

Plant protection in organic production of *Brassica* vegetables and oilseed rape

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Abstract: Growers of organic *Brassica* vegetables and oilseed rape face the same potentially severe plant protection problems as their colleagues in conventional or integrated pest management systems. Management strategies in organic systems rely on preventive measures, use of functional agro-biodiversity, release of biocontrol agents and a few approved pesticides of biological and mineral origin, as well as mating disruption or the use of fine-mesh netting to exclude pests. The methods used in organic production might also be applicable in IPM systems. This paper considers the methods used in organic *Brassica* vegetable and oilseed rape production, and discusses their potential and limitations in the context of their application in integrated pest and disease management strategies.

Key words: Integrated Pest and Disease Management, *Brassica* crops, organic systems

Introduction

Growers of organic *Brassica* vegetables and oilseed rape face the same potentially severe plant protection problems as their colleagues in conventional or integrated pest management systems. Management strategies in organic systems rely on preventive measures (crop rotation, crop isolation, soil management, host plant resistance, farm/field location; manipulate timing of planting or harvest; intercropping, mulching), use of functional agro-biodiversity (reduction of pest by enhancing natural enemies), release of biocontrol agents and a few approved pesticides of biological and mineral origin, as well as mating disruption or the use of fine-mesh netting to exclude pests (Zehnder *et al.*, 2007). The methods used in organic might also be applicable in IPM systems. However, several factors hamper wide implementation of these methods in IPM. Among the main reasons are (1) a lower efficacy compared to standard pesticide treatments, (2) higher costs, (3) lack of knowledge/information/advice on alternative methods, (4) inconvenience, and (5) the need for close collaboration between neighbouring farmers to achieve good control. In the following paper, we describe the methods used in organic *Brassica* vegetable and oilseed rape production, and discuss their limitations.

Discussion

Pest and disease control in organic oilseed rape

Swiss organic farms usually have a 5-7 year crop rotation with grass-clover and cereals as main crops. Most diseases (*Plasmodiophora brassicae*, *Verticillium longisporum*, *Sclerotinia*

sclerotiorum, *Leptosphaeria maculans*) are thus sufficiently controlled. Removal of infected debris and volunteer oilseed rape plants are part of this strategy. *Sclerotinia*, however, also infests many other crops grown in the rotation. A highly effective biocontrol agent *Coniothyrium minitans* is registered against this disease; however, application is rarely considered necessary. On soils with low pH (< 6.5) liming is used to reduce infestation with *P. brassicae*. Healthy, certified seeds are another key factor to avoid diseases, such as *L. maculans*, *V. longisporum*, and *Alternaria brassicae*. Hot water seed treatment or aerated steam can be used for seed disinfection. Yield losses due to *A. brassicae* are reduced by early harvest to avoid splitting of pods.

Pest insects of oilseed rape are more challenging than diseases: damage by autumn pests such as flea beetles or *Athalia rosae* is diminished by early sowing and by creating conditions favourable for rapid plant development. To avoid feeding damage of adult flea beetle, *Psylliodes crysocephala*, silicate rock dusts are applied if necessary. Efficacy of dust applications seems to be higher than the efficacy of spray applications of silicate rock dusts. However, spray applications pose less risk to workers because the risk of inhaling dust is strongly reduced. In addition, most fertilizer spreaders are not suitable for the application of dusts and completely calm conditions are necessary during application. As with flea beetles, slugs mainly cause damage in the autumn before plants reach the 3-leaf-stage. Damage is reduced by avoidance of sowing under moist conditions, higher sowing densities at the borders of the fields, as well as by consolidation of the seedbed after sowing. Organic growers are allowed to use slug pellets based on ferric phosphate which are nearly as efficient, but more expensive than, products based on metaldehyde. *Ceutorhynchus napi* and *Ceutorhynchus pallidactylus* are not perceived as a problem by farmers, because monitoring is difficult. Usually no measures are applied to control these pests. Damage is lower in stronger and better developed plants. Creating good growing conditions in autumn is thus used to reduce damage. However, damage by both species can be observed frequently in organic oilseed rape fields. Pollen beetle (*Meligethes aeneus*) is assumed to be the main pest insect in organic oilseed rape. Fertilization level and plant density within the field influence the ability of the plants to compensate for damage. Damage is reduced by choosing early flowering cultivars and by applications of silicate rock dusts. On-farm experiments showed that applications of sprayable silicate rock dust products increased oilseed rape yield by 23% (Daniel *et al.*, 2013). However, applications of silicate rock dusts are considerably more expensive and more inconvenient than pyrethroid sprays.

