3. The biological target, IRM & Spray operations (1)
The biological target:
- MoA and product selection
- Importance of timing
- PHI (residues, dosage and application)

Nozzles and targeting (mostly hydraulic)

Calibration (to p.m.)
Targeting …

Why?

How to apply?

What to apply?

When to apply?
Resistance

- Monitoring
- Strategy for management
Mode of action (MoA) describes the way a pesticide attacks some biological process (often a biochemical pathway in a particular kind of living cells).

In order to understand and manage resistance and so minimise impact on crop production, four Resistance Action Committees exist as Specialist Technical Groups of CropLife International (formerly the Global Crop Protection Federation and GIFAP).

Pesticide types (herbicide, insecticide etc.)

- Herbicides (HRAC) [http://hracglobal.com/](http://hracglobal.com/)
- Insecticides (IRAC) [http://www.irac-online.org/](http://www.irac-online.org/)
- Fungicides (FRAC) [http://www.frac.info/](http://www.frac.info/)
- Rodenticides (RRAC) [http://www.rrac.info/](http://www.rrac.info/)
KNOWING YOUR INSECTICIDE MODE OF ACTION IS THE KEY TO RESISTANCE MANAGEMENT

Do you know?

• Although there may be many insecticides available to growers, many control insects with the same mode of action
• When insecticides with the same mode of action are used repeatedly, insecticide resistance can develop quickly and the insecticide stops working

Follow this rule

To prevent resistance, alternate insecticide with different mode of action numbers.

1. **Minimise** pesticides use with **IPM** measures:
   - Action thresholds
   - Target the most susceptible life stages of the pest
   - Use insecticides which have a minimal impact on natural pest enemies

2. **Cycle** products containing different MoA

3. **Stop using** products with similar mode of action if it is known that the **target pests** have become resistant to them

4. **Accurate application**: dosage and volume application rates

5. **Avoid counterfeit products**...
Insecticide Mode of Action Classification:
A key to effective insecticide resistance management

Moulting & Metamorphosis
- Group 18 Ecdysone agonist / disruptor
- Diacylhydrazines (e.g. Tebufenozide)
- Group 7 Juvenile hormone mimics
  JH analogues, Fenoxycarb, Pyriproxyfen, etc

Midgut
- Group 11 Microbial disruptors of insect midgut membranes
  Toxins produced by the bacterium Bacillus thuringiensis (Bt): Bt sprays and Cry proteins expressed in transgenic Bt crop varieties (specific cross-resistance sub-groups)

Metabolic Processes
- Many groups acting on a wide range of metabolic processes including:
  - Group 12 Inhibitors of oxidative phosphorylation, disruptors of ATP
  - Diafenthiuron & Organotin miticides
  - Group 12 Uncouplers of oxidative phosphorylation via disruption of H proton gradient - Chlorfenapyr

Nervous System
- Groups 1A & B Acetylcholinesterase (AChE) inhibitors
  Carbamates and Organophosphates
- Group 2 GABA-gated chloride channel antagonists
  Cyclodiienes OCs and Phenylpyrazoles (Fiproles)
- Group 3 Sodium channel modulators
  DDT, pyrethroids, pyrethrins
- Group 4A Acetylcholine receptor (nAChR) agonists
  Neonicotinoids
- Group 5 nAChR agonists (Allosteric) [not group 4A]
  Spinosyms
- Group 6 Chloride channel activators
  Avermectins, Milbemycins
- Group 22 Voltage dependent sodium channel blocker
  Indoxacarb

Non-specific MoA
- Group 9 Compounds of non-specific mode of action (selective feeding blockers)
  Pymetrozine, Flicamid, etc.

