“BOOSTED SIT” AS AN ADDITIONAL TOOL IN AW-IPM PROGRAMMES

Jérémy Bouyer
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LS9 Panel Applied Life Sciences and Non-Medical Biotechnology
THE CHALLENGE
Toxicity and ecotoxicity of insecticides

Reduction of authorized insecticides (by 75% in Europe)

Insecticide resistance

Resurgences

Biological invasions (vectors/pests)

Environmental changes (local/global)

Diseases and pests outbreaks

Economical loses
Toxicity and ecotoxicity of insecticides

Reduction of authorized insecticides (by 75% in Europe)

Insecticide resistance

Resurgences

Environmental changes (local/global)

Biological invasions (vectors/pests)

Diseases and pests outbreaks

Economical losses

INNOVATION
The range of insecticides available for vector control

... worse in Europe!

<table>
<thead>
<tr>
<th>Vector Control Intervention type</th>
<th>Number of WHO recommended insecticide families</th>
<th>Insecticide families</th>
<th>Number of molecules recommended in each family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor Residual Spraying</td>
<td>4</td>
<td>Pyrethroids</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carbamates</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Organophosphates</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DDT</td>
<td>1</td>
</tr>
<tr>
<td>Long-lasting insecticide treated nets</td>
<td>1 (+1)</td>
<td>Pyrethroids</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Piperonyl butoxide)</td>
<td></td>
</tr>
<tr>
<td>Space Sprays</td>
<td>2 (+1)</td>
<td>Pyrethroids</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Organophosphates</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Piperonyl butoxide)</td>
<td></td>
</tr>
<tr>
<td>Larvicides</td>
<td>5</td>
<td>Bacterial larvicide</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Benzoylureas</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Juvenile Hormone mimics</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Organophosphates</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spinosyn</td>
<td>1</td>
</tr>
</tbody>
</table>

Resistance to pyrethroids and DDT is now widespread in many mosquito populations

Source: Justin McBeath ISNTD Bites – March 19th 2015
THE PRINCIPLE
INSECT MODELS
PUBLIC HEALTH

Mosquitoes
Aedes albopictus
Fruit flies
*Ceratits capitata*

Tsetse flies
*Glossina palpalis gambiensis*
THE TEAM
WHAT IS NEEDED TO RUN BOOSTED SIT?
WHAT WILL WE ADDRESS?
Transfer of biocides during mating and impact on female fertility (PP & Bti & Densovirus)
Impact of boosted SIT in semi-field and field trials with the best biocide \( (\text{Ae. albopictus} \& \text{C. capitata}) \)
Relative impacts of SIT and boosted-SIT on population dynamics and resilience

\[ \kappa = \frac{1 - \Phi^l (1 - \xi \psi^T (1 - \eta \Phi^u))}{\xi \Phi^l \psi^T}. \]

Deterministic models

Individual-based models
Mass rearing and irradiation procedures

FAO-IAEA IPCL
Sex separation method (female elimination) and quality control

Sexing of mosquitoes and handling procedures

Quality control of produced strains

2 strategies:
- Development of non-transgenic GSS
- RNAi sexing
Development of an automatic release machine
Regulatory issues and social acceptability of boosted SIT

Risk assessment → Regulatory issues → Social acceptability

Review of regulatory issues, technical constraints and social acceptability of genetic control in Europe
PRELIMINARY RESULTS

Transmission of pyriproxifen
Transfer qualitatively confirmed
(Gaugler et al., 2012)
Strong increase of immature mortality around release sites of coated males (Mains et al., 2015)
Transfer of PP during mating (dry powder)

Contamination technique

20.6ng (SD 26.9)

3ng (100% larval mortality in a 200mL habitat)
Transfer of PP during mating (dry powder)

Contamination technique

Resilience and transfer / mating

20.6ng (SD 26.9)  2.5ng (SD 0.9)

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Transfer breeding sites & impact on fecundity

20.6ng(SD26.9) 2.5ng(SD0.9) 0.01ng(SD0.01)

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20.6ng(SD26.9)  2.5ng(SD0.9)  0.01ng(SD0.01)

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Resilience and transfer / mating

Transfer breeding sites & impact on fecundity

3ng (100% larval mortality in a 200mL habitat)
Transfer of PP during mating (3FInnovation formulation)

- Resilience and transfer / mating
- Transfer breeding sites & impact on fecundity

286.5ng (SD 99.8)

3ng (100% larval mortality in a 200mL habitat)
Transfer of PP during mating (3FInnovation formulation)

Resilience and transfer / mating

Transfer breeding sites & impact on fecundity

![Graph showing dose of PP per mosquito over time]

Dose of PP per mosquito (ng)

Time of exposition (min)
No impact on male survival
Boosted SIT with pyriproxifen, a synergistic combined tactic to eradicate insects

(B) Synergistically combining a density-independent tactic to reduce population density with one that increases an Allee threshold. (Suckling et al. J Eco Entomol 2012)
Preliminary models

Density of sexually active females after 2 years of releasing R males (shown as a proportion of the carrying capacity K)

