Innovation in Chemical Technologies for the Sustainable Intensification of Agriculture

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Contents

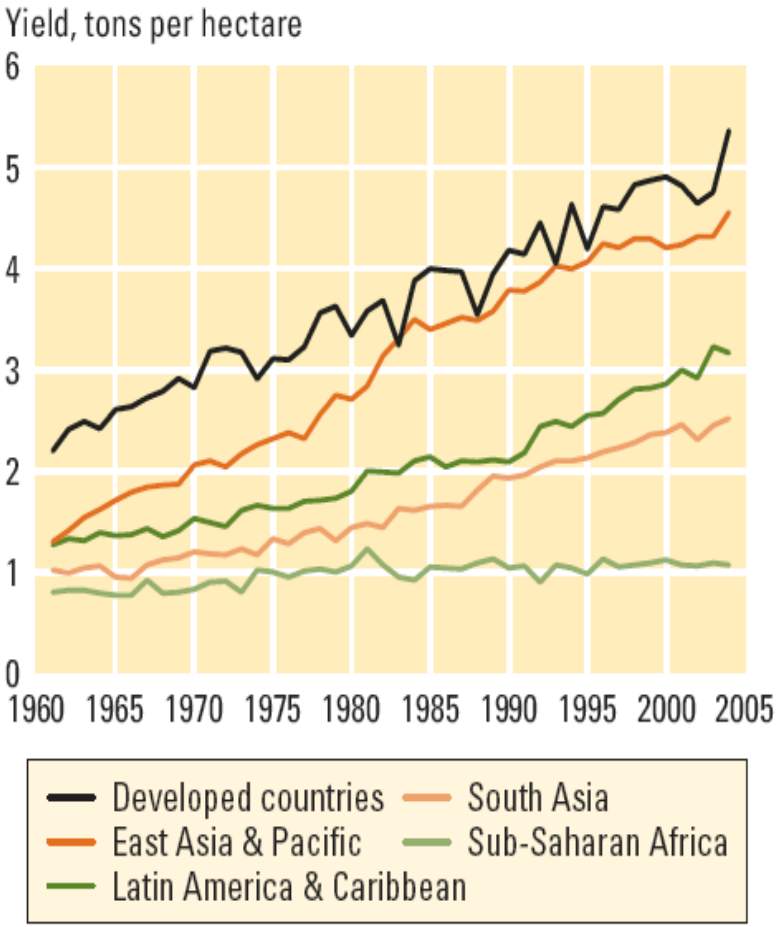
- Drivers for Agriculture
- Sustainable Intensification
- CP in Agricultural Systems
- Personal reflections on current status of Innovation in Crop Protection Chemicals
- Safety of CP technologies
- Future challenges and opportunities
  - It's about pest, weed and disease control

Sustainable Intensification of Agriculture

- Sustainable Intensification of Agriculture
  - **A key concept** from UK Foresight report
- ....defined as producing **more output from the same area** of land while **reducing the negative environmental impacts** and **using all inputs more efficiently** – land, water, nutrients

- Growing More from Less
- Rules nothing out and nothing in
- Applies to all farming systems

How have we met the increased food demand since 1950's?



