 4 day (wet, warm) to 7 day (cooler, drier) grazing duration. Move earlier if pasture getting too short – i.e. 3 inches.

- Allow a long enough rest period that there is substantial L3 die off before animals return to graze.
Barber pole worm population in pastures grazed 2 to 4 weeks
Problem

- Pasture rest periods to control barber pole worm need to be longer
- (60 – 105 days) than normal recommendations for either pasture health or nutritional value
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>FEC (epg)</td>
<td>% Organic Lambs</td>
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<tr>
<td>Avoidance Grazing (3-Day, 57-Day Return)</td>
<td>1841*</td>
<td>83%***</td>
</tr>
<tr>
<td>Challenge Grazing (7-Day, 21-Day Return)</td>
<td>3945</td>
<td>46%</td>
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</tbody>
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* P = 0.06  *** P = 0.001
Things you can do -

- Are there safe “pastures” that animals can be switched to as the grazing season progresses?
  - Brush pastures, hayfield regrowth, pastures that your cattle or horses have been grazing, crop residues, annual pastures

- Can you disrupt the worm cycle by
  - mowing the pasture extremely short during the rest period,
  - grazing other species during the rest period,
  - Harvesting a hay crop or baleage before resuming grazing
Barnyard Effect

- Barnyards with grass or other good forage
  - Lead to high concentration of manure and internal parasites in grazing material
  - Can contribute greatly to herd contamination with internal parasites
  - May have a “barnyard effect” in pastures that border barns and are not rotated
Please note that we are talking about herds that are rotating in the spring and summer and that by late July most of these also had high worm loads.

Worm eggs per gram in kids in herds that rotate vs herds that do not - State #1

- NoRotation: 23750 eggs/gm
- Rotating1: 3575 eggs/gm
- Rotating2: 2250 eggs/gm
Some options to help reduce barnyard effect –
Can you implement any of them?

- Lay down gravel, concrete, or herbicides.
- Close off access to barnyard or provide hay in barn at night when animals come in from pasture to cut down on night grazing in the barnyard.
- Make barn yards small so that no grazing occurs.
- Put in lanes or leave animals out 24/7.
Immune Response

- Good nutrition stimulates immune system

- Many trace minerals (Se, Cu, etc.) and vitamins (Vit. E) important for good immune system. Work at WVU suggests excess protein (over basic requirements), especially bypass protein, may also help boost immune system

- When goat/sheep are very young or lactating or in late pregnancy, immune system is suppressed and does not fight parasites well.
University of Rhode Island Research on “Effect of Vitamin E supplementation on abomasal worm burden”

- Compared adding 5 international units (iu) of Vitamin E/kg live weight versus adding 10 iu of Vit E/kg (2007 NRC recommendation) in the creep feed of lambs artificially infected with barber pole worm larvae.

- VE 10 lambs had lower mean Fecal Egg Counts
Spring Rise in barber pole worm egg counts

- Barber pole worm overwinters as dormant L4 (hypobiotic) larvae in hosts (goats, sheep)

- Drop in immune function and an estrogen surge at birthing or other cues of spring time cause L4 larvae to become adults and mate and produce eggs - Protein consumption at 130% of daily requirements reduced flush of egg laying at parturition in sheep

- Same phenomenon occurs in other strongyle worms— but they may also overwinter outside
Blue line indicates barber pole worm (HC) fecal egg counts for ewes going out to pasture May 15th.
Red line indicates fecal egg counts for ewes kept in barn to flush out worm eggs until June 15th.

Personal com., James Weber NESARE LNE14-337 2015 Annual Report
Genetic Resistance

- Susceptibility to getting infected with worms is affected by environment AND genetics

- Heritability for genetic resistance to strongyle worms appears to be similar to the heritability for milk yield

- Requires lots of records - compare fecal egg counts (FEC) for offspring of different sires – meat goats and sheep farms can enroll in the National Sheep Improvement Program’s on-farm genetic evaluations
Mechanism of biological resistance

1. Animal’s immune system needs to recognize that a parasite infection has occurred – How quickly this occurs varies between breeds and individuals

2. The immune system has to mount an effective response – effectiveness varies between breeds and individuals
Immune cells and barber pole worm larvae
(study and graphics by Scott Bowdridge – WVU)
https://www.youtube.com/playlist?list=PLahuv9m1W2cc395SagUcEYasafoyINhK3