Cuticle Synthesis
- Groups 15 and 16 Inhibitors of chitin biosynthesis
  Benzoylureas (Lepidoptera and others), Buprofezin (Homoptera)

Moulting & Metamorphosis
- Group 18 Ecdysone agonist / disruptor
- Diacylhydrazines (e.g. Tebufenozide)
- Group 7 Juvenile hormone mimics
  JH analogues, Fenoxycarb, Pyriproxyfen, etc

IRAC website: www.irac-online.org

Insecticide Resistance Action Committee

V5.3, July 2007
Modes of action and resistance management

- Nerves and muscles: groups 1-6, 9, 14, 22, 28
- Growth development and moulting: groups: 15-17
- Respiration: group 21
- The insect’s digestive tract: group 11
MoA not to be confused with Mode of dose transfer
to a target pest:
Herbicide resistance

Resistance still rare: but becoming more common
implications are profound when it does occur - especially in genetically modified (GM) crops.
Fungicide resistance risk: very high with rice blast

International cases (FRAC) MoA
1971 (6 yr) D
kasugamycin
1977 (9 yr) F2 phosphorothiolates
1998 (2 yr) C3 strobilurins
2002 (2 yr) I melanin biosynthesis inhibitors (MBI)
<table>
<thead>
<tr>
<th>MoA code</th>
<th>Action / active group</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3</td>
<td>QoI-fungicides (strobilurins)</td>
<td>azoxystobin, trifloxystrobin, edifenphos, iprobenfos (IBP), isoprothiolane, difenoconazole, hexaconazole, propiconazole, tebuconazole</td>
</tr>
<tr>
<td>F2</td>
<td>Cell membrane disruption (phosphorothiolates)</td>
<td></td>
</tr>
<tr>
<td>G1</td>
<td>Triazoles</td>
<td></td>
</tr>
<tr>
<td>I1</td>
<td>melanin biosynthesis inhibitors (MBI) in fungal cell wall</td>
<td>tricyclazole</td>
</tr>
</tbody>
</table>
Resistance management & MoA

Season 1
MoA group X

Season 2
MoA group Y

Season 3
MoA group Z

Generations, purchases?
AI – MoA co-formulated mixtures?
The main method of communication between an agrochemical company and the user.

Always read the label and get advice before using a crop protection product.
China: priority for AI

Resistance management dependent on knowing the active ingredient (AI)

a.k.a. the active substance(s)

SC 687.5: fluopicolide 62.5 g/l + propamocarb hydrochloride 625g/l
Mode of Action (MoA) labelling?

**CAUTION**
KEEP OUT OF REACH OF CHILDREN
READ SAFETY DIRECTIONS BEFORE OPENING OR USING

**Product Name**

SELECTIVE TURF HERBICIDE

ACTIVE CONSTITUENT: 22.5 g/L FORAMSULFURON

GROUP B HERBICIDE

**Product Name**

INSECT CONTROL WITH THE ACTIVE INGREDIENT

® is a suspension concentrate.
Contains 0.43 lb. active ingredient per gallon.

**Active Ingredient**

Chlorantraniliprole 3-Bromo-N-[4-chloro-2-methyl-6-[(methylamino)carbonyl]phenyl]-1-(3-chloro-2-pyridinyl)-1H-pyrazole-5-carboxamide

**By Weight**

<table>
<thead>
<tr>
<th>成分</th>
<th>比例</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorantraniliprole</td>
<td>5%</td>
</tr>
<tr>
<td>Other Ingredients</td>
<td>95%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100%</td>
</tr>
</tbody>
</table>

EPA Reg. No. 

EPA Est. No. 

