IPM GROUP Discussion

Tick Control Strategies: current and future prospects
Tick Control Inventions and Products

Attract and Kill Methods

- Tick Decoy. Pheromone-acaricide impregnated plastic beads applied to pet animals and livestock.

- Tail Tag Decoy. Pheromone-acaricide impregnated plastic collar applied to tails of cattle, other ruminants.

Table 21.1 *Pheromone-pesticide decoys kill male ticks (D. variabilis) and prevent mating when administered at a ratio of 10:1 decoys:live female ticks on rabbits*

<table>
<thead>
<tr>
<th>Location of males on host</th>
<th>Type of treatment&lt;sup&gt;a&lt;/sup&gt;</th>
<th>0–0.5</th>
<th>0–0.5</th>
<th>0–0.5</th>
<th>0–0.5</th>
<th>0–0.5</th>
<th>48</th>
<th>48</th>
<th>48</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) Both pheromones +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>acaricide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) Both pheromones, no</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>acaricide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) 2,6-Dichlorophenol +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>acaricide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4) 2,6-Dichlorophenol, no</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>acaricide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percent of sexually active</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>♀♂ release ± s.d. (hours &gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>♀♂ release)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mating with decoys&lt;sup&gt;b&lt;/sup&gt;</td>
<td>89.0* ± 3.3</td>
<td>0–0.5</td>
<td>73.0 ± 4.8</td>
<td>14.6 ± 1.2</td>
<td>20.0 ± 4.0</td>
<td>0.0</td>
<td>23.0 ± 5.8</td>
<td>10.0 ± 0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attached beside females</td>
<td>11.0 ± 3.3</td>
<td>0–0.5</td>
<td>17.0 ± 1.1</td>
<td>70.8 ± 1.4</td>
<td>24.0 ± 3.8</td>
<td>2.0* ± 2.0</td>
<td>14.0 ± 2.1</td>
<td>25.0 ± 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mating with live females</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>8.3 ± 0.6</td>
<td>6.0 ± 1.6</td>
<td>0.0</td>
<td>19.0 ± 3.3</td>
<td>7.5 ± 1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attached elsewhere</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>6.3 ± 0.6</td>
<td>50.0 ± 0.4</td>
<td>2.0 ± 5.5</td>
<td>44.0 ± 1.3</td>
<td>57.0 ± 1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unattached</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>9.6 ± 4.8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dead</td>
<td>100</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>36.0 ± 4.3</td>
<td>98.0 ± 1.3</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Males dead; two males deposited spermatophores onto decoys before they died.

<sup>b</sup> Two treatments were done with both pheromones, i.e. decoys impregnated with 2,6-dichlorophenol and coated with cholesteryl oleate. In group 1, decoys were impregnated with an acaricide (Propoxur); in group 2, no acaricide was included. Two other treatments were done with only one pheromone, i.e. decoys impregnated with 2,6-dichlorophenol alone. In group 3, decoys were impregnated with an acaricide (Propoxur); in group 4, no acaricide was included.

<sup>c</sup> Mating with decoys = males physically on or in direct contact with the plastic decoys.

<sup>d</sup> Attached beside decoys = males attached to host skin adjacent to decoys but not in direct contact with these devices.
Host-targeted tick control technologies

4-Poster for killing ticks on deer

A patented device developed by USDA, ARS scientists to protect white-tailed deer from blacklegged ticks is now being sold commercially. The American Lyme Disease Foundation, Somers, NY, was licensed to produce the device, called the "4-Poster" Deer Treatment Bait Station, developed by ARS scientists in Kerrville, Texas.

Mixed success, not accepted in all locations, concern about use during hunting season, etc.

Damminix Tick Tubes

Marketed by
ECOHEALTH, INC., 56 Hawes Street
Brookline, MA 02446
Phone 617.742.2400; Fax 617.849.5494
www.Ticktubes.com

Permethrin-impregnated cotton balls collected by mice to use for nesting materials. Kills immature ticks
Deploy Tickbot

U.S. Patent US20060204531A1

Scour environment, collect and kill ticks. 100% kill lone star ticks > 24 h in trails and meadows in field trials

Alternative use: dispense odorant/pheromone – deposit in vegetation.
NATURE COMMUNICATIONS publication (2-9-2016):
Genomic insights into the *Ixodes scapularis* tick vector of Lyme disease
By Monika Gulia-Nuss et al.

- *I. scapularis* genome sequence comprises 1.8 Gbp of which 57% was annotated.
- Predicted 20,486 protein-coding genes, and 4,439 non-coding RNA genes.
- Exploring the tick genome and the (corresponding) transcriptomes of tick organs yields an enormous array of highly specialized gene targets that could be selected for suppression (RNAi) or deletion (**CRISPR/Cas9 kit**).
Chemoreception: host and mate recognition

- Odorant detection by olfactosensilla in Haller’s organ on foreleg tarsi
- Candidate odorant receptor (OR) genes include GPCRs (*G protein-coupled receptors*) and *IR/iGluR* (*ionotropic glutamate related receptors*). Almost all are novel (few insect-related orthologs). Also includes one member of ancestral chemosensory protein (*CSP*) family.

Excellent targets for gene editing, RNAi, etc., to disrupt host finding and mating.
Salivary glands

- Tick specific salivary genes:
  - Genes encoding Kunitz domain proteins: protease inhibition, coagulation, angiogenesis, vasodilation, etc. Ticks have 74 Kunitz domain proteins, 0.4% of the entire genome, probably most of any known haematophagous arthropod.
  - Genes encoding lipocalins: anti-inflammatory activity & other anti-hemostatic roles. Ticks have an unusually high number of such proteins.

Blood feeding and hemoglobin digestion

- Hemoglobin ingestion intracellular, within specialized vesicles.
- Digestion occurs via a cascade of proteolytic enzymes, liberating dipeptides and free amino acids and disseminated via hemolymph throughout the body.
- Genes encoding for cathepsin D (three genes), cathepsin L (three genes), and serine carboxypeptidase (four genes) critically important for digestion.
- Haem from digestion detoxified in unique vesicles (small amounts transported elsewhere and incorporated into vitellogenin and CP
Blood feeding and hemoglobin digestion

- Blood sucking—neuropeptides and neurotransmitters regulating pharyngeal pump. qPCR assay of neurotransmitter receptors in synganglion from fed v. unfed females shows strong upregulation of glutamate (stimulates) versus weak or no regulation GABA (inhibits) consistent with action of pharyngeal pumping during feeding.

From Egekwu et al. (2016)
Disease transmission –

- TROPSA (Tick Receptor outer surface protein A) full sequence known. Candidate for gene deletion via CRISPR/case

- Defensins- antimicrobial peptide (scapularisin) – sequence known

- Toll receptors, IMD pathway and JAKSTAT pathway: upregulation genes in these pathways believed trigger phagocytic hemocytes to phagocytose migrating spirochetes, other bacteria.

- Salp 15, Salp 20, TSLP1 and tHRE facilitate transmission via tick saliva into host body.
TRANSGENIC TICKS
Prospects for disruption disease transmission and tick population control

Transgenic mosquitoes –

- model system may also be applied to ticks and tick-borne diseases. Done in mosquito by injecting embryos, fusing genes, other methods.

- Examples:
Can we create transgenic ticks?

- Tick biology many features similar to mosquitoes (numerous large eggs, single mating, etc.)

- Costs

- Ethical considerations

FUTURE DISCUSSIONS