Primed St. Croix

Primed Suffolk

St. Croix Lambs

Suffolk Crossbred Lambs

Weeks after infection
WFEC (Worm Egg Count, %) – genetic merit for strongyle worm resistance based on fecal egg counts at about 69 to 90 days of age (lower the count, higher the genetic merit)

PFEC (Post Weaning Worm Egg Count, %) – generally taken 30 to 60 days after WFEC and at same time as Post Weaning Weight
Farm trying to use rams with WFEC and PFEC of -90 or better while also selecting for MWWT (maternal weaning weight)
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What’s in our future?
- Worm control strategies in development

- Nematode eating fungi – available now!
- Barber pole worm vaccine
- Copper oxide wire particles
- Botanicals – Condensed tannin forages, etc.
- Deer worm control
Fecal Fungus – *Duddingtonia flagrans*

- >100 species of Nematophagus (nematode eating) fungi occur in nature. Many reside in livestock feces and trap and eat gastrointestinal worm larvae as they hatch and molt.

- The most heavily researched is *D. flagrans*.

- *D. Flagrans* does not kill worms inside the goat or sheep. Instead, it kills larvae in the feces, reducing pasture contamination and breaking the infection cycle. Livestock must eat the spores daily to have sufficient supply in feces to impact the pasture’s worm population.

- International Animal Health (IAH) has developed two products:
  1) **BioWorma** - designed to be top dressed or incorporated into a feed or mineral supplement (pelleting kills the fungus), and
  2) **Livamol** with BioWorma (a feed supplement with BioWorma already added).
**D. flagrans continued**

The spores are eaten by goat or sheep and pass through the digestive tract into the manure along with any worm eggs the animal is also passing. The spores then germinate and trap and consume the hatching worm larvae.

- Both products were registered for use in New York in August 2018. **BioWorma** is available to feed mills and veterinarians from the IAH distributor in Kansas. **Livamol** is available direct to farmers from Premiere1© at a cost @$0.50/day/head for a 110 lb. animal - so more expensive that dewormers. Some reports of palatability issues. Both products are approved for organic certification in Australia. Future studies are planned in the US to test whether products can be given every other or third day rather than daily. As volume sales increase price is anticipated to drop.

- Recommended to start feeding the spores to livestock at the beginning of the grazing season or earlier before barber pole worm or other strongyles become a major problem, and continue feeding it through the worst of the worm season.
Vaccines

- Breakthrough method developed to centrifuge worms from lambs at slaughter plants and harvest the specific immunity-inducing antigen. Further breakthrough now only need to slaughter 1 sheep to get enough antigen to vaccinate 100 sheep. Still dependent on having slaughterhouses that process lots of lambs or goats. **Still can’t synthesize antigen.**

- Vaccine called Barbervax® started being marketed in Australia in October 2014. Attempted to extend registration to goats but vaccine effectiveness was too variable among the 3 study farms and request denied in 2017.

- The vaccine requires 5 injections, first 3 “primers” are given 3 to 4 weeks apart, next 2 “boosters” are given 6 weeks apart. Protection only lasts ~6 weeks and does not start until 3rd dosage. Cost effective? Not much savings over deworming. **General thought was that it and new dewormers developed for sheep in Australia were unlikely to be marketed in U.S. However, Canada is interested in obtaining them and there is an effort underway to explore the possibility of getting them approved for both North American countries.**
For the last 5 years, Cornell has collaborated on studies testing:

- the effectiveness of dosing sheep and goats with copper oxide wire particles (COWP) to control Haemonchus contortus (barber pole worm),
- whether establishing and grazing birdsfoot trefoil pastures has potential to control barber pole worm and other strongyles, and
- whether ivermectin should be included in the arsenal of treatments of animals infected with deer-worm.
- Funding thru NESARE, USDA OREI, Federal Formula Funds and NNY Ag Dev. Program.
Copper Oxide Wire Particles

- Copper oxide wire particles (COWP) were developed as a slow release source of copper for cattle on copper deficient soils.

- Sheep are ten times more susceptible to copper toxicity than cattle. 12.5 and 25 gram boluses for calves and cows need to be repackaged into far smaller doses suitable for growing goats and sheep!

- COWP particles must be retained in the abomasum long enough to permit acid solubilization of the copper. The stomach acids are responsible for this. If the pH of the stomach is not acidic enough, the copper will not go into solution and will be ineffective.