**Action Thresholds:**

Only apply when necessary

<table>
<thead>
<tr>
<th>Crop stage</th>
<th>vegetative phase: first 40 d.</th>
<th>40 days (tillering) to booting</th>
<th>booting to flowering</th>
<th>ripening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module: (new format)</td>
<td>3</td>
<td>5, 7</td>
<td>9</td>
<td>11</td>
</tr>
</tbody>
</table>

**Key:**

- Pesticide application
  - Avoid if possible or unlikely to be effective
  - Do not apply pesticides

**Pest:**

**Plant-hoppers:**
- BPH, WBPH
  - 2-3 insects /tiller if virus diseases are not present on farm [see box 1].

**BPH, GLH & other hoppers:**
- Virus risk
  - ONLY in response to warnings from local authorities (agricultural officers) or when symptoms seen in fields

**Leaf-folder** and other leaf feeders *
- 100 living insects per m²
- 40 living insects per m²

**Stem borers**
- 2 egg masses per m² (see parasitism ¶)
- One egg mass per 2 m² ¶
  - Too late for effective control

**Thrips**
- Insecticides mostly ineffective or not economic to control

**Gall midge**
- Identify problem if > 5% flag leaves with lesions (pesticides probably not effective)
  - Too late for effective control

**Panicle rice mite/sheath rot**
- Spray max. 2 X for neck blast if disease present and humid
  - Max. 3 sprays / season

**Rice blast** (with susceptible varieties)
- Progressive scouting [see box 2]
- Increasing lesions on 10% of leaves: 10 leaf samples in 4 sides of the field

**Bacterial leaf blight**
- Chemical controls have limited efficacy: only apply at early stage of disease

**Late season pests:**
- Especially **rice bugs**
  - 10 insects per m²: at milky stage (7-10d after flowering)

**Herbicides**
- If direct seeded

**Golden Apple Snails**
- GAS: 10 /m² if >1 ha

**Rodents**
- Community strategy at early stage
  - Not effective

---

**Proposed Table for VN**

---

[see box 1] [see box 2]
Pesticide residues

- Timing
- Dosage => application
High levels of pesticide residue in shipments of high-quality (jasmine) rice exceeding MRL were found: all commonly used in rice. Rejected: 94 rice containers (1,700 tons) of rice. Residues can cost (big) money!
Pesticide labels: PHI

Pre-harvest interval (PHI)
Pesticide break-down and food safety

- Relies on pesticide breakdown pathways
- **Trading standard** is the Maximum Residue Limit (MRL of an AI)
- ... not the same as (but usually better than) known safety limits

(axes are linear)
Biological activity: of the active ingredient (AI)

$LD_{50}$: the median lethal dose

Diagram showing the relationship between dose (log scale) and % responding. The $LD_{50}$ is indicated as the dose at which 50% of the population responds.
What proportion of the general public understand these concepts (even in outline)?
‘Safety’ margins rely on pesticide breakdown degradation time (half life)