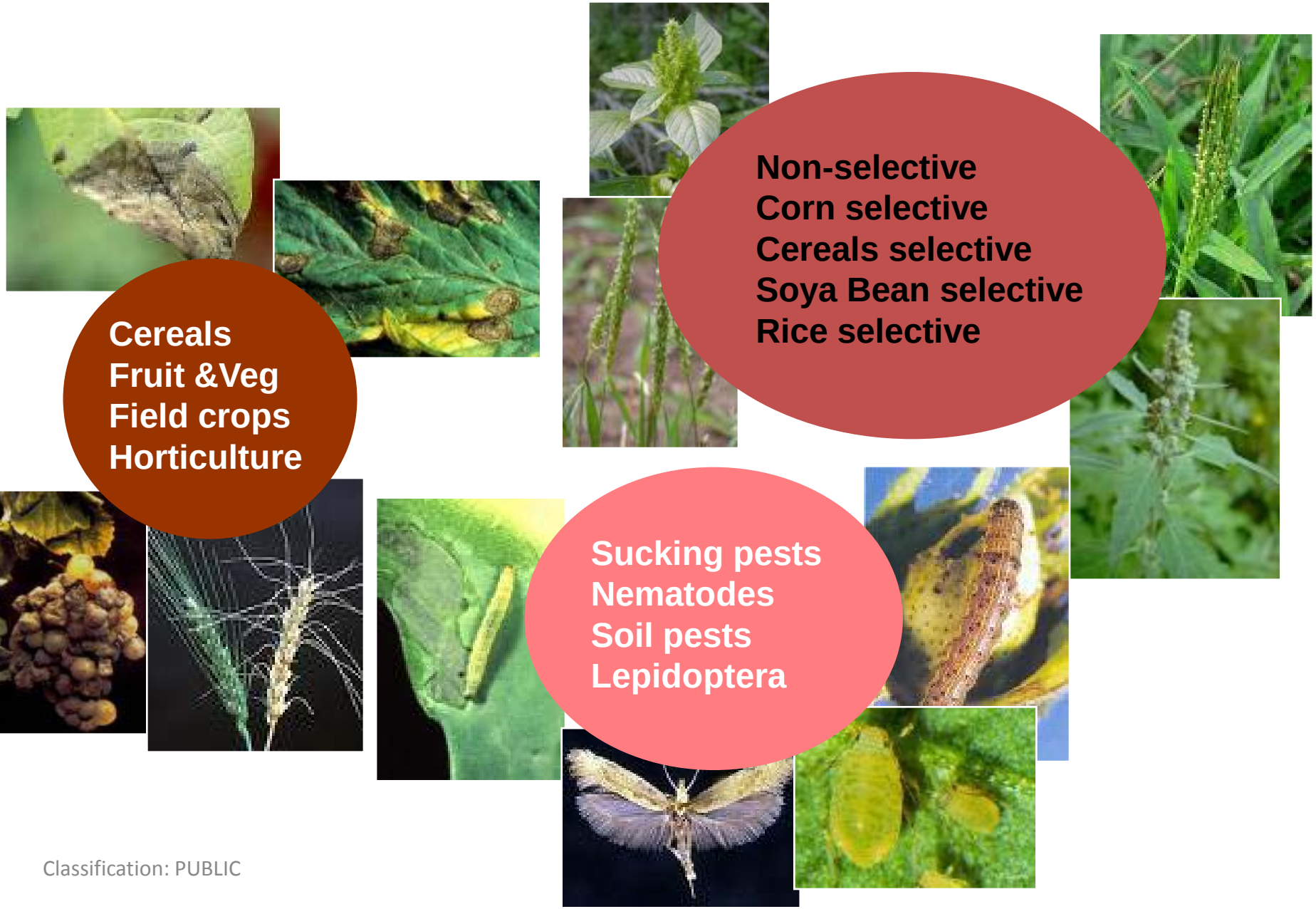
Source: http://faostat.fao.org, accessed June 2007.

The role of crop protection

40% of the world's food would not exist without crop protection products

- Delivering genetic potential
- Protecting Yield
- Increasing Yield Quality

Disease, Insect, Weed Control Research Targets



Crop diseases can be devastating

Effects of Potato Late Blight (*Phytophthora infestans*) exemplifies why agricultural fungal control is so important to global agriculture!

Drivers for innovation : New disease issues

- New disease pandemics can occur
- Example : Soybean rust (Phakopsora pachyrhizi)
  - a billion $ opportunity in N & S America that didn't exist 10 years ago.
  - a virulent strain from the Far East first identified in 1902
  - rapid defoliation and dramatic yield losses (up to 80%).
- Rapid spread from Zimbabwe in 1998 to S. Africa, S. America and USA by 2004.

Fungicide treated vs. untreated soya in Brazil

Drivers for innovation: Resistance

- Resistance drives need for product refreshment
  - Can develop faster than R&D can deliver new technologies
- Resistance management is a major issue

- Different types of resistance development and impact – so monitoring is important
  - Azoles – “creeping” tolerance
  - Strobilurins – sudden and total failure

Septoria tritici

Weeds are more than a nuisance!