- Acid solubilization results in gradual release of copper from the COWP which reduces risk of copper toxicity.
Copper Oxide Wire Particles

- Works only on worms in stomach, not worms in intestines. Damages barber pole worm but not brown stomach worm.

- If there are too many brown stomach worms, the copper will not be available, why?

- SE researchers said - worked poorly in animals that were stressed or run down. Did not appear effective in just weaned kids or lambs – instead give 2 weeks before or after weaning

- When it worked → Quite effective, killing 75-95% of Barber pole worms
Using a cat pill gun

Using a metal bolus or balling gun with plastic head

Large boluses are easier to see if spit out
NEW YORK
1 Goat Dairy

- Treatments consisted of
  - 1 gram COWP/head,
  - 2 gram COWP/head, or
  - 1 gram COWP/22 lb. live weight

- 15 to 16 lactating does per treatment

- Looked at fecal egg counts, FAMACHA scores, curd formation in 4 cheeses, Cu in milk, AST (a liver enzyme) in blood
Effect of copper oxide wire particles (COWP) on the change in fecal egg counts after 14 days.

<table>
<thead>
<tr>
<th>COWP</th>
<th>Strongyles</th>
<th>Haemonchus</th>
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</thead>
<tbody>
<tr>
<td>1 g/22 lb. BW</td>
<td>-1153 ± 469.4</td>
<td>-1185 ± 462.7</td>
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<tr>
<td>2 g/doe</td>
<td>-1227 ± 484.8</td>
<td>-1191 ± 477.9</td>
</tr>
<tr>
<td>1 g/doe</td>
<td>107 ± 484.8</td>
<td>75 ± 477.9</td>
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</table>

P-value for 1 g/doe vs average of 1 g/22 lb. and 2 g/doe

<table>
<thead>
<tr>
<th></th>
<th>Strongyles</th>
<th>Haemonchus</th>
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</thead>
<tbody>
<tr>
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<td>0.036</td>
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P-value for 1 g/22 lb. vs 2 g/doe

<table>
<thead>
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<th></th>
<th>Strongyles</th>
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<tbody>
<tr>
<td>0.914</td>
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<td>0.993</td>
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</table>
Conclusions

- Not as effective as a dewormer (assuming there is no resistance to the dewormer). No long term significant effect noted.

- No discarding of milk necessary

- Curd formation for cheese production normal

- Copper in milk well below allowable levels, AST levels in blood did not indicate any Copper toxicity.

- **2 grams of COWP per head** appeared to work as well as 1 gram per 22 lb. live weight in adult, lactating dairy does and did not significantly increase the copper levels in milk
Effect of COWP level given on Day 0 (2 weeks prior to weaning) on barber pole worm egg counts in lambs over a 42 day period at the St. Lawrence County Extension Leaning Farm

Table 4. ELF 2013.

<table>
<thead>
<tr>
<th>Effect</th>
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<th>FAMACHA</th>
<th>Log10</th>
<th>Geometric mean</th>
<th>Log10</th>
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<tbody>
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<td>3.07</td>
<td>1180</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>60.6</td>
<td>2.3</td>
<td>2.10</td>
<td>124</td>
<td>1.97</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>63.5</td>
<td>2.0</td>
<td>2.16</td>
<td>142</td>
<td>1.98</td>
<td>94</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td>3.72</td>
<td>0.15</td>
<td>0.240</td>
<td></td>
<td>0.262</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td>0.771</td>
<td>0.352</td>
<td></td>
<td>0.012</td>
<td></td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td>Day</td>
<td>0</td>
<td>59.0</td>
<td>1.7</td>
<td>2.15</td>
<td>141</td>
<td>2.10</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>64.0</td>
<td>1.9</td>
<td>1.87</td>
<td>74</td>
<td>1.74</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>63.2</td>
<td>2.3</td>
<td>2.85</td>
<td>712</td>
<td>2.71</td>
<td>516</td>
</tr>
<tr>
<td></td>
<td>42</td>
<td>65.2</td>
<td>2.8</td>
<td>2.93</td>
<td>858</td>
<td>2.80</td>
<td>628</td>
</tr>
<tr>
<td>SEM</td>
<td>2.19</td>
<td>0.13</td>
<td></td>
<td>0.223</td>
<td></td>
<td>0.228</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td></td>
<td>0.001</td>
<td></td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>COWP x Day</td>
<td>P-value</td>
<td>0.369</td>
<td>0.079</td>
<td>0.114</td>
<td></td>
<td>0.051</td>
<td></td>
</tr>
</tbody>
</table>
Effect of COWP level on barber pole worm egg counts in lambs over a 56 day period at the Cornell Univ. Sheep Farm (CUSF) and at the St. Lawrence County Extension Learning Farm (ELF) when given 2 weeks pre-weaning, 2 wks. post weaning or not at all. Note, while it was very effective at ELF, there was essentially no effect at CUSF. This may have been because worm infection at CUSF did not start until after the post weaning COWP dosing. Also CUSF lambs received free choice total mixed ration as well as pasture.
Conclusions

