Funded by the Erasmus+ Programme of the European Union

Erasmus Plus for Organic Sector

Control of pests and diseases in organic plant production

Eve Veromann & Anne Luik

Estonian University of Life Science

In natural ecosystems as well as in fields and gardens, several organisms – fungi, bacteria, mites, insects, etc. – are connected with plants in the ecological food web. Some of them can cause, in the case of high abundance, loss of plant yield and that is why they are called diseases and pests. However, both diseases and pests are a natural part of field and garden communities. The task of the plant grower is to prevent high abundance of pests and diseases, which means avoiding the loss of yield. Principally, the organic agro-ecosystem should function as an independent self-organising organism in harmony with nature. Therefore, preventative measures play a major role in organic farming, but when needed, it is also possible to use direct control methods.

Preventive methods

They are:

1. Conservation and enhancement of biodiversity in the agro-ecosystem
2. Control of pests and diseases with cultural methods
3. Monitoring of pests and diseases

1. Conservation and enhancement of biodiversity in agro-ecosystem.

Biodiversity is high in a natural ecosystems and the population abundance of phytophagous organisms is balanced by their natural enemies. In agro-ecosystems the number of species is decreased and self-regulation characteristics of natural communities are lost because humans modify such communities by breaking the fragile thread of community interactions. This breakdown can be repaired by restoring the elements of community homeostasis through the addition and enhancement of biodiversity. Two distinct components of biodiversity can be recognized in agro-ecosystems. The first component, **planned biodiversity** includes the crops and livestock included in the system by the farmer, which will vary depending on the management inputs and spatial and temporal arrangements of crops. The second component, **associated biodiversity**, includes all flora and fauna, herbivores, carnivores, decomposers etc., that colonize the agro-ecosystem from surrounding environments and that will thrive in that agro-ecosystem depending on its management and structure. The agro-ecosystem can be diversified with the use of high crop diversity in time and space, diminishing the size of fields, creating structural mosaic of adjoining crops and uncultivated land – field boundaries, hedgerows, grassy strips within a field, different natural areas – ponds, coppices etc., which provide shelter and alternative food for natural enemies of pests – parasitoids and predators.

Parasitoid is an organism that lives during its development in or on the body of a single host individual, eventually killing that individual. Thus, they are parasitic only in their immature stages but are free-living insects as adults. Most insect parasitoids are found in the order Hymenoptera and roughly 10% of all described insect species are parasitoids. In addition to hymenopteran parasitoids, the other important group comprises dipteran parasitoids in the family Tachinidae. Adult parasitoids generally feed on nectar and pollen from flowers. Therefore, species-rich field margins are important as providers of adequate food for adult parasitoids.

In addition to parasitoids, almost all pest species are attacked by a number of different predators. **Predators** are free-living organisms that feed on other organisms, their prey, devouring them usually rapidly and sometimes completely. Major predators of insects include birds, lizards, frogs, snakes, shrews, bats, spiders, mites and other insects - earwigs, different bugs, ladybird beetles, ground beetles, lacewings, and hoverflies. Coppices, shrubs, diverse field margins are offering habitat conditions for predators and parasitoids which can kill a significant part of plant pests. Also, the diverse and wide range of microorganisms controls the development of diseases and pests. D. Coombes and N. Sotherton (1986) showed that beetles could be recovered up to 200 m into the fields but there is significant decrease of abundance in the direction to the field centre. Considering the predatory polyphagous nutrition the carabids play a definite role in agro-ecosystems as natural pest-control agents, they feed on aphids, moth- and sawfly larvae etc. Some ground beetles eat also slugs and snails and seeds of weeds. All the larvae of ground beetles are voracious predators. In the Baltic crop fields, depending on crop, management and surroundings, around fifty carabid species are established. Carabids have been demonstrated to reduce cereal aphid populations in their early colonization phase. Their abundance is higher in winter crops and especially in the field parts which were bordering other winter crops. Several surveys prove that the field margin with the width of at least three meters covered with multiple species of plants providing sufficient shelter and hibernation for the natural enemies of pests can fulfil the tasks of plant protection.

Consequently, the plant protection starts from the choice of crops in diverse rotation, locations of fields and their surroundings.

2. Control of pests and diseases by using cultural methods

The first method - choice of healthy propagation material. The prerequisite for successful crop production is the use of disease-free planting material that is proper for local conditions. Only strong and healthy plants can actively fight against pests and diseases by synthesizing secondary metabolites for this purpose or isolating the pest with special tissues which inhibit further development of the harming organism.

One of the cornerstones of health is certified seed material. The propagation material infected with diseases or inhabited with pests supports the quick growth of their abundance and consequently the resulting losses of yield. The Danish research has revealed that when the seed of wheat is infected with 10 spores of stinking smut per one gram of seeds, the yield loss can be up to 70% and the quality has been spoilt to the degree of 100%.

