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

Jérémy Bouyer
Third FAO–IAEA International Conference on Area-wide Management of Insect Pests, 22-26 May in Vienna
Toxicity and ecotoxicity of insecticides

Reduction of authorized insecticides (by 75% in Europe)

Resurgences

Insecticide resistance

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)

Resurgences

Insecticide resistance

Biological invasions (vectors/pests)

Environmental changes (local/global)

Diseases and pests outbreaks

Economical loses

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>Spinosyns</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
SIT

Boosted SIT

Bouyer & Lefrançois Trends Parasitol 2014
INSECT MODELS
Mosquitoes
*Aedes albopictus*
Tsetse flies
*Glossina palpalis gambiensis*

Fruit flies
*Ceratitis capitata*
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 (*Ae. albopictus & C. capitata*)

*Semi-field trials* → *Experimental field trials*
Relative impacts of SIT and boosted-SIT on population dynamics and resilience

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

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)

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

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

Graph showing:
- 20.6ng (SD 2.9)
- 2.5ng (SD 0.9)
- 0.01ng (SD 0.01)

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

Contamination technique

Resilience and transfer / mating

Transfer breeding sites & impact on fecundity

20.6ng (SD 26.9)  2.5ng (SD 0.9)  0.01ng (SD 0.01)

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

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

Box plot showing:
- 286.5ng (SD 99.8) for males
- 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

![Diagram showing the transfer of PP during mating and its impact on resilience and breeding sites.](image)

Box plots showing the dose of PP per mosquito (ng) at different times of exposition (min): 1, 5, and 10.
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)
What about associating SIT to DENSOVIRUSES?
Drawn by Steve Higgs

Eggs

"Early" infection

AeDNV virions (environmentally stable)

"Late" infection

Disease

Pupa

Infected adults (transduced?)

Vertical transmission to progeny at low rate

Death and virion release
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

Carlson et al. 2006
Advances in virus research

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