

# Biopesticides: integrating and optimising biologicals with chemicals



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crops 30 – 40 % lost before harvest

>10 % after harvest



### Food and Agriculture Organisation of the United Nations

# FAO promotes biological pest control agents and IPM/IVM

"Pro-actively favouring registration of less hazardous products where such alternatives are viable and available"

### IPM – Sustainable Use Directive 2009/128/EC

"On the basis of Regulation (EC) No 1107/2009 and of this Directive, implementation of the principles of integrated pest management is obligatory and the subsidiarity principle applies to the way the principles for integrated pest management are implemented. Member States should describe in their National Action Plan how they ensure the implementation of the principles of integrated pest management, with priority given wherever possible to non-chemical methods of plant protection and pest and crop management."

'integrated pest management' means careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of populations of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment. 'Integrated pest management' emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

'non-chemical methods' means alternative methods to chemical pesticides for plant protection and pest management, based on agronomic techniques such as those referred to in point 1 of Annex III, or physical, mechanical or biological pest control methods.

#### EU Sustainable Use Directive 2009/128/EC



#### Alternative plant protection products



Global biopesticide market Increased over 200% 2000-2012



# Global market 2019

over \$6 billion



#### Biocontrol investment



From: Biopesticideindustryalliance.com

#### Biopesticides – USA products

	Insecticide	Fungicide	Herbicide	Nematicide	Other
Microorganism Bt	44	-	-	-	-
Microorganism non-Bt	18	41	5	3	1
Botanical	8	6	1	2	1
Semio-chemical + pheromones	56	-	-	-	-
Other	25	8	3	0	21
Total	151	55	9	5	23

#### Biopesticides – EU active substances

#### Updated Jan 2013

	Insecticide	Fungicide	Herbicide	Nematicide	Other
Microorganism Bt	4	-	-	-	0
Microorganism non-Bt	12 (2)	15 (10)	0	1 (2)	0
Botanical	5 (4)	0 (4)	1	0	6 (1)
Semio-chemical	29	-	-	-	2 (2)
Other	0	1	1	0	
Total	52 (6)	16 (14)	2	1 (2)	8 (3)

<sup>79 (25) = 104</sup> 

#### Updated October 2015\*

	Insect	Fungi	Weeds	Nematodes	Other	
Micro-organism Bt	9	-	-	-	-	
Micro-organism non-Bt	11 (2)	24 (9)	-	2	-	
Botanical	5 (2)	7	1	1	7	
Semio-chemical	28 (2)	-	-	-	-	
Other	8	1	1	0	0	
Total	61 (6)	32 (9)	2	3	7	

\* Definition of biopesticide not fixed so approximate numbers only Figures in bracket = pending

106(15) = 121

EU biopesticide actives trebled to >120 2000-2015

BIOPESTICIDES

# EU plant protection products – pending registration\*



\* October 2016

#### DRIVERS

- Efficacy killing target pest
- Efficacy yield and quality improvement
- Host specificity
- Use in **IPM** programmes
- Useful for resistance management
- Useful for residue management
- Growers crop management
- Worker safety
- Favourable environmental footprint
- Use in organic production

#### Natural forces already manage pest populations

1 cabbage aphid + 1 year = 250 million tonnes



Information and photo: courtesy of D. Chandler, Warwick Crop Centre and eplantswholesale.com.au respectively



# **Reductionist principles**

# Holistic principles

# Systems biology

Complex

#### Macroorganisms

![](_page_16_Picture_1.jpeg)

#### Semio-chemicals

![](_page_16_Picture_3.jpeg)

#### Botanicals

![](_page_16_Picture_5.jpeg)

#### Microorganisms

![](_page_16_Picture_7.jpeg)

#### Multiple modes of action

Kill host

Competition

Stimulate plant defenses

Confer plant resistance

Endophytes – MoA?

![](_page_17_Picture_6.jpeg)

#### Pheromones - semio-chemicals

Semio-chemicals "... chemicals emitted by plants, animals, and other organisms - and synthetic analogues of such substances - that evoke a behavioural or physiological response in individuals of the same or other species"

Pheromones are semio-chemicals that modify the behaviour of other individuals of the same species

Straight-chained lepidopteran pheromones (SCLPs) ... unbranched aliphatics having a chain of 9-18 carbons, containing < 3 double bonds, ending in an alcohol, acetate or aldehyde functional group. This structural definition encompasses the majority of known pheromones produced by insects in the order Lepidoptera, which includes butterflies and moths.