Different varieties have different susceptibility to pests and diseases and that is also depending on growing conditions. Therefore it is necessary to choose the crops and the varieties which will suit for the local a biotic - soil and weather – conditions. When the predecessors of cultured plants are compared with the present crop plants, the wild plants are usually more resistant to pests and diseases. It is the result of long-term mutual adaptation. Also, biochemical composition of cultured plants differs from composition of their ancestors'. Sometimes it makes them more susceptible to the harmful effect. However, with plant breeding it is also possible to develop the varieties, which are tolerant or resistant to one or other harmful organism. For example, the nematode resistant potato varieties are bred, however, these varieties may be more susceptible of viral or fungal diseases. There is no multifunctional resistance. In general, plants of earlier ripening varieties with quicker initial development, are less susceptible by pests and diseases. For example, early varieties of cabbage are usually not colonised by cabbage butterflies. Also, varieties with quick initial development compete better with weeds. Cereal varieties with quick sprouting ability and with longer straws have advantages in weed suppression. It is not possible to have a variety resistant to all detrimental effects but if the problematic pests and diseases of cultivated crops are known, it is possible, while purchasing the propagation material, to bear in mind the particular type of resistance. It must be kept in mind that varieties and harming organisms are mutually adapting during different vegetation periods and therefore seeds of varieties are losing initial resistance level. Therefore after certain growing periods it is important to renew healthy seeding material. If growers are using their own seeds, the seed health should be tested. Sometimes there is not sufficient direct examination but examination after incubation to show if pathogens are present is needed. Also, it is expedient to grow different varieties because their different resistance ability. If one variety suffers in some conditions, the other, on the contrary, can produce a better yield in the same conditions. Generally old indigenous varieties have better adapted to local conditions and survive better. Therefore one of the preferences in organic farming is to use also old indigenous varieties.

The second method – chose of optimal growth and development conditions. When sowing or planting the propagation material is done in optimal conditions, the plant obtains the maximal growth energy in its initial stage of development and has stronger defensive ability against different damagers. Optimal feeding conditions are extremely significant and among them the central role of plant protection is played by the organic matter content in soil. Large degree of organic matter content in soil means the diversity of both macro- and micro-organisms from which many are natural enemies of pests and diseases. The high organic matter content of soil favours the growth and the development of decomposing organisms – earthworms and springtails. These are improving soil fertility and structure. That promotes the development of roots of the plants. Springtails, in turn, constitute a partial feeding base for the beneficial predator arthropods which regulate the number of plant pests. In the microbiologically active soil, antagonists kill many pests and pathogens during their certain life stages and hibernation. Soils with high organic matter content and biological activity generally exhibit good soil fertility, as well as complex food webs and beneficial organisms that prevent infection.

The third method – crop rotation. The crop rotation proper for the local conditions, should create optimal growth and development conditions to crops and decrease the abundance of pests and diseases isolating them from the host plant both spatially and in time. Crop rotation is one of the most effective strategies to control soil-born pathogens. It is one of the oldest cultural practices that maintain soil fertility and soil structure and controls serious weed problems. Growing the same crop in the same field should have a minimum interval of four years. Within this period the abundance of pathogens and pests is decreasing because of the lack or absence of food. Also, it should be taken care that crops with similar pests must not be cultivated in the close neighbourhood, which creates preconditions for a quick spread of harmful organisms to the neighbouring fields. For example, the pests and diseases hibernating in winter cereals can very easily spread to the spring cereals in the neighbouring field.

In the organic crop rotation the legumes plants (primarily clover) play a crucial role. Beside the enrichment of soil with nitrogen and organic matter they also help to improve the soil health because they are increasing microbial biomass and changing their structure. Also, several weeds are suppressed by clover in competition. Also, it is important to include green manure crops to rotation.

The forth method – soil tillage. Soil tillage is influencing the life cycles of plant pests and hereby also affects their abundance. Ploughing kills several pests pupating or hibernating in the soil. Also, the soil microorganisms are changing places and the seeds of weeds get deeper into the soil where they do not have suitable conditions for germination.

Harrowing during initial period of the development of crop kills weeds and harms some soft bodied insects, at the same time airing improves the soil microbiological activity which is supressing pathogens. However, it should be born in mind that also beneficial organisms, especially ground living arthropods, are killed or depressed during tillage. Under certain soil conditions minimum tillage is also possible to be used in organic production and that can enhance plant development and yield.

