BioGreenhouse

Plant health

How to integrate biopesticides in organic greenhouse growing systems

Biological pest control is usually based on releases of biological control agents, especially in greenhouse growing systems. However, pesticide use is often inevitable for pest control, when pest propagation is too early and too fast, climate conditions are not in favour of beneficial organisms, or suitable beneficials are lacking. Additionally, disease control is still dominated by using fungicides. Many pesticides, even those on a natural basis, have negative effects on natural enemies. Mitigation of undesired side-effects can be achieved by selecting compatible pesticides. A careful assessment of the overall side-effects (including sub-lethal effects) is essential to develop truly selective pesticides for their inclusion in organic greenhouse crops.

Biopesticides

Biopesticides used to control pests and diseases in organic greenhouse crops are commonly based on botanicals, microbials and minerals (Table 1). They vary in their mode of action, chemical families and formulation.

Table 1. Examples of biopesticides.

Origin	active ingredients (a.i.)	class*
plant extract	azadirachtin, pyrethrins	I
	soybean lecithin	F
	geraniol	I, H
plant oil	fatty acids (rape oil)	I
	essential oils	I
microbial	*Bacillus thuringiensis*	I
	spinosyn	I
	Coniothyrium minitans	F
mineral	bicarbonate salt	F
	copper	B, F
	sulphur	F, A
	iron(III) phosphate	M
animal	chitosan	I

*I = insecticide; A = acaricide; F = fungicide; B = bactericide; H = herbicide; M = molluscicide.

Mode of action

Most biopesticides act by contact, and only some, such as azadirachtin (neem tree seed extract) (Fig.1), are transported systemically within the plant. Additionally, many biopesticides are based on physical and mechanical action and only some are directly toxic.

a) Examples for insecticides and acaricides

Oils and sugars have insecticidal effects by physical and mechanical action. They form a film that covers and, thereby, asphyxiates insects. Due to their volatility, they are usually harmless after drying. Pyrethrins are very toxic, and act fast and unspecifically against many insect pests by disrupting their nervous system. Initially, they cause paralysis with death occurring later. Combining rapeseed oil with pyrethrins is shown to broaden the range of target pest species.

b) Examples for fungicides

The best known substance sulphur acts against powdery mildew by converting into sulphur dioxide which builds a toxic barrier to fungi and mites. Bicarbonate salt acts by contact and inhibits the development of fungal mycelium and spores. The fungus *Coniothyrium minitans* parasitises and degrades the sclerotia of *Sclerotinia* species.

Figure 1. Fresh and dry neem fruits.

Preconditions for suitable biopesticides

Several traits qualify a biopesticide as suitable for its use in organic growing systems:

a) selectivity toward beneficials
b) fast action
c) short time effect
d) no phytotoxicity
e) no preharvest interval
f) low resistance development
g) no residues
h) safety to operators, workers and consumers.

Most insecticides with a physical mode of action (e.g. oils) or developed by plants as unspecific substances (e.g. pyrethrins) are usually not selective (a). However, as they often have a low photochemical stability, the length of their effect is limited (c), and beneficials may be introduced shortly after. For traditionally used biopesticides, application modes are well known so that phytotoxicity risk is low (d). On the other hand, the unspecific or multi-site mode of action is a warrant for a low risk of resistance of most substances (e). If necessary, plant oils can be added to reduce resistance development.

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Most biopesticides are safe (h), require no or only a short preharvest interval (f), and leave no or nearly no residues (g). Lecithin and sodium hydrogen carbonate for instance are foodstuff and submitted as basic substances.

Side-effects on beneficials

As pest control in organic greenhouse growing systems is mainly based on the release of beneficial insects and mites, side-effects have to be regarded in detail. Beneficials may be adversely affected even by biopesticide applications via: a) direct contact during spray application or spray residues on the plant surface, b) ingesting contaminated plant tissue or fluids, and c) being exposed by feeding on contaminated hosts. Besides lethal effects, also sub-lethal effects, that affect the physiology and behaviour of natural enemies (i.e. development, longevity, fecundity, mobility, mating, etc.), and persistence of residuals must be considered.

Figure 2. Natural enemies of aphids: parasitoids (mummies) and larvae of *Aphidoletes aphidimyza*.

The side-effects are also depending on the beneficial species, their habitat and life stage. Species or developmental stages living in the soil (e.g. nematodes) are usually less affected by spray applications. Parasitoid wasps are vulnerable at adult stage but protected during larval development within the host (e.g. aphid mummies) (Fig.2). A negative impact may occur during host feeding by systemic insecticides. Predator adults and their larvae (mites, true bugs, ladybirds, gall midges, lacewings) are most affected by pesticide spraying. Copper is a traditional fungicide and bactericide. Although it is a naturally occurring metal, it causes problems by its accumulation in the soil after long term use, and it is toxic to soil organisms and particularly to earth worms. Therefore, its use becomes more and more restricted by EU regulation.

Information on side-effects

Widely accepted toxicological protocols have been developed by the International Organization for Biological Control (IOBC) – WPRS Working Group ‘Pesticides and beneficial organisms’ for instance (IOBC Pesticide Side-Effects Database). Today, pesticide side-effects are classified in four classes:

Class	evaluation	explanation
1	harmless	<25% reduction
2	slightly harmful	25-50% reduction
3	moderately harmful	50-75% reduction
4	very harmful	>75% reduction

Strategies to reduce side-effects

Undesired side-effects on natural enemies can be reduced by adapting the timing, place and mode of pesticide application or by developing new release methods. Today, different methods are available such as:

a) prophylactical use (e.g. repellent substances)
b) attract and kill
c) trap crop/push and pull
d) hotspot/band application
e) drench application (only systemic pesticides)
f) beneficial release in safe sachets
g) open rearing systems or banker plants for beneficials.

Repellents can be used to prevent insect pests from invading the crop (a). Strategies (b) to (d) are aimed at alluring and controlling the pest out of the crop or in treated restricted areas, while protecting most of the beneficials. With a drench application (f) a contact with beneficials on the plant is prevented as well as with sachets for mite release (g). Open rearing systems and banker plants act as a refugium for beneficials (h).

Research gaps

Suitable biopesticides are needed for organic growing systems, as quality demands for the produce are high and comparable to those for conventional farming. Even beneficial organisms or their devices can cause problems during marketing. To enhance organic growing systems we detected the following research gaps:

- simplification of the registration process
- research and development of new substances
- side-effect testing (i.e. estimation of lethal and sub-lethal toxicity on natural enemies)
- development of strategies for beneficial release
- research on alternatives to copper

References: Cloyd, 2012. Indirect effects of pesticides on natural enemies. Intech: 127-150. El-Wakeil *et al.*, 2013. Side effects of insecticides on natural enemies and possibility of their integration in plant protection strategies. Intech: 3-56. Messelink *et al.*, 2014. Approaches to conserving natural enemy populations in greenhouse crops: current methods and future prospects. BioControl 59:377-393.

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