![](_page_18_Picture_4.jpeg)

#### What are botanicals?

#### From the EU Botanical Guidance document (rev. 8)

A 'botanical' active substance: obtained by subjecting plants or parts of plants to a process such as pressing, milling, crushing, distillation and/or extractions. The process may include further concentration, purification and/or blending, provided that the chemical nature of the components is not intentionally modified/altered by chemical and/or microbial processes.

The plants are live or dried plants or parts of plants, including fruits and seeds but excluding genetically modified plants.

![](_page_19_Picture_4.jpeg)

Micro-organism biopesticides

Cydia pomonella granulosis virus Pasteuria penetrans Trichoderma harzianum FUSARIUM OXYSPORUM Isaria fumosoroseus Bacillus firmus Clonostachys rosea Coniothyrium minitans **BACILLUS THURINGIENSIS** Bacillus subtilis Gliocladium catenulatum Lecanicillium lecanii Metarhizium anisopliae Ampelomyces quisqualis Tríchoderma asperellum Beauveria bassiana

#### Microorganisms - multiple modes of action

Trichoderma spp.

![](_page_21_Picture_2.jpeg)

#### Bacillus subtilis

![](_page_21_Picture_4.jpeg)

#### Baculoviruses

![](_page_21_Picture_6.jpeg)

Metarhizium spp.

![](_page_21_Picture_8.jpeg)

Beauveria spp.

![](_page_21_Picture_10.jpeg)

#### Microbial production systems

![](_page_22_Figure_1.jpeg)

#### In vivo production

#### Microbial innovations

	Cells	Media	Secondary compounds
Common species	±	±	±
Product formulation - inert	±	±	±
New species	±	±	±
New MoA - endophytes	±	±	±
Split fermentation - solid	±	±	±
Split fermentation - solid + liquid	±	±	±
Split fermentation - liquid + liquid	±	±	±
Product formulation - storage	±	±	±
Product formulation - persistence on leaf	±	±	±
Product formulation - synergists	±	±	±
Co-packs - adjuvants	±	±	±
Additives	±	±	±

#### Biofungicides – UK

Active Substance	Product Name	Target(s)
Ampelomyces quisqualis strain M10	AQ10	Powdery mildew
Bacillus subtilis strain QST713	Serenade ASO	<i>Botrytis</i> spp.
Candida oleophila strain O	Nexy1	Post harvest diseases
Coniothyrium minitans strain CON/M/91-08	Contans WG	<i>Sclerotinia</i> spp.
<i>Gliocladium catenulatum strain J1446 (new species name Clonostachys rosea)</i>	Prestop	Botrytis, soft rots
Lecanicillium muscarium strain V-6*	Mycotal	Whitefly, thrips, scale
Peniophora gigantea	PG Suspension	PGR
Streptomyces griseoviridis strain K61	Mycostop*	Soft rots
Trichoderma atroviridae strain T34	T34	<i>Fusarium</i> sp. on dianthus
Trichoderma harzianum strain T22	Trianum P	Root diseases

## Technology innovation areas

#### Active substances

#### Production

#### Formulations

Delivery

#### Society requires regulation

Consumer safety Operator and worker safety Environmental safety Crop safety Assure product quality

#### Plant Protection Product Registration EU - timelines

1107/2009	Year 1												Ye	ear	r 2					Year 3											Year 4										
	1	2:	3 4	ł 5	67	78	9	1 0	1 1	1 2	1	2:	3 4	4 5	6	7	89	9	1 0	1 1	1 2	12	23	84	56	67	8	9 :	1 0	1 1 :	1 1 2	L 2	3	4	56	57	8 9	€ 1 (	1 : ) :	1 1 1 2	1 2
A.S. Dossier Submission																																									
Completeness check																																									
Rapporteur evaluation																																									
DAR completed																																									
EFSA comment on DAR																																									
EFSA peer review																																									
Standing committee vote																																									
Positive List (Annex I)																																									
Application - zonal product																																									
Zonal evaluation																																									
Country evaluation																																									
Product approval																																									

- Orange boxes indicate first the SANTE vote then it takes 6 months to be ratified
- Purple box indicates when product can be sold
- This is a broad schematic there can be some variability depending on a.s.
- There can be some extra time added e.g. during active substance review if an expert consultation if needed

### Regulatory groupings

#### Out of scope

# Entomopathogenic nematodes

Root symbionts

#### **Basic substances**

Not PPP but may be used for plant protection

**Registered PPP** 

Microorganism Semio-chemicals Botanicals

Biorationals (acetic acid fatty acids Paraffinic oils) Regulatory status?