- Weeds are the number 1 cause of yield loss
- With a good fertiliser regime you can grow 12t/ha maize
  - or 6t maize and a lot of weeds
- Compete with the crop for light, water and nutrients
- Costly to control manually
- Herbicide programmes need to be safe to the crop while controlling the key weeds

Crop protection compounds: a long road to market

Research

Discover

100'000
compounds

Profile

5000
compounds

Evaluate

30

Develop

1 - 2

Development

Stage
Gate
Process

Time

syngenta

Innovation is alive and well!

- Path to market through R&D is long and expensive
- Questions asked at the Development decision
  - Does it work?
  - Can we make it?
  - Is it ours?
  - Is it safe?
  - Can we sell it?
  - Can we make money?
- **Great stories of innovation in AI design/optimisation**
  - Underpinning science and technology – design, screening, analysis
  - Screening and profiling methodology
  - Bioscience - Moa, Biokinetics, Metabolism, **Understanding safety**
  - Physical Science - polymorphs
  - **Route development, waste elimination, cost reduction**

State of Innovation in Crop Protection (1)

- Major global R&D companies continue to bring new Active Ingredients to Market – e.g. Syngenta
  - Maize and Sugar cane herbicide (HPPD)
  - Broad spectrum fungicide family (SDHI's) – foliar and ST
  - New insecticides based on bisamide chemistry

2 sprays IZM 0.75 + Proline 0.4
13.6t/ha (+5.1t/ha)

Innovation in Crop Protection Chemistry (2)

- In 1984 there were 15 Global companies with Herbicide Discovery Programmes
  - (1980 Wood MacKenzie Top 50)
- In 2012 there are 4 or 5
- Industry consolidation
- High costs of discovery and development
- Success of Glyphosate tolerant crops

- No new Blockbuster moa since HPPD (1991)

- Serious weed resistance problems in USA and Australia

Innovation in Crop Protection Chemistry(3)

- Not all about active ingredients
- Formulation and delivery systems
- Controlled release
- Seed Treatment
- Innovative products from mixtures

- Systems level thinking offers new opportunities
- Chemistry + genetics (+ agronomic practices)
- Biocontrol methods
  - Chemistry + biologicals

Biocontrol of Varroa Mite

- Entomopathogenic fungi as potential biocontrol agents of the ecto-parasitic mite, Varroa destructor, and their effect on the immune response of honey bees (Apis mellifera L.)
- Mollah Md. Hamiduzzaman, Alice Sinia, Ernesto Guzman-Novoa , Paul H. Goodwin
- Guelph, Canada
- **Journal of Invertebrate Pathology 111 (2012) 237–243**

- Metarhizium anisopliae, Beauveria bassiana and Clonostachys rosea
- Entomopathogenic fungi could reduce varroa mite damage to honey bee brood by both infecting the parasite and preventing varroa-associated suppression of honey bee immunity.

GM Plants with insect resistance

Corn borer resistant (Bt) maize

Corn root worm resistant maize

Corn Pest control: Innovative combinations

Pest	Common Name	Vip3A (Viptera)	Cry1Ab (CB)
Helicoverpa zea	Corn Earworm	✓	✓
Spodoptera frugiperda	Fall Armyworm	✓	✓
Agrotis ipsilon	Black cutworm	✓	
Striacosta albicosta	Western bean cutworm	✓	
Papaipema nebris	Common stalk borer	✓	✓
Ostrinia nubilalis	European corn borer		✓
Diatraea grandiosella	Southwestern corn borer	✓	✓

Stacks offer outstanding control of all these pests

Innovation in traits for Insect control?

- Bt leps and coleoptera
- VIP distinct moa
- Programmes with chemicals to complete spectrum and help manage resistance
- Refugia concepts