The fifth method – mulching. Mulching with both organic and all other covering materials, for example, paper or plastic, round the plants affects the conditions of development of plants and the organisms connected with them. Mulching is used mainly in horticulture. Organic mulches – fresh grass, hay, straw, peat plate, compost, etc. – increase the amount of organic matter in soil, suppress weeds and create a covering barrier for many pests which cannot reach the plants through the thick mass of the mulch. For effective suppression of weeds organic mulch layer should be 7-10 cm. Mulching enhances ground living arthropod predators. Moreover, some mulch can disorientate pests. For example, mulching with fresh leaves of poplar and bird cherry can repel flee beetles in cabbage plants. Paper and plastic mulches also regulate the humidity of the soil and suppress weeds. But in some cases they create more favourable conditions for pests, for example in strawberry plantations the black plastic mulch enhances strawberry mites.

The sixth method – change of seeding time. With the change of sowing or planting time it is possible to isolate the potential pest from the crop in time. This method is mainly practised in some horticultural crops. In Estonian conditions, if one seeds carrots in the last decade of June around Midsummer Day, by the time of sprouting, the flight and oviposition of carrot rust fly, as well as carrot psylla, is over and the plants remain unsettled and undamaged by them.

The seventh method – mixed cropping. Mixed or intercropping – in the same field the crops grow either mixed or in stripes or islets within each other - avoids or decreases the colonization of pests and diseases and offers new habitats for beneficial organisms. The chemical compounds emitted by different plant species make the orientation of pests more difficult or stop it entirely. Also, spreading of plant pathogens is more suppressed in mixed crops. In mixed cropping, diseases develop more slowly due to interception of the pathogen or its vector. In addition to the effect on disease suppression, intercropping uses resources more efficiently and soils are generally less prone to erosion.

Certainly, the proper cultures for mixed cropping must be found. For example, the damage of carrot rust fly, as well as carrot psylla, was significantly lower in carrots, which were grown in 3-meter rows in garden beans. At this condition the predator carbides were more abundant than in carrot monoculture. Mixed cropping of fabae beans and spring barley was reducing the incidence of black bean aphid. It is found that white clover between the cabbage rows repels cabbage pests – cabbage butterflies and flea beetles. When cabbage rows were altered with *Tagetes* spp., then *Pieris rapae* layed significantly less eggs on cabbage plants than in the monocrop. *Tagetes* root exudates have nematocidal properties, therefore growing *Tagetes* among other plants can avoid nematode problems.

It is made more difficult for pests to find the crops and also reduce the build-up of pest and disease problems in the complex crop rotation and intercropping.

The eighths method – trap crops. The concept of trap cropping fits into the ecological framework of habitat manipulation of agro-ecosystem for the purpose of pest management. Trap crops have been defined as particular plant stand that are deployed to attract, divert, intercept, and/or retain targeted insects or the pathogens they vector in order to reduce damage to the main crop.

Crop location by phytophagous insects involves recognising the habitat of host plants and accepting host plant, for that the insect needs to respond behaviourally to different visual and olfactory cues. Manipulation with these cues and pest behaviour can be used in trap crop strategy to protect the main crop. Trap crop aim is to reduce pest colonization in main crop by attracting pests to trap crop areas planted in proximity to the main crop. It has been argued that for successful trap cropping systems, high trap crop retention is a more important criterion than attractiveness of a trap crop plant. Trap cropping is one side of the 'push-pull' strategies. 'Push-pull' strategies are exploiting insects' behaviour-modifying stimuli, especially with cues of host plant locating, to manipulate the distribution of pests and their natural enemies on a crop. Attractive stimuli are used to 'pull' the pests to a trap crop and repellent or deterrent stimuli are used to 'push' pests from the protected crop. The strategy relies mostly on pests behaviour and food resource preferences. Because the attractiveness of trap crop species to the target pest may

depend upon its phenology, ideally plantings need to be synchronized to match the most vulnerable stage of the main crop. Some crop varieties or wild plants are more preferred by the pests. If such crops grow at the field margins, the pests can colonize these plants and the occupation of main crop or variety decreases significantly. For example, it is possible to grow turnip rape or black mustard at the edges of the oilseed rape field. These cultures start to flower a bit earlier than oilseed rape and are more attractive for pollen beetles (the main pest of oilseed rape). Thus, the pollen beetles eat and lay eggs on the flowers of trap crop and the main crop stays less damaged. Also, it is possible to kill pests: when insect pests are concentrated into the trap crop, they can be killed with insecticides or destroyed by ploughing in the trap crop. This way it is possible to decrease the abundance of the pest population significantly.
The success of trap cropping is directly influenced by the deployment strategy. In general, guidelines for trap cropping recommend 10% of the total crop area to be planted with the trap crop; however the actual needs of each particular system may vary.

