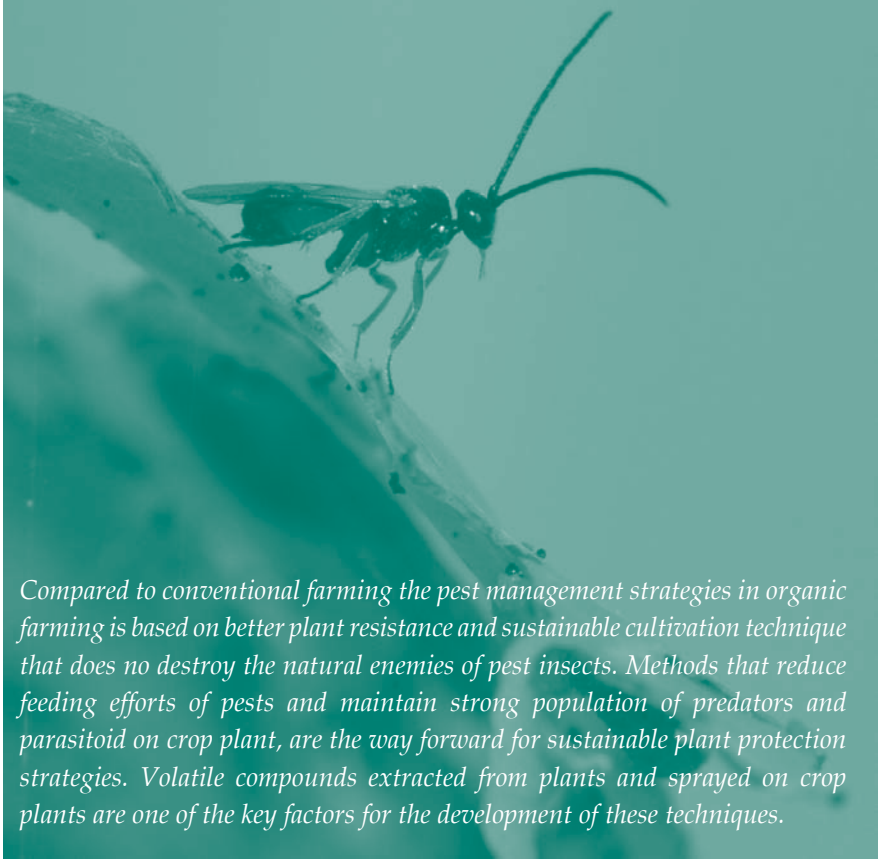
Improvement of biological control by volatile plant compounds



Compared to conventional farming the pest management strategies in organic farming is based on better plant resistance and sustainable cultivation technique that does no destroy the natural enemies of pest insects. Methods that reduce feeding efforts of pests and maintain strong population of predators and parasitoid on crop plant, are the way forward for sustainable plant protection strategies. Volatile compounds extracted from plants and sprayed on crop plants are one of the key factors for the development of these techniques.

<– Cotesia plutellae *parasitoid ready to attack on Diamond Back Moth larva.*

Figure 1. Relative importance of different odour sources in orientation behavioural of parasitic wasps of cabbage pests. –>

The restrictions of the use of pesticides in organic farming have positive impact on insects and other arthropod populations. Compared to conventional farming the communities of e.g. soil-living predatory beetles are substantially larger in biological and biodynamical fields. These natural enemies of pest insects create a "buffer" that limit the increase of many pest populations. However, often this strategy is not sufficiently efficient to prevent insect outbreaks on organic crops. To reduce crop loss some pest control measures are needed.

Pest insects are harmed by plant chemicals

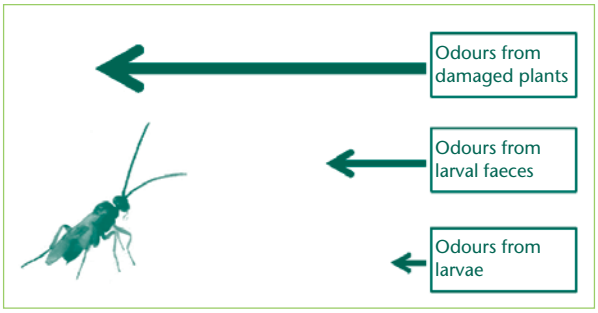
Plants have specialised hairs and thorns which form mechanical barrier against herbivorous insects and mites. Many plant species produce various chemical compounds that could be repellent or deterrent or even toxic for plant feeding insect and mites. Some of these compounds are also toxic to the plant itself, and therefore they are stored in special resin canals or in glandular structure on plant surface. These chemical weapons are aimed directly against the plant feeding animal i.e. the chemical compounds act as direct defence.