- RNAi

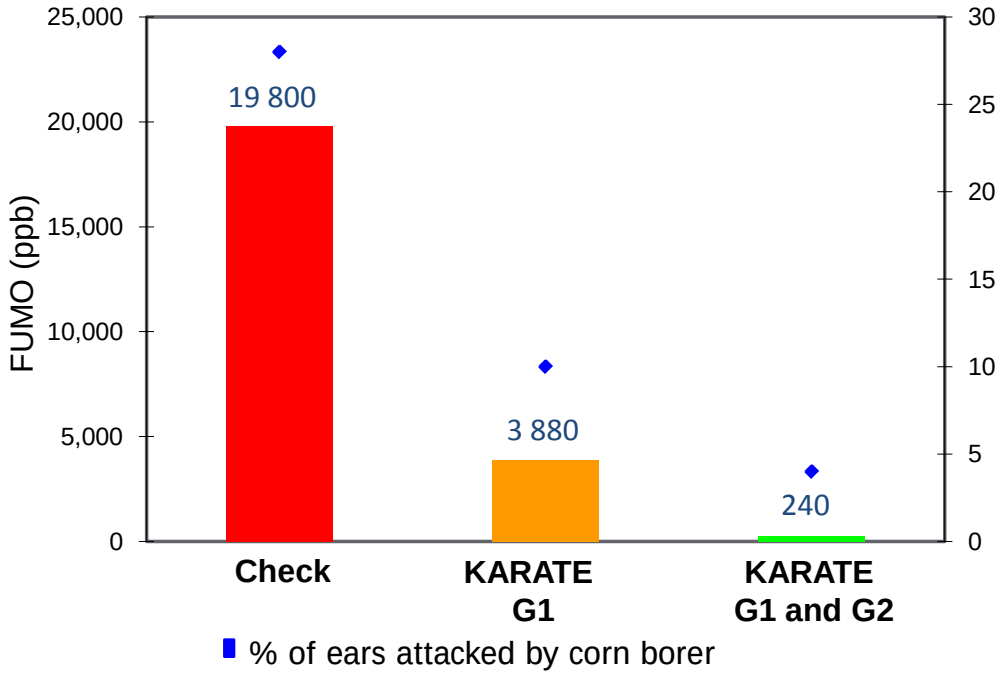
Fungal mycotoxins: a growing problem

- Secondary metabolites produced by *Aspergillus*, *Fusarium* & *Penicillium spp*
- Aflatoxins are greatest risk to human and animal health
  - Up to 25% of the world's food crops significantly contaminated*
  - Acute exposure can be fatal; chronic exposure causes serious health problems
- Dietary exposure managed in developed countries
  - Food Chain and Food Safety Agency monitoring and action
  - Significant economic losses
- Kenya 2011**
  - 30-60% maize samples tested had aflatoxin levels above the action level
  - Up to 163x safe concentration

* Source: WHO 1999

** Source: IFPRI

Insect control reduces mycotoxin levels in corn



- Insecticide control of corn borer infestation reduces fumonisin levels
- Bt corn (GM) also reduces crop losses through mycotoxin contamination*

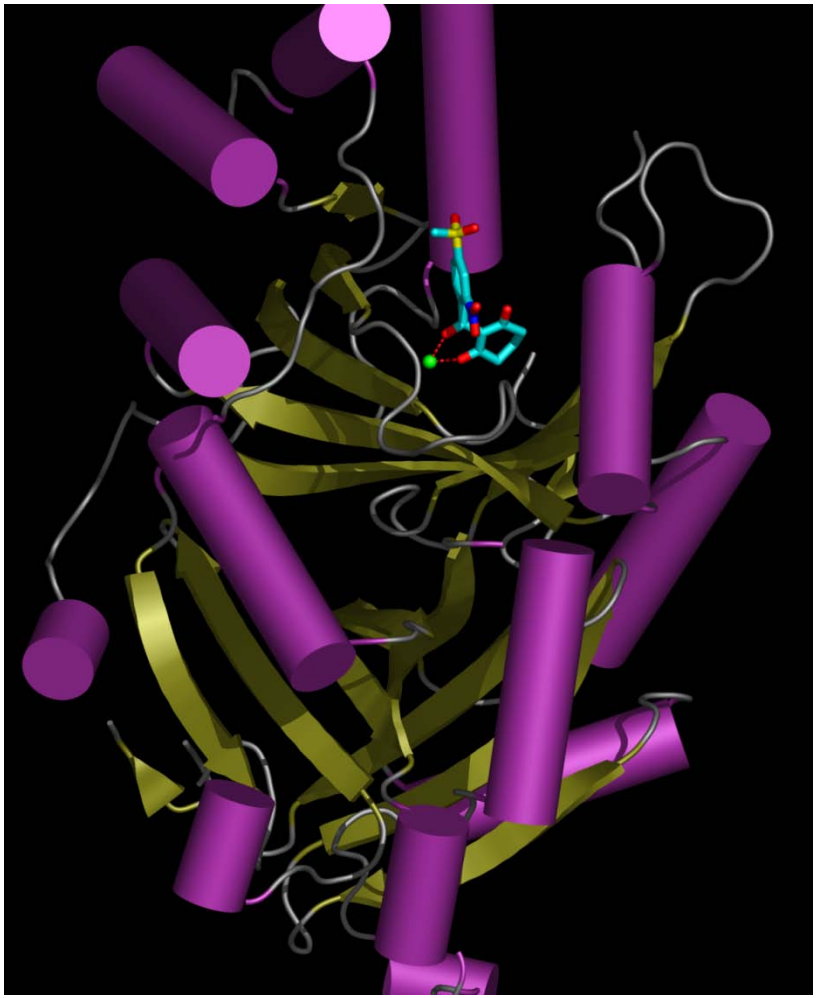
*Source: G Brookes, PG Economics June 2009