- In most herds, COWP did not work as effectively or abruptly as chemical dewormers.

- .5 gram per head dosages appears to be as effective as 1 gram per head for lambs. More uncertain on goat kids. The Cornell Veterinary Diagnostic lab has observed some toxicity in some lambs at 2 g dosages.

- Although it had a very effective, long term impact at one farm for 3 years of testing, it only had a short term effect on most farms and was ineffective on some. Why do results vary across different farms?

- Possible explanations: diet, timing of dosing in relationship to timing of infection, exposure of earlier generations of worms to other sources of copper, acidity of true stomach? Seemed to work best when animals already had some worm load when dosed, pre-weaning, and when animals were not consuming large quantities of grain.

- Need controlled studies comparing different types of flock management to identify why we see so much variation between farms.
Copper Oxide Wire Particles continued

We advise that farmers wanting to use COWP follow the recommendation of COWP researchers in SE US:

1. Use it in combination with FAMACHA and 5 point checks – give COWP to your vulnerable “3s” (lambs, kids, lactating or late pregnant females) rather than giving a commercial dewormer,

2. Give animals with a FAMACHA score of 4 or 5 an effective dewormer instead,

3. Follow up with regular FAMACHA scoring, fecal egg sampling, to see if COWP actually works in your herd or flock.
Condensed Tannins

- Grazing the forage legume, *Sericea lespedeza* (SL), for ≥4 weeks as ≥25% of the diet reduces strongyle worm populations in sheep and goats. Thought to be due to the particular condensed tannins in the plant, seem to reduce hatching in worm eggs and inhibit "exsheathment".

- Tannins are found in many plants. They are a compound that often gives plants an "astringent taste" – "Pucker". Condensed tannins are the most common type of tannin.

- Not all condensed tannins seem to work – Oak, peanut skins, grape pulp? have not worked well in most experiments so far

- Promising studies with cranberry leaves at University of Rhode Island

- Ground pine bark (11 to 13% Crude Protein). As 33% of the DM diet, it reduced worms 30% more than in the control goats (Tuskegee Univ.).

- SL is not winter hardy in the Northeast US. Potential for *Birdsfoot trefoil* (BFT) or Sainfoin? BUT Sainfoin has trouble with acid and/or wet soils so not ideal for New York.
Condensed Tannins

- Forage legumes that contain Condensed-tannins (CT) include birdsfoot trefoil (BFT) but not alfalfa or clovers.

- CTs have a complex structure. They bind with the protein in plants → leading to the formation of rumen bypass protein.

- As compared to rumen degradable protein (i.e. protein that rumen microbes can utilize as a nitrogen source), Rumen bypass protein causes → less ammonium to be released into the environment, higher milk solids, and far less incidence of bloat than with clovers and alfalfa.

- Additionally, Immune response to parasite infection requires protein in excess of what is needed for growth; It could be that when rumen bypass protein is limiting in the diet of sheep and goats, the feeding of a forage legume high in condensed tannins helps supply more rumen bypass protein and boosts the immune system.
1.6 Acre Field Bruce BFT
Germtown, NY
Colombia County

- Soil Type: Raynham
- Soil pH: 6.0
- Buffer pH: 6.0
- P: 4 lbs/acre
- K: 249 lbs/acre
- Ca: 2,706 lbs/acre
- Mg: 351 lbs/acre
- % OM: 3.9
- 400 lb. bone char per acre (65 lb. P²O⁵) banded in at planting