Weeds can also play a trap crop role in different ways. Weeds within a crop system can reduce pest incidence by attracting pest insects away from the crop. For example flea beetles concentrate their feeding more on the wild black mustard plants than on collards. In addition to 'pulling' effect of weeds, they have also positive impact on the presence of natural enemies of pests. Several studies have showed pest reduction due to an increase of natural enemies in weedy crop fields. It is found that the parasitoid *Cotesia glomerata*, a parasitoid of two cabbageworm species on crucifer crops, obtained nectar from wild mustard flowers. In England, winter barley plots with grass weeds had fewer aphids and more than ten times the number of predator staphylinid beetles than plots without weeds. So moderate weeding offers alternative food for natural enemies and supporting natural regulation of pests.

<u>The ninth method – avoidance of alien species</u>. The introduction of alien species (pests, diseases, weeds) must be avoided, because in local conditions they usually do not have natural enemies and may have advantages in interspecific competition compared with indigenous species. Therefore, it is very difficult to control invasive alien species.

Monitoring of pests and diseases. For the estimation of crops' health and to find damage outbreaks in time, the crops should be regularly monitored. With this purpose the observation of crop plants should be carried out during different growth and development stages. Such kinds of observations need special knowledge in plant pests and diseases. In addition, it is also possible to use some supplementary monitoring traps. For example, very many insects are attracted to yellow colour. This makes it possible to monitor the occurrence of certain groups (aphids, pollen beetles, carrot rust fly etc.) with yellow (water or sticky) traps. Pheromone traps, based on the specie's specific attractive odour, allow establishing the incidence of particular insect species. There are pheromone traps available for different orchard pests (codling moth, leaf rollers etc.).

Direct control

Direct control is needed in the case of high abundance of pests and diseases. The control measures must be environmentally safe. Direct control methods are:

1. physical-mechanical,
2. biological,
3. chemical.

1. Physical-mechanical control method

The most popular measures are the removal of damaged plants (especially with viral disease) or parts of plants, picking off pests, the use of different defences, barriers, covering veils and thermal killing. For example, for picking the pests in orchards, about 20 cm-wide paper trap belts are tied to the trunks of fruit trees after flowering. Pests congregate under the belts for shelter and a place of hibernation. After harvesting, the belts will be removed, the beneficial insects released, and after that, belts with pests will be burnt. Under the bushes, where the larvae of sawfly are feeding, a sheet should be laid out. Then, the branches are shaken and larvae will fallon the sheet, from which they will be collected and destroyed.

Temperature, both low and high, may also limit the incidence of pests and diseases. Hot water treatment of seeds helps to control seed borne pathogens. Hot water treatment, often pre-soaked seeds are treated at the temperature of 50°C to 55°C for 10 to 120 minutes, depending on the specific seed type. The optimal treatment range for the main vegetable species was determined to be 50°C to 53°C for 10 to 30 minutes. The infestation of *Alternaria radicina* was significantly decreased by exposing carrot seeds at +50°C during 30 minutes. Brushing of seeds before sowing removes pathogens and can decrease the larvae of leaf stripe and net blotch infection in cereals up to 99%.

2. Biological control methods

Biological control is based on the use of:

- antagonists of plant pests and diseases,
- modifying behavioural reactions of pests,
- plant strengthening natural compounds.

Antagonists of plant pests and diseases. All phytophagous organisms, including nematodes, insects, mites, different plant pathogens and weeds, have their natural enemies. Their incidence can be supported by creating good conditions for their growth and development in agro-ecosystems, therefore the enhancement of biodiversity in the agro-ecosystem is needed.

One possibility for that is the establishment of ecological compensation areas within the fields. For example A. Nentwig (1998) prepared seed mixture consisting of twenty-four species of wildflowers sown as 3- to 8-m-wide weed strips planted every 50 to 100 m within fields. These strips serve as the refuge area and the dispersal centre of natural enemies.

Enriching of plant communities is offering more habitats conditions for beneficial insects. Spectacular parasitism increase has been observed in annual crops and orchards with rich undergrowth's of wild flowers. In apple orchards, parasitism of tent caterpillar eggs and larvae and codling moth larvae was eighteen times greater in those orchards with rich floral undergrowth than in orchards with sparse floral undergrowth.

In orchards to promote nesting of birds, nest boxes should be put up. For the enhancement of the earwig number in orchards, it is possible to use flowerpots filled with wood chips fastened to the branches. Earwigs eat aphids, mites and small caterpillars. They are hydrophilic and active at night. To enhance the abundance of earwigs it is necessary to create shelters for them.

A big number of pests' natural enemies can be multiplied in commercial laboratories or so-called bio factories and later introduced to the crops. Such multiplied organisms are mainly used in greenhouses and less in field crops.