- Simplified
- Breakdown products not included …

(axis scales are linear)
Normal response to pesticide application

Cumulative normal distribution
Dosage and application

- Overdose
- Reduced dosage

Pest mortality (%) vs. time after application

Typical application

Improved application

MRL

Label dosage
Coffee break

What is the LD$_{50}$ of caffeine?
<table>
<thead>
<tr>
<th>Substance</th>
<th>Trade Name examples</th>
<th>Use</th>
<th>Oral LD50 (Rats) mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphetamine</td>
<td>Drug</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Methomyl</td>
<td>Lannate, Marlin</td>
<td>Insecticide</td>
<td>13</td>
</tr>
<tr>
<td>Strychnine</td>
<td>Poison</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Nicotine</td>
<td>Tobacco</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>MDMA</td>
<td>Ecstasy</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>Dursban</td>
<td>OP Insecticide</td>
<td>135</td>
</tr>
<tr>
<td>Caffeine</td>
<td>Coffee</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Paraquat</td>
<td>Gramoxone</td>
<td>Herbicide</td>
<td>138</td>
</tr>
<tr>
<td>Aspirin</td>
<td>Aspirin</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>2, 4-D amine</td>
<td>Seldom used.</td>
<td>Herbicide</td>
<td>300</td>
</tr>
<tr>
<td>DDT</td>
<td>Not sold</td>
<td>Insecticide</td>
<td>500</td>
</tr>
<tr>
<td>Penicillin</td>
<td>Several products</td>
<td>Antibiotic</td>
<td>1000</td>
</tr>
<tr>
<td>Material</td>
<td>Brand</td>
<td>Category</td>
<td>Concentration</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------</td>
<td>------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Pendimethalin</td>
<td>Stomp</td>
<td>Herbicide</td>
<td>1150</td>
</tr>
<tr>
<td>Malathion</td>
<td>Malathion</td>
<td>OP Insecticide</td>
<td>1400</td>
</tr>
<tr>
<td>Isoproturon</td>
<td>IPU</td>
<td>Herbicide</td>
<td>1825</td>
</tr>
<tr>
<td>EDTA</td>
<td>Various</td>
<td>Makeup, soap, lotions</td>
<td>2000</td>
</tr>
<tr>
<td>Fluroxypyr</td>
<td>Starane</td>
<td>Herbicide</td>
<td>&gt;2000</td>
</tr>
<tr>
<td>Sodium Chloride</td>
<td>Common Salt</td>
<td>Food additive</td>
<td>3300</td>
</tr>
<tr>
<td>Tebuconazole</td>
<td>Folicur</td>
<td>Fungicide</td>
<td>4000</td>
</tr>
<tr>
<td>Chlorothalonil</td>
<td>Bravo</td>
<td>Fungicide</td>
<td>4200</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>Roundup</td>
<td>Herbicides</td>
<td>4300</td>
</tr>
<tr>
<td>Metsulfuron-methyl</td>
<td>Ally</td>
<td>Herbicide</td>
<td>&gt;5000</td>
</tr>
<tr>
<td>Chlormequat</td>
<td>Cycocel</td>
<td>Growth Regulator</td>
<td>6000</td>
</tr>
<tr>
<td>Trifluralin</td>
<td>Treflan, Trifluralin</td>
<td>Herbicides</td>
<td>&gt;10000</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td></td>
<td>Alcohol</td>
<td>14000</td>
</tr>
</tbody>
</table>

*It’s also about the formulation!*
Improving application: nozzles

- Droplet size?
  - Nozzle design / size
  - Pressure, ~ management

- Flow rates?
Limitations of equipment

Are we trying to apply 21st century control agents ... using technology of the 19th century?
Cone nozzles

- Usually fine sprays → good coverage
- Local manufacture (low engineering tolerances)
- Very common in Asia!

break-up of conical sheet
Nozzles: original standard types

• (Variable cone)

• Hollow cone

• Flat fan

• Deflector
Cone nozzle types

- **Disc and Core**
  - Filter
  - Side view
  - Swirl plate
  - Orifice

- **Chinese Type** (e.g. 'River Mountain')
  - Orifice plate
  - Diagonal, off-centre hole creates swirl
  - Plastic 'O' ring

- **Hollow Cone Tip**
  - ('Conejet', 'Hollow Tip', etc)

- **Variable Cone**
Variable cone nozzles - designing-in bad practice?
Nozzle variability!
What to recommend to a farmer?

Output from 3 variable cone nozzles

Conclusion: impossible to calibrate!
How not to spray high branches!

Large droplets bounce off leaves and fall to the ground

‘jet’ mode - very popular
Remote pump systems

- ≥2 person operation
- hand or foot operated
- moderately high (>1 mPa) pressures possible

Extended lance (lightweight: glassfibre)
Europe, America especially: spray drift and its mitigation
Experimental / demonstration nozzle boom system

Lower drift nozzles
The existing nozzle/spray classification scheme is based on:

- conventional flat fan nozzles
- droplet size distributions only

It is used:

- on product labels
- in Codes of Practice...
- includes LERAP (UK: Local Environment Risk Assessment for Pesticides)
Using improved nozzles requires standard nozzle holders …

Can get complicated!

- Nozzle colour code for flow rate (ISO)
  - (but not disc/core cones)

- Nozzle body (ISO Standard)

- Screw fittings*:
  - >5 screw different screw threads used, ‘unofficial’ 18 mm standard
  - Would farmers seek out adapters?