- Ram lams after weaning were grazed for 6 wks. on either conventional grass/clover/alfalfa pasture (CP) or birdsfoot trefoil pasture (BFT)
Fecal egg counts for both groups rose sharply after weaning but were similar until Wk 6 when the average egg count for the BFT group was substantially less. Spot checks indicated that most strongyles were barber pole worms. BFT * Day interaction not statistically significant but 4 of 10 CP lambs had to be dewormed at the study’s end based on FAMACHA score and poor health and only 1 of 9 BFT lambs had to be dewormed and that was based not on FAMACHA but on diarrhea later attributed to Queen Anne’s Lace.
Strongyle worm eggs per gram (expressed in LOG10) over time for the individual lambs grazing conventional pasture (CP) or grazing BFT. Note that one CP ram lamb, #688, was quite an outlier and appears to have developed his own immune response much sooner than any other lambs.
Average dairy gains in lbs. (ADG) for grazing trials on weaned kids and lambs comparing Birdsfoot trefoil (BFT) to other forages (OF). In some cases treatments also included oral dosing with copper oxide wire particles (COWP).

<table>
<thead>
<tr>
<th>Farm</th>
<th>ADG on BFT</th>
<th>ADG on BFT + COWP</th>
<th>ADG on OF</th>
<th>ADG on OF + COWP</th>
<th>ADG on Hay + Grain + COWP</th>
<th>P value for ADG betw. treatments</th>
<th>Type of OF</th>
<th>Concentrate supplemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinton Cty, NY Goat kids</td>
<td>0.34</td>
<td>NA</td>
<td>0.34</td>
<td>NA</td>
<td>NA</td>
<td>0.787</td>
<td>Conventional pasture (CP)</td>
<td>½ to 1 lb/head/day</td>
</tr>
<tr>
<td>Greene Cty, NY Goat kids 57 d</td>
<td>0.21</td>
<td>NA</td>
<td>0.07</td>
<td>0.10</td>
<td>NA</td>
<td>0.022</td>
<td>CP, then annual mix (millet, cow peas, brassica)</td>
<td>None</td>
</tr>
<tr>
<td>Penoloscot Cty, ME Goat kids</td>
<td>0.18</td>
<td>NA</td>
<td>0.13</td>
<td>NA</td>
<td>NA</td>
<td>0.008</td>
<td>Woodlot regrowth</td>
<td>¼ lb/head/day</td>
</tr>
<tr>
<td>Tompkins Cty, NY Goat kids</td>
<td>0.20</td>
<td>NA</td>
<td>0.10</td>
<td>NA</td>
<td>NA</td>
<td>0.002</td>
<td>CP</td>
<td>¼ lb/head/day</td>
</tr>
<tr>
<td>Columbia Cty, NY Lambs 41 d</td>
<td>0.46</td>
<td>NA</td>
<td>0.38</td>
<td>NA</td>
<td>NA</td>
<td>0.208</td>
<td>CP</td>
<td>None</td>
</tr>
<tr>
<td>Cortland Cty, NY Lambs 40 d</td>
<td>0.33</td>
<td>NA</td>
<td>0.12</td>
<td>NA</td>
<td>NA</td>
<td>0.000</td>
<td>Unimproved pasture</td>
<td>None</td>
</tr>
<tr>
<td>Oneida Cty, NY Lambs</td>
<td>0.20*</td>
<td>NA</td>
<td>0.23*</td>
<td>NA</td>
<td>NA</td>
<td>0.208</td>
<td>CP</td>
<td>1/3 lb/head/day*</td>
</tr>
<tr>
<td>St. Lawrence Cty, NY Lambs</td>
<td>0.20</td>
<td>0.33</td>
<td>0.05</td>
<td>0.11</td>
<td>0.22</td>
<td>0.000</td>
<td>CP</td>
<td>None except for hay/grain treatment – 1 lb/head/day</td>
</tr>
</tbody>
</table>

*Final weight comparison may not be equitable between BFT and CP treatments in the Oneida Cty, NY study. BFT lambs were given no grain the last week of study and were held in barn 15 to 18 hrs. prior to final weighing while CP lambs got grain all week and were brought to barn only 1 to 2 hours prior to weighing.
Barber pole worm egg counts of goat kids grazing either conventional pastures (CP) or birdsfoot trefoil pastures (BFT) when COWP also administered on day 8/22/2017
Study at St. Lawrence Extension Farm (ELF) compared weaned lambs on conventional pastures (CP) with lambs on BFT and lambs in a drylot (HG) on free choice hay and 1 lb./grain/head daily. Half the lambs grazing CP or BFT also got COWP at the start of study as did all lambs on HG. Treatments that got COWP appeared to have lower worm egg counts throughout the study than their counterparts who did not. COWP * Day interaction for egg count was significant (P = 0.001). Four lambs had to be dewormed on the CP treatment without COWP and 2 lambs had to be dewormed on the HG study with COWP.