In greenhouses, to limit the populations of plant-feeding mites, different predatory mites, for example more widely used *Phytoseilus persimilis* is produced. For the regulation of greenhouse aphids green lacewings and gall midge *Aphidoletes aphidimyza* are commercially produced. Against whiteflies commercially produced parasitoids *Encarsia formosa* and *Aphidius matricariae* can be used.

NB! The admissibility for using predator and parasitic organisms must be checked in the national registration list of plant protection products and the national regulation for organic plant production.

Microbiological control - microbiological preparations of bacteria, viruses and fungi and their use have been worked out. The major microorganisms causing diseases in insects are bacteria, viruses and fungi. They may cause diseases that kill insects outright, reduce their reproductive capabilities, or slow their growth and development. These organisms cause disease epidemics in insect populations naturally. Particularly, the genus *Bacillus* has been used. 95% of commercial preparations are based on *Bacillus thuringiensis*. The preparation contains spores and toxin crystals. After ingestion, the proteinaceous crystal (called delta endotoxin), associated with a spore in sporangium, quickly dissolves in the insect mid gut, causing gut paralysis. The host larva then may be killed immediately by the toxic crystal, or the crystal may enhance the penetration of the gut by spores, which consequently cause a lethal septicaemia. Another form of *Bt* containing another toxin (beta-exotoxin) has been developed, which expands its use to other pests not managed with the *Bt* endotoxin. However, in many cases the resistance to *Bt* toxins has developed in pests. For inhibiting fungus diseases in the soil the bacterium *Paenibacillus polymyxa* promotes the growth of plants, liberates phosphorus and produces polymyxin which depresses development of fungi. For the treatment of seeds for depression of seed-born diseases bacterial preparation Cedomon (*Pseudomonas chlorographis*, strain MA 342) is developed in Sweden. Preparations based on *Pseudomonas fluorescens* and *Bacillus subtilis* are useful for the depression of *Rhizoctonia solani* in potato seed stock.

The best-known viruses of insects are the baculoviruses, including the nuclear polyedrosis viruses (NPV) and the granulosis viruses (GV). NPV viruses have posted more recorded successes in the insect pest management than any other group. NPV viruses develop in the host cell nucleus where one or several virus rods occur singly or in groups encased in an envelope. The envelopes are encased in many-sided crystals called polyhedra. When infected, the larval skin darkens, and the larvae climb the highest point of their host plant, where they die.

Fungi from more than 750 species are known to infect insects. Some of the more widespread fungi causing disease epidemics in insects include those from genera *Beaveria*, *Nomuraea*, *Metarhizium*, *Entomophthora* and *Zoophthora*. Fungi attack insects through the cuticle. Usually a spore attaches to the cuticle, germinates, and penetrates the body wall. Once in the body cavity, the fungus spreads, colonizing the hemocoel, and producing toxins.

The fungi *Trichoderma* spp suppress the plant pathogens in the soil, emitting antimicrobial compounds and promoting the growth of plants. Some commercial preparations are developed on the basis of these fungi (for example, Bio-Fungus (De Ceuster, Meststoffen N.V., Belgium)). On the basis of non-pathogenic *Fusarium oxysporum* the preparation Biofox C (S.I.A.P.A., Via Vitorio Veneto 1 Galleria, 40010; Bologna, Italy) is developed for seed treatment. Against grey mould and other fungal diseases, different preparations have been worked out on the basis of *Trichoderma harzianum* (Supresivit, from Borregaard Bio Plant; Helsingforsgade 27B, DK-8200) and *Gliocladium catenulatum* (PreStop®, PreStop®Mix, Mycostop® etc. Lallemand Inc. www.lallemand.com; www.verdera.fi).

NB! The admissibility of use microbiological preparations must be checked in the national registration list of plant protection products and the national regulation for organic plant production.

<u>Modifying behavioural reactions of pests</u>. Insect behaviour patterns that result in many interactions can be related to the degrees of attraction and repellence, for example, males are attracted by females, and individuals are repelled by a noxious plant. Associated behaviours, where shorter distances are involved, include stimulation and deterrence. These behavioural responses are mediated by chemicals from the exocrine systems of interacting individuals. These mediating chemicals are called semiochemicals. Of these, pheromones are involved in intraspecific communication, and allelochemics, involved in interspecific communication. Insects have different types of pheromones: sex, alarm, trail-marking and aggregation pheromones.

The chemical composition of sex pheromones has been established for more than a thousand species of insects. Some firms are involved in producing synthetic pheromones, which are in pest control mainly used either for mass trapping or for mating disruption. In mass trapping, insects are attracted to a source and killed there. Different types of traps are baited with pheromones for this purpose and the attracted specimens are caught. If a large portion of one sex is attracted and killed, mating success is reduced, and numbers in the next generation fall. Mating disruption by air permeation is so called confusion method. The use of synthetic pheromones for confusion has been successful and widely used in codling moth.