Yield and yield limiting factors in organic oilseed rape

Yield in organic oilseed rape production is considerably lower than in IPM or conventional production. A system comparison of IPM, Extenso (no fungicides, no insecticides, no growth regulators; herbicides and mineral fertilizer are allowed) and organic (no pesticides, no growth regulators, no mineral fertilizer) in Switzerland (Zihlmann *et al.*, 2010) showed, that IPM oilseed rape yielded on average 4.24 t/ha, whereas Extenso oilseed rape yielded only 3.45 t/ha. Yield losses were mainly attributed to pollen beetle damage. However, even in years with heavy pollen beetle damage, an Extenso yield of 2.8 t/ha was obtained, whereas under organic conditions high variations in yield (1.23-3.77 t/ha) were observed. Yield losses in organic production were mainly attributed to weed competition and insufficient nitrogen supply. Due to the fact that only organic fertilizers are allowed, nitrogen availability is often low in early spring because of slow mineralization.

Pest and disease control in organic Brassica vegetables

Cultural practices are the most important basis for disease control in organic *Brassica* vegetables. These include practices such as a four year crop rotation, removal of infected debris, control of *Brassica* weeds, no use of green manures or intercropping with *Brassica* species, hygiene/sanitation measures, the use of healthy certified seeds, and adapted irrigation regimes (e.g. drip irrigation, irrigation in the morning instead of in the evening).

Hot water treatments or aerated steam are used to treat seeds. The efficacy of seed treatments is generally very good for diseases on the seed surface, such as *Alternaria*, but not for diseases within the endosperm. Seed treatments are usually applied by the seed producers, because control of the temperature and duration of treatments needs expert knowledge to find the balance between good efficacy and potential negative effects on the germination capacity of the seeds.

Plasmodiophora brassicae is mainly avoided by site selection: avoiding waterlogged and acid soils, distance to infested fields, and long crop rotation, as well as by the choice of tolerant/resistant cultivars. Soil liming is used on acid soils. Fertilizers containing chitin showed a disease reducing effect if applied regularly over several years (Heller *et al.*, 2008).

Hyaloperonospora parasitica (*Peronospora parasitica*) is favored by high humidity. Thus, prevention aims at reducing humidity: such as ebb and flow systems instead of overhead sprinkling during the seedling stage, adapted ventilation in production of young plants, field irrigation during the morning instead of the evening, and reduced plant densities in autumn crops in order to foster ventilation. Disease-free seed and the choice of tolerant cultivars also play an important role.

Strategies to control *Alternaria brassicae* and *A. brassicola* also consist of disease free seed, crop rotation, tolerant/resistant cultivars, reduced plant densities for better aeration and reduced N fertilization. In most years, *Alternaria* is sufficiently controlled by these measures. Economically important damage only occurs under very wet and rainy conditions.

Sclerotinia sclerotiorum is reduced by crop rotation. In addition, biocontrol (*Coniothyrium minitans*) is applied with good success. However, treatments have to be applied at least three months before crop establishment or on the residues of the previous crop.

For the control of *Xanthomonas campestris* pv. *campestris* preventive measures are used: such as disease free seed, crop rotation, sanitation measures (disinfection of boxes and areas for young plant production), resistant plants, and lower plant densities. Bottom-up irrigation of seedlings considerably reduces the spread of the disease. Drip irrigation in the field would also be effective, but this approach is not compatible with mechanical hoeing in organic production systems. Cultivation work in infested fields should only be conducted under dry weather conditions to avoid the spread of disease by guttation drops. As cauliflower is more susceptible than broccoli, farmers in infested areas choose to produce broccoli, especially in summer and autumn. Copper treatments can slow down infestation, but are rarely used because of very low efficacy.

Verticillium longisporum is a soil-borne disease: crop rotation and rapid mulching of plant residues, followed by incorporation, reduces the survival of microsclerotia. Activation of soil microbes by incorporation of green manure and compost also decreases microsclerotia survival. Tolerant/resistant cultivars are available.

Control of different lepidopteran larvae is achieved mainly by the use of biocontrol agents (*Bacillus thuringiensis* subsp. *kurstakii* and *Bt* subsp. *aizawai*). The use of *Bt* provides reliable control of most lepidopteran species. The strain *Bt* subsp. *aizawai* can also be used against noctuid species. However, *Bt* products are more expensive than most IPM-insecticides. In addition, exact timing of application is crucial. Adapted application

techniques, such as dropleg technology for spraying the lower surfaces of the foliage of vegetable and field crops, improve the efficacy of *Bt* products, but are not available on most farms. In addition, preventive measures are taken, such as soil cultivation in early spring to destroy overwintering pupae. Crop residues on heavily infested plots are immediately ploughed in after harvest in order to avoid pupation of pest insects. The use of functional biodiversity (flowering strips and within-field companion plants) is so far only used in cabbage for Sauerkraut production. Crop netting and the use of Spinosad are further options available to organic farmers. However, these options are only used if other pest insects occur, because use of netting is complicated and Spinosad has side effects on many beneficial insects (especially Hymenoptera).