Strongyle worm count by treatment over days after treatment
The treatments on BFT appeared to gain weight similarly to the treatment on hay and grain while the treatments on conventional pastures (CP) appeared to grow slower.
In 2018 assessed how barber pole worm is affected in vitro by looking at the effect of water extracts from 45 varieties of BFT on:

- Egg hatch inhibition and larval mortality, and
- *in vitro* exsheathment

Preliminary results of 13 commercial varieties indicated a lot of variation between varieties:

- Larval mortality after 42 hr. incubation in water extracts of BFT ranged from 18 to 92%.
- The percent of live larvae that exsheathed ranged from 21 to 96%

Type of condensed tannins may be more important that actual amount! Need much more work.
Egg hatch inhibition and L1 mortality assay –

Despite having higher levels of condensed tannins in its forage, the water extracts from the variety, Bruce, performed poorer in the in vitro studies at lower concentration levels.

<table>
<thead>
<tr>
<th>BFT</th>
<th>PAC (DMAC)</th>
<th>Egg Hatch Inhibition (%)</th>
<th>L1 Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.75 mg/mL</td>
<td>1.5 mg/mL</td>
</tr>
<tr>
<td>Commercial</td>
<td>mg/g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bull</td>
<td>3.7</td>
<td>4 ± 1</td>
<td>90 ± 12*</td>
</tr>
<tr>
<td>Empire</td>
<td>4.2</td>
<td>4 ± 2</td>
<td>87 ± 12*</td>
</tr>
<tr>
<td>Norcen</td>
<td>3.5</td>
<td>17 ± 3*</td>
<td>78 ± 1*</td>
</tr>
<tr>
<td>Leo</td>
<td>6.0</td>
<td>11 ± 2</td>
<td>48 ± 10*</td>
</tr>
<tr>
<td>Pardee</td>
<td>8.0</td>
<td>2 ± 1</td>
<td>30 ± 3*</td>
</tr>
<tr>
<td>Bruce</td>
<td>12.0</td>
<td>0 ± 2</td>
<td>6 ± 2</td>
</tr>
</tbody>
</table>
## L3 Mortality and Exsheathment Assay

<table>
<thead>
<tr>
<th>BFT Variety</th>
<th>PAC (DMAC) mg/g</th>
<th>L3 Mortality (% at 25 mg/mL)</th>
<th>Exsheathment Inhibition (% at 25 mg/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pardee&lt;sup&gt;+&lt;/sup&gt;</td>
<td>8.0</td>
<td>92 ± 2*</td>
<td>66 ± 12*</td>
</tr>
<tr>
<td>228286</td>
<td>3.7</td>
<td>91 ± 2*</td>
<td>75 ± 10*</td>
</tr>
<tr>
<td>655626</td>
<td>4.2</td>
<td>74 ± 5*</td>
<td>61 ± 9*</td>
</tr>
<tr>
<td>Empire&lt;sup&gt;+&lt;/sup&gt;</td>
<td>4.2</td>
<td>88 ± 4*</td>
<td>51 ± 14*</td>
</tr>
<tr>
<td>325379</td>
<td>1.5</td>
<td>91 ± 3*</td>
<td>42 ± 14</td>
</tr>
<tr>
<td>Bull&lt;sup&gt;+&lt;/sup&gt;</td>
<td>3.7</td>
<td>71 ± 4*</td>
<td>43 ± 9*</td>
</tr>
<tr>
<td>304523</td>
<td>17.2</td>
<td>84 ± 4*</td>
<td>33 ± 11</td>
</tr>
<tr>
<td>Norcen&lt;sup&gt;+&lt;/sup&gt;</td>
<td>3.5</td>
<td>38 ± 6*</td>
<td>22 ± 9</td>
</tr>
<tr>
<td>Leo&lt;sup&gt;+&lt;/sup&gt;</td>
<td>6.0</td>
<td>72 ± 6*</td>
<td>20 ± 7</td>
</tr>
<tr>
<td>193725</td>
<td>24.4</td>
<td>53 ± 5*</td>
<td>18 ± 6</td>
</tr>
<tr>
<td>251143</td>
<td>5.2</td>
<td>30 ± 5*</td>
<td>56 ± 5*</td>
</tr>
<tr>
<td>306182</td>
<td>2.8</td>
<td>28 ± 6*</td>
<td>3 ± 3</td>
</tr>
<tr>
<td>Bruce&lt;sup&gt;+&lt;/sup&gt;</td>
<td>12.0</td>
<td>17 ± 5</td>
<td>0 ± 2</td>
</tr>
</tbody>
</table>