NB! The admissibility of use of pheromone traps for different species must be checked in the national registration list of plant protection products and the national regulation for organic plant production.

From allelochemicals, chemicals, which orient insects to smell the source, are called attractants. Host plants are attracting insects with certain smells. Allelochemicals that cause insects to direct their movement away from a source are called repellents. Chemicals, which influence only in contact, preventing feeding or oviposition by insects, are called deterrents. Many non-hostplant compounds of certain insect species, act as repellents or deterrents.

Behavioural changes of pests can be caused by altering olfactory and taste stimuli from the host plant by treating it with certain plant extracts. The extracts of *Artemisia absinthum* affected aphids as a deterrent or a repellent because they left from the treated tomato plants. Cabbage butterfly laid significantly less eggs on plants treated with extracts *Tanacetum vulgare* and *Matricaria inodora*. Some insect species are repelled by the odour of *Tagetes* spp. for example – the greenhouse whitefly and the carrot rust fly.

Plant strengthening products. Plant strengthening products are intended to enhance the plant's resistance to harmful organisms. There is the wide range of products based on organic substances, for example, plant - and compost extracts.

NB! Plant products are included in the list of substances allowed for fertilizing in organic farming. Consequently, plant extracts can be used for strengthening the health of a plant.

Plant compounds can also change the pest food quality and via this decrease pests' survival. The water extracts of garlic, camomile, tansy, absinth, yarrow, mugwort, tomato, rhubarb, nettle, field horsetail etc. influence different caterpillars, trips and aphids etc. quite effectively. Garlic and chamomile extracts are also used for seed treatment.

When making extracts, it should be taken into consideration that the amount of active plant compounds may vary depending upon the growth conditions and the age of the plant. In general, 10–20% of raw plant material should be taken for crude water extracts. The liquid is filtrated and could be used for spraying of plants. For better covering of plant surfaces some adhesive substances should be added. In the fermented extracts the diversity of microbes is developed which suppresses pathogens and also influences as fertilizer. The fermented extract of compost can strengthen the health of plants. The compost extract can be made in the ratio: 1 part of manure compost, 5–10 parts of water. The bovine and horse manure compost has produced the best results. Good results have been obtained in controlling of leaf blights, grey mould and rust diseases with fermented compost.

NB! Even with using natural compounds and methods it is always necessary to find out if they are allowed for use in organic plant production regulations.

3. Chemical control

In organic farming it is allowed to use only certain plant protection products, which are mainly of natural origin. The allowed plant protection products are listed in the EU regulation 2092 part B but every member state can make special restrictions. Sulphur compounds influence on fungus diseases and mites, whereas potassium salt soaps are efficient in the control of soft-bodied sucking insects. Potassium permanganate is allowed to be used for pathogen suppression on fruit trees. Bordeaux mixture is a mixture of copper sulphate and quicklime and it is used to prevent a disease spread. Milk hydrolyzates in sprays cover the bodies of aphids and trips with membranes, which destroy the metabolism of insects. Paraffin oils can be used for spring spraying of trees in orchards. Quartz sand is a repellent, gelatine covers the surface of the body of arthropods and glues their stigmas and pests die. Commercial bio-pesticides based on plant compounds: Quassia from *Quassia amara,* Rotenon from *Derris* spp, pyrethrins from *Chrysanthemum cinerariafolium*, asadirachtin from *Azadirachta indica*) are effective for control of aphids, Colorado potato beetle, different caterpillars etc. But, for example, in Germany Rotenon is not permitted because of its toxicity to bees. The European Union list also contains some synthetic pesticides, which are allowed to be used, but only in traps – for example molluscoid metaldehyde and some parathyroids. Although, in Germany their use is prohibited in organic production.

NB! The admissibility of the use of plant protection products, fertilizers and other means must be checked in national registration list of plant protection products and the national regulation for organic plant production!

In many countries intensive research is presently under way with the purpose of introducing new suitable plant protection products of natural origin. For example, the dressing of cereal seeds with mustard powder (10g kg^{-1}) and acetic acid (20 ml kg^{-1}) has helped to control the common bunt.

It is important to take into consideration that the allowed products are not selective and any treatment influences not only on the target group, but also other organisms. Therefore, all the treatments should be made very carefully. First – the plant health problem has to be clearly identified and a proper product should be found. Furthermore, only relevant areas should be treated and in still weather to prevent drift. Never spray where bees and other beneficial insects work.

NB! In organic farming the main attention should be paid to the development of organic agro- ecosystem as a self-regulating organism. Therefore, the diversification of cropping systems and the agricultural landscape play a crucial role in organic plant protection.