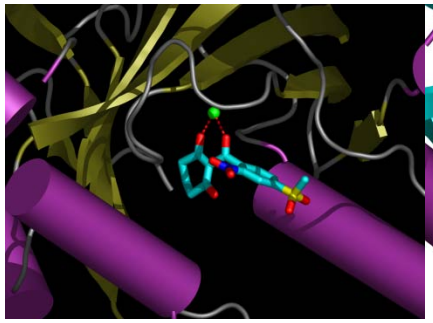
There has never been a better time to be a scientist in Ag research….

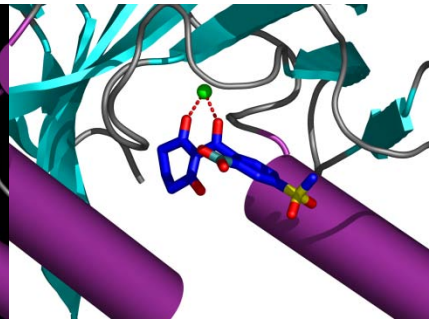
…..or a more important time

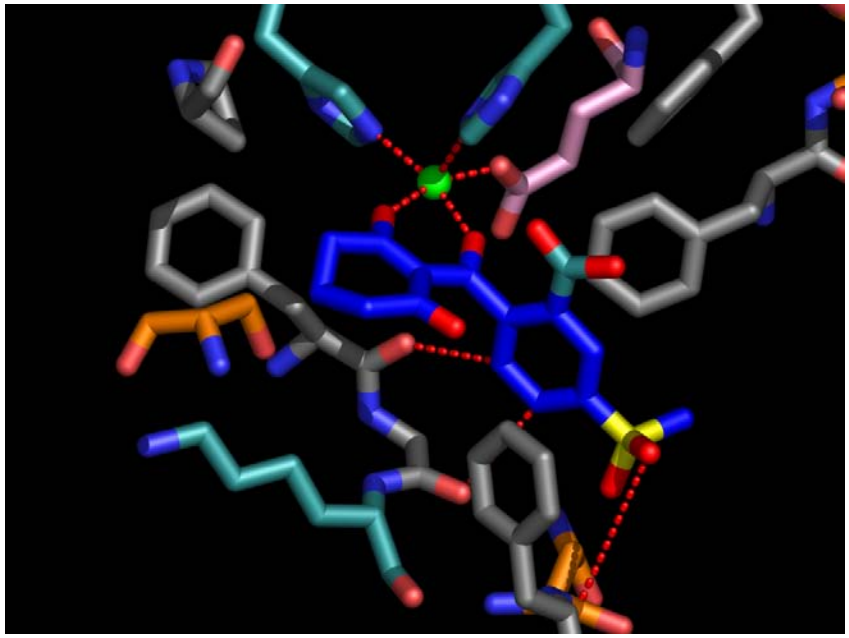
CAN WE MAKE IT? DOES IT WORK?

Innovative approaches: Hi-technology tools for Design









- Protein Science, crystallography, modelling, Smart Assays

Automation for Formulation Design

- Explore more design space; unleash creativity
- Stability; tank mix compatibility

CAN WE MAKE IT? IS IT SAFE?
CAN WE SELL IT?