6 mg/mL

| Bruce-PAC | Standard | 4 ± 0 | 100 ± 0* |

*<i>p ≤ 0.001 versus negative control (0.0 mg/mL)</i>
BFT Establishment

- BFT seed is small – needs a smooth, firm seedbed
  - Seeding depth is only ¼ inch!
- Seed heavy to improve competition with germinating weeds
- Brillion seeder is best
  - If not available, cultivate after tillage, broadcast seed, then roll or cultipack again
- Mow regularly just above trefoil to reduce weed competition, mow out annuals
Managing BFT

- BFT-grass mixtures produce more biomass than pure BFT
  - Must be managed carefully, especially in Spring, or grass will out-compete BFT

- BFT has indeterminate growth, flowering continuously June – August
  - Maintains quality better than grass
  - Lower leaves get shaded out, so taller plants ≠ more yield

- Do not mow or graze in 6 weeks prior to expected first frost !!!

- Can graze after frost

- Plan to reseed (or let BFT self-seed) every 3rd year to maintain density
Conclusions

- When animals have worm loads, animals on BFT appear to be more resilient (as exhibited by better FAMACHA scores)
  - Is this simply due to better nutrition?
  - Or are there compounds in BFT that boost their immune systems and make them more able to cope?

- Grassfed lambs and kids appear to grow well on lush BFT pastures

- Will grazing BFT for at least 4 weeks help to control strongyle worms? Jury is still out.

- In grass-fed flocks where COWP is effective and barber pole worms are present, dosing with COWP and feeding BFT appear to improve lamb/kid performance (lower FAMACHA scores and weight gains) as compared to doing only one or the other.

- In our studies, we had no replicates of pasture groups. Therefore difficult to separate out the effects of better nutrition versus the possible anthelmintic effects of BFT.
USDA NIFA Organic Transitions project objectives (Sept. 2018 – May 2021)

- Evaluate agronomic practices to improve Birdsfoot trefoil (BFT) establishment in existing pastures.

- Field-scale grazing trials to evaluate efficacy of BFT pastures to increase tolerance to GIN parasites, as well as replace or minimize grain supplementation.

- Determine the anti-parasitic effect of feeding BFT in various forms including: BFT hay, BFT high-moisture round bales, and BFT hay pellets on experimental and pasture GIN parasite infected lambs.
Meningeal worm (deer, brain worm)  
**Parelaphostrongylus tenuis**

by Dr. Mary Smith DVM, Michael Thonney & Dr. tatiana Stanton

- Parasite of White Tail Deer – Nonpathogenic in them
- Small ruminants are an abnormal host (sheep, goats, fallow deer) also llamas, alpacas, elk, etc.
- Parasite has indirect life cycle – snails and slugs needed for infection
Life cycle in deer

- Deer eats forage that contains a slime trail, slug or snail that is infected with the 3rd stage larvae.
- Larvae migrate through the stomach wall to the peritoneal cavity.
- Enter lumbar spinal nerves.
- Reach spinal cord in 10 days.
- Develop in an orderly manner in the grey matter of the spinal cord.
- Return to surface of spinal cord at 40 days mature and migrate to cranium to live and reproduce -> eggs laid into blood vessels.
- Eggs hatch into first-stage larvae in the lungs.
- 1st stage larvae enter bronchial tree, coughed up, swallowed and passed in feces.
Deer worm life cycle continued

- 1\textsuperscript{st} stage larvae excreted in the mucous coat of fecal pellets 90+ days after deer infected
- killed by drying and/or solar radiation but resist freezing
- land snails and slugs crawl over deer feces and larvae penetrate gastropod’s foot
- develop to infective (3\textsuperscript{rd} stage) in 2 to 3 mo. (depends on temperature)
- persist for life of snail or slug or excreted in slime trail onto vegetation
- mean of 3 larvae for each infected snail
In Abnormal Hosts - Larvae travel from intestinal tract to the grey matter of the spinal cord and become disoriented, causing Nerve damage (can include lameness, gait abnormality, or constant itching in one spot) can be as extreme as paralysis or even DEATH (rare)

Animals typically maintain appetite
Current research – takes a little over 2 to 3 months to develop to L3 in snail -> possibly less chance of infection for about 3 months after winter is over.