References

1. Akanda S.I., Mundt C.C. 1996. Effect of two-component wheat cultivar mixtures on stripe rust severity. Phytopathology 86, 347–353.
2. Altieri M.A., Nicholls I.C. 2004. Biodiversity and pest management in agroecosystems. Food Products Press, New York, London, 236 p.
3. Cook S.M., Khan Z.R., Pickett J.A. 2007a. The use of push-pull strategies in integrated pest management. Annual Review of Entomology 52: 375–400
4. Cook, S.M., Rasmussen, H.B., Birkett, M., Woodcock, C.M., Murray, D.A., Pye, B.J. *et al.* 2007b. Behavioural and chemical ecology of the success of turnip rape (*Brassica rapa*) trap crops in protecting oilseed rape (*Brassica napus*) from the pest *Meligethes aeneus*. Arthropod-Plant Interactions 1, 57–67.
5. Coombes D.S., Sotherton N.W. 1986. The dispersial and distribution of polyphagous predatory coleopteran in cereals. Ann. Appl. Biol., 108, 461–474.
6. Endersby N.M., Morgan W.C. 1991. Alternatives to synthetic chemical insecticides for use in crucifer crops. Biol. Agricult. and Horticult., 8, 33–52.
7. Hansen L.M., Lorentsen L. 2005. Intercropping of fabae beans (Vicia fabae L.) and spring barley (Horedeum vulgare L.) to reduce the incidence of the black bean aphid. Organic farming for a new millennium. NJF-seminar 369. NJF Report, 1, P. 193-196.
8. Hokkanen, H.M.T. 1991. Trap cropping in pest management. Annual Review of Entomology 36, 119–138.
9. Hokkanen H. 1999. Biological and agrotehnical control of the rape blossom beetle *Meligethes aeneus* (Col., Nitid.). Acta Entomologica Fennica 53, 25–29.
10. Holden, M.H., Ellner, S.P., Lee, D-H., Nyrop, J.P., Sanderson, J.P. 2012. Designing an effective trap cropping strategy: the effects of attraction, retention and plant spatial distribution. J. Appl. Ecol. 49, 715-722.
11. Kaasik, R., Kovacs, G., Luik, A., Veromann, E. 2012. The impact of companion planting on the parasitism rate of the small white butterfly Pieris rapae (Lepidoptera: Pieridae). *In: IOBC wprs Bulletin: IOBC/wprs Working Group Meeting "Landscape Management For Functional Biodiversity", 7-10 May 2012, Lleida, Spain.* 2012, (75), 109 - 113.
12. Kaasik, R., Kovacs, G., Kaart, T., Metspalu, L., Williams, I. H., Veromann, E., 2014. Meligethes aeneus oviposition preferences, larval parasitism rate and species composition of parasitoids on Brassica nigra, Raphanus sativus compared with Brassica napus. Biol. Control 69, 65-71.
13. Kovacs G, Kaasik R, Metspalu L, Williams IH, Luik A, Veromann E (2013) Could Brassica rapa, B. juncea and Sinapis alba facilitate the control of the cabbage seed weevil in oilseed rape crops? Biol Control 65:124–129.
14. Kromp B. 1999. Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation impacts and enhancement./ Agric. Ecosyst. Environ.,74, 187–228.
15. Kühne S., Jahn M. 2002. Regulations on the use of plant protection and plant strengthening products in organic farming in Germany. Proc. 14th IFOAM Organic World Congress, 21-24 August, Victoria, Canada, 45 p.
16. Kühne S.Verschwele A., Hörsten,D., Jahn, M. 2005. Implementation bioherbicides and seed treatment in organic farming. Proc. of 15th IFOAM Organic World Congress, 21-23 Sept. 2005, Adelaide, 150–153.
17. Leius K. 1967. Influence of wild flowers on parasitism of tent caterpillar and codling moth // Can. Entomologist, 99, 444–446.
18. Luik A. 1997. The influence of plants on insects. (In Estonian with English summary). Tartumaa kirjastus, Tartu, 89 p.
19. Luik A., Kuusik A., Metspalu L., Hiiesaar K., Ploomi A. 1999. Effects of the extracts of the Estonian local plants of some pests behaviour. Abstracts of 14-th International Plant Protection Congress (IPPC). Jerusalem, Israel, 29, p.114–117.