Safety all around

Toxicology

Food

People

Protection of employees

Operator safety

Environment

Environment

Development of integrated solutions

Increasing level of integration and risk mitigation

Pest (IPM)

Threshold Concepts

Beneficials Management

Traps, Pheromones

Resistance Management

Crop (ICM)

Programs

Altenative Solutions

Residue Minimization

Seed Care

Product Stewardship

Forecast Models

Alert Systems

Field / Farm

Field Margins

Pollinator Habitat

Application Technology

Farm Stewardship

C / N Footprint

Landscape

Refuge Management

Biodiversity Concepts

Water Protection

Land Use Concepts

ICM in Vegetables

- **Andalucia (Almeria) Spain**
  - 2008- 100% of peppers, cucumbers and egg plant treated with ICM
  - Combination of cultural, chemical and biological control methods

Biological control of insects: Syngenta Bioline

Predatory mites

Amblyseius cucumeris – thrips

A swirskii – whitefly

A.andersoni – spider and russet mites

Phytoseuilus persimilis - spidermites

Hypoaspis miles - sciarids

Parasitoids

Encarsia and eretmocerus – whitefly

Aphidius – aphids

Diglyphus - leafminer

Bugs

Orius sp – thrips

Macrolophus - whitefly

Intensive Vegetables, Flowers and ornamentals as part of a management program

Integrated Weed management

- Reducing the Risks of Herbicide Resistance: Best Management Practices and Recommendations
- Jason K. Norsworthy, Sarah M. Ward, David R. Shaw, Rick S. Llewellyn, Robert L. Nichols, Theodore M. Webster, Kevin W. Bradley, George Frisvold, Stephen B. Powles, Nilda R. Burgos, William W. Witt, and Michael Barrett
- Weed Science 2012 Special Issue:31–62

- Herbicides are the foundation of weed control…
- Programs for herbicide-resistance management must consider use of all cultural, mechanical, and herbicidal options available for effective weed control in each situation

BMP's for weed control

1. **Understand the biology of the weeds present**
2. Use a diversified approach toward weed management focused on **preventing weed seed production** and reducing the number of weed seed in the soil seedbank
3. Plant into weed-free fields and then keep fields as weed free as possible
4. **Plant weed-free crop seed**
5. Scout fields routinely.
6. **Use multiple herbicide MOAs** that are effective against the most troublesome weeds ….

BMP's for weed control (2)

7. Apply the labelled **herbicide rate** at recommended weed sizes
8. **Emphasize cultural practices** that suppress weeds by using crop competitiveness
9. Use mechanical and biological management practices where appropriate
10. Prevent field-to-field and within-field movement of weed seed or vegetative propagules.
11. **Manage weed seed at harvest** and after harvest to prevent a build up of the weed seedbank.
12. Prevent an influx of weeds into the field by **managing field borders**

IWM

- Don’t think of a new Herbicide with a new moa as a “silver bullet”
- Think - “How can this product fit best into a system that provides sustainable control of weeds”
  - Mechanisation, soil nutrients, genetics and chemicals – plus agronomic practices

Does it work in practice?

- Penang (Malaysia) 2008 – government investment in Seed Mills
- 100% certified seed goal
- Contracting certified growers auditing for very high varietal purity
- Certified seed growers are model farms!

Does it work in practice?

- Tom Robinson in Crops 19th May 2012
- "Joined up Innovations in machinery and agronomy are gathering pace"

- Higher seed rate of wheat (var. Gallant) with higher rate of Defy herbicide increased blackgrass control from 74% to 96% with no post-em herbicide
  - cf standard seeding and herbicide rate
- Opportunity for precision application to patches in field within label constraints
- See also "Getting the best from Weed Control"; Adam Clarke – Crops 28th July 2012

Sustainable Intensification of Agriculture

……a key concept from UK Foresight report

Ag Systems that deliver better outcomes

- more crop yield from the same area of land
- reduced negative environmental impacts
- using all inputs more efficiently – land, water, nutrients

Both agricultural productivity AND better environmental outcomes are pre-eminent under sustainable intensification

Growing More from Less

Summary

- Pests, Weeds and Diseases are a major cause of yield and crop quality loss, and farm income reduction
- Continued innovation is an imperative for food security
- Chemical crop protection agents are essential to meet the global food security challenge
- Advances in plant science offer an opportunity for better genetics for pest and disease resistanceSystems approaches are vital
- Knowledge exchange with farmers on BMP's

- Sustainable Intensification is our challenge