The control of *Delia radicum* is mainly based on preventive measures, such as crop rotation, destruction of infested roots immediately after harvest, and distance to other and previous cabbage fields. Young plants are particularly affected; therefore crop netting is used after transplanting in regions with known occurrence of *D. radicum*. In addition, seedlings are planted deeper and earthed up after transplanting in order to stimulate growth of secondary roots. Minor damage can be compensated for by strong root growth. Eggs are sensitive to drought; therefore reduced irrigation has a certain effect on infestation. Machines for mechanical weed control ‘finger weeder’ and ‘blowers’ also have an effect on *D. radicum*. Exclusion fences are used only very rarely, mainly to protect young plant production. A drench application of Spinosad on seedlings directly before transplanting was recently registered in many European countries and allows *D. radicum* to be controlled directly. Good results were obtained with entomopathogenic nematodes (*Steinernema feltiae*), but this strategy is not yet implemented by farmers, because of open questions concerning the optimal timing of applications (Beck *et al.*, 2014).

Aphids (*Brevicoryne brassicae*) are normally sufficiently controlled by naturally occurring antagonists, such as hoverflies. Flowering strips (e.g. buckwheat) and companion plants can further enhance their efficacy, whereas the use of broad spectrum insecticides (pyrethrins and Spinosad) negatively affect the antagonists (Hommes, 2011). Mainly young plants, before and shortly after planting and especially during dry weather conditions, are susceptible and can be protected by nets. However, the use of nets might also exclude the natural enemies. Additional irrigation can mitigate aphid damage and promote quick plant growth. Vegetable oils and soaps are available for direct pest control and should be applied using dropleg technology in order to reach the insects on the lower leaf surfaces.

Damage by *Contarinia nasturtii* mainly depends on the density of *Brassica* production in an area. *C. nasturtii* adults are very weak flyers: a distance of 100 m to other or previous cabbage and oilseed rape fields and production in locations open to wind, limit immigration and damage. Crop netting is used in fields at risk. In addition, Spinosad can be used as a final last option, but it has side effects on many beneficial insects. Pheromone traps are used to monitor flight periods, nevertheless, optimal timing of application is difficult for farmers to determine. Insect fences were developed but are rarely used by farmers due to their inconvenience.

Flea beetle densities are also influenced by the density of *Brassica* production in an area and the distance to other and previous *Brassica* fields. However, flea beetles are observed throughout vegetable producing areas. Serious damage only occurs in June in young, newly-planted crops under dry and hot weather conditions. Fields at risk can be protected using silicate rock dusts or crop netting. Increased irrigation helps to mitigate damage. Spinosad is also registered to control this pest. However, up to five applications are necessary to control continuously immigrating individuals. In view of the side effects of Spinosad, most farmers would rather use silicate rock dusts instead of Spinosad.

Cabbage whitefly (*Aleyrodes proletella*) are usually no problem in cauliflower, broccoli and headed cabbage. Severe damage can occur on Brussels sprout, Savoy cabbage and kale. Crop netting can worsen the situation because of the exclusion of natural enemies. For good efficacy, spray applications of Neem oil, pyrethrum and vegetable oils need to be applied using dropleg technology.

Yields and yield limiting factors in organic Brassica vegetables

Yields in organic *Brassica* vegetable production are about 20-30% lower than in conventional production. Depending on climate conditions and location, different pests and diseases are the reasons for yield limitations. Under cool and rainy weather conditions, nitrogen mineralization becomes one of the yield limiting factors.

Aphids are no problem because they are controlled by naturally occurring antagonists. Control of lepidopteran larvae is also supported by enhancing functional agrobiodiversity (wildflower strips and companion plants). In addition, *Bt* can be used to control lepidopteran larvae. Side effects of *Bt* on beneficial insects are considered to be very low, thus the stability of the system is not challenged by the use of these products. The opposite is true for Spinosad: its broad spectrum activity leads to side effects on many beneficial insects. Hymenopteran parasitoids of lepidopteran larvae, as well as aphid antagonists (parasitoids, ladybirds, syrphids, lacewings) are harmed. The reduced activity of antagonists make additional, subsequent treatments against aphids and Lepidoptera necessary, which in turn further imbalance the system. Crop netting also has this de-stabilising effect by excluding antagonists. However, the side effects of crop netting are more restricted in time and space than the side effects of Spinosad. Crop netting also affects disease outbreaks by increasing humidity. Netting should therefore only be used when absolutely necessary. Thus, the limiting factors for sustainable production of *Brassica* vegetables are *Contarinia nasturtii* and *Delia radicum* because they make the application of Spinosad necessary. In order to overcome these limiting factors, new methods, free from side-effects, are needed to control these pests. The use of insect-proof fences to exclude these pests from the fields has been investigated. Unlike crop netting, such fences would still allow the immigration of many antagonists. However, current prototypes are rather inconvenient to use and are therefore not employed by farmers. Improvement of these prototypes or the development of new, selective methods of control for *C. nasturtii* and *D. radicum* is therefore needed. In addition, the whole system approach needs to be reflected in economic thresholds and in the advisory strategies: i.e. if the treatment of a primary pest, leads to extinction of antagonists and thus to the necessity of treatments against secondary pests, a higher economic threshold for the primary pest seems appropriate – from the economic as well as from the ecological point of view.

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