20. Luik A., Hanni L., Merivee E., Ploomi A., Tarang T., Veromann E. 2005. Studies in environmentally friendly plant protection in Estonia. Organic farming for a new millenium. NJF-seminar 369. NJF Report, 1, 173–177.
21. Merfield C., Hampton J., Murry H., Wratten S. 2005. The effect of seed moisture content and the duration of hot water treatment on carrot seed viability and the control of Alternaria radicina. Proc. of 15th IFOAM Organic World Congress, 21-23 Sept. 2005, Adelaide, 542–545.
22. Metspalu L., Hiiesaar K., Kuusik A. 1997. Taimedega kahjurputukate vastu. Mahepõllumajanduse leht No. 5, 16–19.
23. Navi S.S., Bandyopadhyay R. 2002. Biological control of fungal plant pathogens In. Waller,J.M., Lenne, J.M., Waller, S.J. (Eds.) Plant pathologist's pocketbook, 354–365.
24. Rovira A.D. 1969. Plant root exudates // Botanical Review, 35, 35–39.
25. Shelton, A.M., Badenes-Perez, F.R. 2006. Concepts and applications of trap cropping pest management. Annu. Rev. Entomol. 51, 285-308.
26. Sopp P.I., Chiverton P.A. 1987. Autumn predation of cereal aphids by polyphagous predators in Southern England: a 'first look' using ELISA. Bull SROP/WPRS, 1, 103–108.
27. Tamutis V. 2000. Carabid beetles species diversity and abundance in some agrobiocenoses. Development of environmentally friendly plant protection in the Baltic region. Proc. Int. Conf. Tartu, Estonia, September 28-29, Transact. Est. Agricult. Univ. 2009, 200–203.
28. Thacker. JR.M. 2002. An introduction to arthropod pest control. Cambridge Univ. Press, 343p.
29. Theunissen J. 1994. Effects of intercropping on pest populations in vegetable crops. IOBC/WPRS Bulletin, 17,8, 153–158.
30. Turnbull A.L. 1969. The ecological role of pest populations. Proc. Tall Timbers Conf. on Ecol. Animal Control by Habitat Management 1, 219–232.
31. Uvah I.I., CoacerT.H. 1984. Effect of mixed cropping on some insect pests of carrots and onions. Entomol. Exp. Appl., 36, 159–167.
32. Vacali C., Sidiras N., Bilalis D., Köpke U. 2002. Possibilities and limits of reduced primary tillage in organic farming. Proc. 14th Organic World Congress, 21-24 August 2002, Victoria, Canada, 27 p.
33. Vandermeer J., Perfecto I. 1995. Breakfast of biodiversity. Food First Books, Oakland, California, 205 p.
34. Veromann E, Kaasik, R, Kovacs G, Metspalu L, Williams IH, Mänd M. 2014. Arthropod-Plant Interactions 8: 373-381.
35. Veromann E., Kevväi R., Luik A., Williams I.H. 2008. Do cropping system and insecticide use in spring oilseed rape affect the abundance of pollen beetles (*Meligethes aeneus* Fab.) on the crop? Int J Pest Manage 54:1–4.
36. Veromann E., Williams I.H., Kaasik R., Luik A. 2011. Potential of parasitoids to control populations of the weevil *Ceutorhynchus obstrictus* (Marsham) on winter oilseed rape. Int J Pest Manage 57:85–92.
37. Veromann, E., Luik, A., Kevväi, R. 2006. The impact of field edges on the incidence of Meligethes aeneus Fab. larvae and their parasitisation in spring and winter oilseed rape. Agronomy Research, 4(Special Issue), 447 - 450.
38. Veromann, E., Metspalu, L., Williams, I.H., Hiiesaar, K., Mand, M., Kaasik., R., Kovacs, G., Jogar, K., Svilponis, E., Kivimagi, I., Ploomi, A., Luik, A. 2012. Relative attractiveness of *Brassica napus*, *Brassica nigra*, *Eruca sativa* and *Raphanus sativus* for pollen beetle (*Meligethes aeneus*) and their potential for use in trap cropping. Arthropod-Plant Interactions, 6, 385-394.

39. Veromann, E.; Saarniit, M.; Kevväi, R.; Luik, A. 2009. Effect of crop management on the incidence of Meligethes aeneus Fab. and their larval parasitism rate in organic and conventional winter oilseed rape. Agronomy Research, 7, 548–554.
40. Veromann, E.; Toome, M. 2011. Pollen beetle (*Meligethes aeneus* Fab) susceptibility to synthetic pyretroids – pilot study in Estonia. Agronomy Research, 9(1-2), 365–369.
41. Williams, I.H. 2010. The major insect pests of oilseed rape in Europe and their management: an overview. In: Williams I.H. (ed.) Biocontrol-Based Management of Oilseed Rape Pests Springer, 1–43.
42. Williams I.H., Cook S.M. 2010. Crop location by oilseed rape pests and host location by their parasitoids. In: Williams I.H. (ed.) Biocontrol-Based Management of Oilseed Rape Pests. Springer: 215–244.