Plant strengthener Biostimulant Growth stimulant Biological inoculant

Label claims and packet contents  $\neq$  out of scope

#### **Biostimulants**

There are proposed changes to the fertiliser regulations which potentially clarifies the boundary between 'fertiliser' biostimulants and PPP\*

Of particular relevance for many microorganisms - from the Fertiliser Regulation:

(15) Certain substances, mixtures and micro-organisms, commonly referred to as plant biostimulants, are not as such nutrients, but nevertheless stimulate plants' nutrition processes. Where such products aim solely at improving the plants' nutrient use efficiency, tolerance to abiotic stress, or crop quality traits, they are by nature more similar to fertilising products than to most categories of plant protection products. Such products should therefore be eligible for CE marking under this Regulation and excluded from the scope of Regulation (EC) No 1107/2009 of the European Parliament and of the Council21. Regulation (EC) No 1107/2009 should therefore be amended accordingly.

(16) Products with one or more functions, one of which is covered by the scope of Regulation (EC) No 1107/2009, should remain under the control tailored for such products and provided for by that Regulation. Where such products also have the function of a fertilising product, it would be misleading to provide for their CE marking under this Regulation, since the making available on the market of a plant protection product is contingent on a product authorisation valid in the Member State in question.

\* To note this fertiliser CE mark regulation is not yet ratified however, it is unlikely that there will be substantial changes now

#### Biostimulants

And from the Fertiliser Regulation Annexes: Biostimulants are now defined as follows:

#### **PFC : PLANT BIOSTIMULANT**

1. A plant biostimulant shall be a CE marked fertilising product stimulating plant nutrition processes independently of the product's nutrient content with the sole aim of improving one or more of the following characteristics of the plant:

(a) nutrient use efficiency, (b) tolerance to abiotic stress, or (c) crop quality traits.

#### Further:

#### PFC 6(A): Microbial plant biostimulant

1. A microbial plant biostimulant shall consist solely of a micro-organism or a consortium of microorganisms referred to in Component Material Category 7 of Annex II.

#### And:

#### CMC 7: MICRO-ORGANISMS

*Azotobacter spp. Mycorrhizal fungi Rhizobium spp. Azospirillum spp.*  Why do we not get

the results

we wanted

or expected

for biopesticides ?

### Working -what does this mean?

![](_page_33_Figure_1.jpeg)

#### **Biopesticides – efficacy**

![](_page_34_Figure_1.jpeg)

#### Results from multiple trials

![](_page_35_Figure_1.jpeg)

### Typical results ?

![](_page_36_Figure_1.jpeg)

#### Dose response curves

![](_page_37_Figure_1.jpeg)

# Variability x dose

![](_page_38_Figure_1.jpeg)

# Variability x dose

![](_page_39_Figure_1.jpeg)

## Summary 1

Efficacy will be by POPULATION MANAGEMENT

based on:

**Biological characteristics of products** 

Relationship between dose and effect

Modes of action

### Summary 2

Biological systems:

Biopesticides multiply variance in the system, variation in outcome is the PRODUCT of the natural variation in the target population AND biopesticide population.

#### Programme use

![](_page_42_Figure_1.jpeg)

![](_page_43_Figure_0.jpeg)

Improved delivery systems (formulation, application, *etc.*) will not save an underperforming biopesticide but...

...performance of a biopesticide, as with a chemical pesticide, may be reduced substantially by a poor delivery system.

- Tank agitation is important.
- Nozzle choice and calibration
- Nozzle wear
- Tank and sprayline cleaning...

Where do particles go?

- Concentration of particles in suspension  $(X \times 40^{2})$ 
  - (X x 10<sup>Y</sup> conidia / litre)
- Droplet size spectrum
- Size of particles will they fit into a droplet?

![](_page_45_Picture_5.jpeg)

![](_page_45_Picture_6.jpeg)

#### Knowledge intensive – communication to farmers ?

![](_page_46_Figure_1.jpeg)

Sustainable crop production and protection

Biology Ecology Population management

#### Recipe for success?

Employ systems biologists

Embrace variability

Good technology transfer

Maintain innovation

Directed by technology

# Thank you for your attention

![](_page_49_Picture_1.jpeg)

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