Sheep or goat does not have to eat the snail or slug. The L3 emerge from snail/slug in slime trail and can survive on vegetation.

After about 10 days of infection much harder to kill worm in sheep or goat. May take up to 60 days for signs to develop.
Treatment of *P. tenuis* in aberrant hosts

- No controlled studies in sheep and goats

- Cornell has completed a 3 year study comparing two treatment protocols on naturally infected sheep and goats on 14 farms in Ithaca, NY region

- Infected animals scored on a “neurologic score card” and video taped within the first day or two of treatment and post treatment
Research Study

- Goal: Determine if Ivermectin is needed in the treatment *P. tenuis* in sheep and goats. Theoretically, Ivermectin cannot pass through the blood brain barrier → should not aid in treatment

- Treatment Protocol:
  - Dexamethasone (steroid): 0.2 mg/kg IM for 3 days, 0.1 mg/kg for 2 days (if instead Banamine, 50 mg flunixin per cc at 1 cc/100 lb. lw, 60 d withdrawal sheep), AND
  - Fenbendazole (Safeguard): 25mg/kg PO for 5 days (10 d withdrawal goats, 54 d sheep) AND
  - Ivermectin OR ivermectin Placebo: 0.5mg/kg SQ for 5 days (96 d withdrawal for goats & sheep)
Study Design

- Producer recognized an animal with signs of *P. tenuis* and begins treating with either Treatment A or B
- A veterinarian or researcher did an initial neurologic exam on the animal when treatment is started
- A second neuro exam was done after treatment is completed
- Improvement based on the neuro exam and final outcome of the animal were compared to determine ivermectin’s role in improving the outcome
Neurologic Exam

click anywhere on page to view video

Video link: https://www.youtube.com/watch?v=qNKqIMcjNfQ
Infected sheep

Video link: click anywhere on page, MOV file should appear on lower left of computer screen, click file to view video
Infected sheep – post treatment

Video link: click anywhere on page, MOV file should appear on lower left of computer screen, click file to view video
Infected goat

Video link: click anywhere on page, MOV file should appear on lower left of computer screen, click file to view video
Infected goat – post treatment

Video link: click anywhere on page, MOV file should appear on lower left of computer screen, click file to view video
Figure 1. Serum antibody concentrations to P. tenuis in 19 mo. old ewes initially in either a control group or a group treated with 20 L3 at 7 mo of age → then challenged or not challenged with 100 L3 at 19 mo of age (P < 0.001)
Deer Worm Study Results

- 38 animals (20 goats, 18 sheep) treated over 3 years. All 11 goats whose treatment included ivermectin recovered, while six of nine treated with the placebo recovered without further treatment, and 3 required additional treatment. Six of 9 sheep whose treatment included ivermectin recovered but 3 had to be euthanized. Five of 9 sheep whose treatment did not include ivermectin (got the placebo) recovered without further treatment; 2 required additional treatment, and 2 had to be euthanized.

- Higher pretreatment scores improved outcome ($P = 0.002$). Given the significance of pretreatment score, close observations of animals at high risk for *P. tenuis* infection is recommended in order to start treatment promptly.

- Studies with larger numbers of animals are needed to definitively state whether including ivermectin in addition to fenbendazole and dexamethasone improves outcome and is worth the substantially increased drug withdrawal period. However, if the animal is very valuable and/or is not going to be slaughtered regardless of outcome, we cannot rule out that the addition of ivermectin might improve outcome.

- We had no Control Group. However, general consensus is that our overall recovery rates, especially for goats, were far better than if animals had been left untreated.

- Challenge study indicates the potential for a deer worm vaccine for sheep & goats
IPM for parasite control

- Targeted selective deworming and evasive grazing are two effective tools – BUT require planning and labor commitments

- Jury still out on new and prospective controls listed in this presentation
QUESTIONS?