Proportion of larvae surviving in the contaminated site

C=0.93  D=33.3  K=10000

SIT
What about associating SIT to DENSOVIRUSES?
A. Release of sterile males coated with a densoivirus

B. Adult horizontal transmission to the breeding site

C. Multiplication of the densoivirus plus larval horizontal transmission

D. Adult vertical transmission to new breeding sites
Availability of infectious clones
AalDV2 (*Aedes albopictus* Densovirus strain 2)

+40% mortality
(10e7 - 10e8 viral genomes / larva)

Probability of survival of *Aedes albopictus* larvae (Weibull regression model)
Availability of infectious clones

High specificity
**High specificity**

![Image](image_url)

**TABLE II**

**Pathogenesis of AeDNV to Invertebrate Species**

<table>
<thead>
<tr>
<th>Animal species</th>
<th>Number of individuals</th>
<th>Developmental stage</th>
<th>Route of infection</th>
<th>Pathological effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ae. aegypti</td>
<td>1140</td>
<td>Instar I–IV larvae</td>
<td>PO</td>
<td>+</td>
</tr>
<tr>
<td>Ae. albopictus</td>
<td>550</td>
<td>Instar I larvae</td>
<td>PO</td>
<td>+</td>
</tr>
<tr>
<td>Ae. togoi</td>
<td>450</td>
<td>Instar I larvae</td>
<td>PO</td>
<td>+</td>
</tr>
<tr>
<td>Ae. vexans</td>
<td>419</td>
<td>Instar I, II larvae</td>
<td>PO</td>
<td>+</td>
</tr>
<tr>
<td>Ae. geniculatus</td>
<td>233</td>
<td>Instar I larvae</td>
<td>PO</td>
<td>+</td>
</tr>
<tr>
<td>Ae. caspia dorsalis</td>
<td>905</td>
<td>Instar I, II larvae</td>
<td>PO</td>
<td>+</td>
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<tr>
<td>Ae. cantans</td>
<td>440</td>
<td>Instar II larvae</td>
<td>PO</td>
<td>+</td>
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<tr>
<td>Ae. caspia caspia</td>
<td>90</td>
<td>Instar II larvae</td>
<td>PO</td>
<td>+</td>
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<tr>
<td>C. pipiens pipiens</td>
<td>915</td>
<td>Instar I, II larvae</td>
<td>PO</td>
<td>+</td>
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<tr>
<td>C. p. molestus</td>
<td>641</td>
<td>Instar I larvae</td>
<td>PO</td>
<td>+</td>
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<tr>
<td>C. annulata</td>
<td>315</td>
<td>Instar I, II larvae</td>
<td>PO</td>
<td>+</td>
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<tr>
<td>An. maculipennis</td>
<td>548</td>
<td>Instar I, II larvae</td>
<td>PO</td>
<td>–</td>
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<td>Chironomus sp.</td>
<td>142</td>
<td>Larvae</td>
<td>PO</td>
<td>–</td>
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<tr>
<td>M. domestica</td>
<td>335</td>
<td>Instar III, IV larvae</td>
<td>PO, IL</td>
<td>–</td>
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<tr>
<td>P. regina</td>
<td>210</td>
<td>Instar III, IV larvae</td>
<td>PO, IL</td>
<td>–</td>
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<tr>
<td>A. mellifera</td>
<td>200</td>
<td>Adult</td>
<td>PO</td>
<td>–</td>
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<tr>
<td>G. mellonella</td>
<td>450</td>
<td>Instar III, IV larvae</td>
<td>PO, IL</td>
<td>–</td>
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<tr>
<td>B. mori</td>
<td>115</td>
<td>Instar III, IV larvae</td>
<td>PO, IL</td>
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<tr>
<td>A. crataegi</td>
<td>184</td>
<td>Instar III, IV larvae</td>
<td>PO, IL</td>
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<tr>
<td>M. neustria</td>
<td>270</td>
<td>Instar III, IV larvae</td>
<td>PO, IL</td>
<td>–</td>
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<tr>
<td>P. dispar</td>
<td>225</td>
<td>Instar III, IV larvae</td>
<td>PO, IL</td>
<td>–</td>
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<tr>
<td><strong>Crustaceans</strong></td>
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<td></td>
</tr>
<tr>
<td>Daphnia sp.</td>
<td></td>
<td>Adults and youth</td>
<td>PO</td>
<td>–</td>
</tr>
<tr>
<td>Cyclops sp.</td>
<td></td>
<td>Adults and youth</td>
<td>PO</td>
<td>–</td>
</tr>
<tr>
<td><strong>Worms</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumbricus sp.</td>
<td>50</td>
<td>Adults</td>
<td>SC</td>
<td>–</td>
</tr>
</tbody>
</table>

Carlson et al. 2006
Advances in virus research
EXPECTED BREAKTHROUGH
Fundamental expected breakthrough

Quantification of vertical and horizontal transfers of biopesticides in mosquitoes in natural populations

Quantification of the impacts of SIT ± biocides on population dynamics & evolutionary response of target populations
→ generic conclusions on the sustainability of boosted SIT versus chemical control
Applied expected breakthrough

New biological control technique for mosquitoes

Operational data for stakeholders applying genetic control
Thanks!