- Pressure regulation?

* details: www.dropdata.org
Nozzle materials

- Brass: traditional, poor wear life, corrodes (especially with fertilisers)
- Stainless steel: good wear life, excellent chemical resistance, expensive
- Ceramic: excellent wear life (WPs etc.) and chemical resistance, very expensive
- Engineering plastic: good wear life but may become damaged, cost effective

... and can be colour coded ...
International coding systems


BCPC notation: *e.g.* F110/1.2/3 is a 110° standard fan nozzle emitting 1.2 L/min at 3 bar (300 kPA).

<table>
<thead>
<tr>
<th>Colour</th>
<th>Flow rate (l/min. at 300 kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange</td>
<td>01 0.4</td>
</tr>
<tr>
<td>Green</td>
<td>015 0.6</td>
</tr>
<tr>
<td>Yellow</td>
<td>02 0.8</td>
</tr>
<tr>
<td>Lilac</td>
<td>025 1.0</td>
</tr>
<tr>
<td>Blue</td>
<td>03 1.2</td>
</tr>
<tr>
<td>Red</td>
<td>04 1.6 etc.</td>
</tr>
</tbody>
</table>

0.4 US gallons per minute at 40 psi (only approximately equivalent)
<table>
<thead>
<tr>
<th>Letter code</th>
<th>Nozzle type</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(EF)</td>
<td>Deflector</td>
</tr>
<tr>
<td>F</td>
<td>Fan - standard</td>
</tr>
<tr>
<td>FE</td>
<td>Even spray fan</td>
</tr>
<tr>
<td>RD</td>
<td>Pre-orifice (reduced drift)</td>
</tr>
<tr>
<td>LP</td>
<td>Low pressure</td>
</tr>
<tr>
<td>HC</td>
<td>Hollow cone</td>
</tr>
<tr>
<td>OC</td>
<td>Offset fan</td>
</tr>
<tr>
<td>Al</td>
<td>Air inclusion (‘Bubble jet’)</td>
</tr>
</tbody>
</table>
Example: flat fans (Spraying Systems)

- **Standard**
- **Even**

**fan angle** (e.g. 80°, 110°)

**flow rate** (e.g. 0.4 US gall./min)
Patternator readings: fan nozzles

25 mm channels

standard
even
Air inclusion (AI) nozzles

- Now >50% of EU hydraulic nozzle market
- Reduced drift, larger droplets
- Air inclusion: good levels of crop retention, but different form of deposit
Equivalent nozzles (same flow rate & pressure)

TTI-02 (Al)

FF110-02
$/€ millions spent on equipment specifications and nozzle development since 1980s

International specifications for application equipment: improved safety, durability (FAO, WHO, ISO, ASTM, EU, etc).

Nozzles for improved deposition, reduced drift ...

... but these need standard fittings!

- e.g. nozzle housing: ISO 8169
Objective: maximise spray retention on the leaf to enhance performance of fungicides, herbicides and growth regulators

Reduce the risk of spray drift

Operated at reduced volume application rates

'Hawk': a herbicide formulation for black grass

'Amistar':

LERAP *** ‘go faster’

General purpose turf
Spraying cocoa
Optimising dose transfer: the ‘Cocoa Nozzle’

- A recipe not a product
- Narrow cone disc-core
- Fixed setting
- Optimised droplet size

Pressure Regulating Valves

- Ensures reproducability (excellent trial tool)
- Probably reliable (but are they worth the extra €/$10 to small-holder farmers?)
Non - Pressure Retaining Sprayers

Designed for public health (mosquito control - IRS)
For discussion:

How to deliver difficult messages to farmers in SE Asia?

Spraying techniques, better application technology
- Choice of sprayers
- Improved nozzles and quality standards
- Safe application practices
- ‘It pays to calibrate’