There are two types of direct chemical defence: 1) in constitutive defence non-attacked plants contain chemical defence compounds, 2) in induced defence plants start to synthesize special defence compounds only after tissue damage by harmful organisms. In this way plants reduce their investment in otherwise unnecessary defence compounds and the resources can be invested in growth. Plant defence compounds belong to a wide variety of chemical compound groups like phenolics, terpenes, alkaloids and glucosinolates. In current cultivars the concentration of these mostly bitter-tasting compounds are very low which make crop plants more susceptible to plant feeders than their natural counterparts.

Volatile alarm chemicals attract natural enemies

One of the fascinating traits of plants is their ability to attract natural enemies of their foes. This so-called indirect plant defence occurs when herbivore-damaged plants release volatile compounds that are attractive to predators and parasitoids of herbivore. The natural enemies of pests use the induced volatiles in orientation, while the volatile compounds released directly from pest larvae or from their faeces are less attractive e.g. to wasp parasitoids (figure 1).

The volatile compounds that act in plant signalling to natural enemies are dominated by two major compound groups: green leaf volatiles (GLV) and terpenes. GLVs have normally six carbon atoms (C6) in a molecule and they form a typical smell of cut grass. GLVs are released from plant tissues immediately after mechanical damage of insect mouth parts or any other mechanical damage that breaks plant cell membranes.



Cotesia plutellae *parasitoid is sensing the odours coming from damaged leaf and larval faeces.*

Chemically GLVs are mostly short-chained ketones, aldehydes, alcohols and esters. Many of these compounds induce strong behavioural response in females of parasitoid wasps, but also polyphagous predators show response.

Typical odour of terpenes is the smell of conifer resin or mint. Terpenes are composed of basic units of five carbon atoms (C5). Volatile monoterpenes have two and sesquiterpenes three C5 units. Homoterpenes have an extra carbon atom in their two or three unit structure. Some plant species store monoterpenes in special structures like glands and resin canals, others like cabbage do not store monoterpenes but synthesize them when temperature is high and photosynthesis is most active. Sesquiterpenes are typically emitted from flowers. Plants damaged by pest insects release some new monoterpenes like (*E*)-ß-ocimene, sesquiterpenes and homoterpenes from foliage a few hours after start of feeding.

Manipulation of chemical plant defence

Production of plant secondary chemicals is under strong genetic control. Molecular biology gives possibilities for engineering the biosynthesis of these compounds in plants and "programming" to attract the natural enemies of pest before the pest outbreak. However, such genetically modified cultivars are not suitable for organic farming, but can be used in conventional farming to decrease the use of pesticides. In organic agriculture compounds extracted from plants can be used as biopesticides to kill or repel pest insects or as suppressants for fungal pathogens. Also combinations of specific monoterpenes of plant essential oils like limonene and carvone in different ratios can be sprayed on crop plants to attract natural enemies and to repel the pest insect during the attack period.

Some natural plant extracts act as elicitors and activate direct and indirect defence of crop plants simulating the processes that occur in nature when plants are attacked by pests or pathogens. Methyl jasmonate (MeJa) is a typical fragrance compound of jasmine (*Jasminum officinale*) flowers. MeJa is also an important signal compound (volatile plant hormone) in damaged plants. It mediates the information from the damaged tissues to intact plant parts of the plant or even to the neighbouring plants to activate the production of defence compounds like phenolics or glucosinolates. Furthermore, plants sprayed with MeJa in low concentrations (0,1 % solution) started to emit the homoterpenes and sesquiterpenes typical to the emissions of plants attacked by pest insect. This observation suggests that MeJa can be used to activate indirect defence of crop plant in organic agriculture. E.g. the primary parasitoids (*Cotesia plutellae*) (see pictures) of Diamond Back Moth (*Plutella xylostella*) can be attracted to crop plants already when the moth larvae hatch from the eggs and thus the feeding damage can be nearly totally avoided.

Conclusions

Chemical and ecological research in recent years has increased our understanding of the natural defence mechanisms of plants. Volatile compounds produced by plants have an important role in plant-pest and plant-carnivore interactions. The research of pest control strategies in organic farming should take advantage of this knowledge and develop pest control methods that reduce palatability of crop plant for pest larvae, but at the same time make the crop plant attractive to natural enemies of pest. However, when crop plants are treated with natural plant extracts, it is important to monitor any increase of the secondary compounds in crop plants that might have harmful effects on the human health. ■

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