Challenges of Organic Arable Farming

5th module
Crop-specific problems and potential solutions in cereals, legumes, fruit and vegetables





Module objectives

- The yield gap between organic and conventional production varies from crop to crop due to different crop-specific factors. While cereals and tubers mainly suffer from nutrient availability (basically nitrogen deficiency), legumes are difficult to be managed because of weeds and diseases. Insect pests are particularly important in oil crops. Each crop group shows different susceptibility to the various yield-limiting factors. Hence, agricultural practices such as variety selection and crop rotation design have a major impact on crop yield and quality.

- This module will highlight the main challenges in the growth of five crop categories (cereals, legumes, oil crops, tubers and fruit trees), focusing on the yield limiting factors. The reasons behind yield gaps between organic and conventional production as well as key pests and potential solutions are discussed. Practical tools will provide management skills to develop a suitable and integrated management strategy for each discussed crop category.

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1. Introduction

- Agricultural practices are used to improve the growth, development, and yield of agricultural crops. In organic agriculture, the combination, timing, and sequence of the used practices depend on the biological characteristics of crops (whether winter or spring crops), the harvested form (grains, green feed, fruits), the sowing methods (row, nest, or wide-row), the age of the plants, the soil, and climatic conditions.

- Specific crop-managing practices for individual crops include hilling, suckering, pinching, and chopping. Other field practices include crop irrigation and mechanical, biological, and chemical methods to control weeds, pests, and diseases.

- Keeping in mind the concerns about the ecosystem health, a properly managed organic field might improve the yield and be economically advantageous.

2. Cereals

2.1. Challenges and potential solutions

- Cereals can be a useful component in the cropping system. Barley prevents pea lodging, thus reducing the losses during threshing, and increases the quality of the harvested crop. Cereal crops also improve the soil cover and weed suppression. Growing another crop with cereals at the same time reduces the risk of yield loss.

- Yield gap in cereals has been found to vary between conventional and organic production from -84% to +37% (table 1). The main reason is that most wheat, barely and maize verities have been bred to thrive in high input conditions, meaning that they perform less under low input systems.
- Escaping from key pests, organic maize farmers tend to delay planting date which cause a low productivity as the soil becomes warm with high mineralization rate.

Table 1. Yield gaps between organic and conventional cereals.

Crop	Yield gap
Cereals in general	-7% to -54%
Barley, oats	-35%
Corn	-62% to +37%
Sorghum	-16 to -27%
Wheat	-84% to NS

Minus (-) indicate lower yield in organic crops.
NS: No difference.

2. Cereals

2.1. Challenges and potential solutions

- Indeed, nitrogen availability is considered the primary factor that limits cereal productivity. For instance, N mineralization rate poorly matches the timing of greatest N uptake in wheat.
- Nitrogen plays an important role in grain protein content, which is the most reliable indicator of cereals quality, as it contributes to baking properties. Studies have found 3 - 23% lower protein content in organic wheat than conventional.
- Extreme frost in cold winters can lead to soil movements and cracks that damage plant roots and grain hypocotyls. This makes growth more difficult in spring and makes the grain very susceptible to the low soil moisture especially before the 3-leaves growth stage.
- Grain varieties designed for high-input monoculture do not provide the genetic and physical diversity needed to increase crop capacity and resilience. Organic cereals production requires plant varieties that are disease resistant, competitive against weeds and effective at scavenging for nutrients.

2. Cereals

2.1. Challenges and potential solutions

- Nitrogen availability can be increased by the organic practices we discussed in the 2nd module (such as legumes, cover crops, green manure and intercropping). Amending soil with 50 kg ha^{-1} farmyard manure raised organic cereal yields by 0.4 - 1.3 t ha^{-1} under N-limited system.

- While conventional farmers use late fertilization to boost grain protein, organic ones should adjust the time of amendments application to have an adequate available content after the mid of the season. Such strategy prevents nutrients' leaching into groundwater and reduces nitrate pollution.

- Regarding frosts, rolling the grains in spring helps reconnect soil crumbs and supports the soil water capillarity and water availability in the topsoil. The pressure of the roller increases grain stability and thus reduce the risk of falling over.

- Genetic and physical crop diversity can bring stability and increase productivity. Fruitful results were achieved in this regard and can be found here.

2. Cereals

2.2. Key pests and pest management

- Even though cereals are attacked by different pests, they can rarely cause a complete crop loss.
- Damages caused by *Oscinella frit*, aphids and *Oulema* sp. usually remain below the economic threshold.
- Soil tillage, especially plowing and skimming, are important measures in the prevention and control of *Oscinella frit*. It is also useful to early sow spring cereals and delay winter ones. This pest prefers laying the eggs on young plants and therefore it is important to boost fast development of early spring cereals, which reduce the possibility for insects to find attractive plants when they spread.
- To control aphids, cereal fields must be designed to ensure enough insulation spaces, thus preventing aphids movement between crops.
- Biological insecticides were developed to overcome *Oulema* sp., especially the beetle larvae. In addition, azadirachtin and spinosad were found effective (31.6 to 77.2% reduction of insect population).

2. Cereals

2.3. Maize as example

2.3.1. Challenges

When comparing organic and conventional cultivation, yield gap is generally smaller for maize than other cereals in temperate zones with sufficient water availability. A major limiting factor for maize is weed pressure, accounting for 23% of the yield gap.

Maize also faces a problem of late-sow date with a large row spacing and slow early development, making the soil more vulnerable to erosion. In addition, soil compaction due to the use of heavy harvest machinery contributes to soil erosion.

In maize production, European corn borer (*O. nubilalis*), Western corn rootworm (*Diabrotica virgifera*), and wireworms (*Elateridae*) are the most common enemies. The western corn rootworm (*D. virgifera*) causes significant root damage, while wireworms attack seedlings and can be a problem in some years and locations.

2. Cereals

2.3. Maize as example

2.3.2. Potential solutions

Yield gap tends to reduce when weed management is done effectively. Mechanical weed cultivation is a successful measure able to decrease the yield gap from 26% (the case of no weeding) to only 1%.

Soil ploughing as weed control measure is efficient but harmful due to the associated soil erosion, compaction and runoff side-effects. Therefore, a direct sowing technique of maize was developed. Watch this video.

Crop rotation plays an important role when organic maize is grown in rotation with multiple cover crop species. Maize is ideal to catch cropping with pure or mixed clover (for stockless farms), or with overwintering, single-year grass-clover (for livestock-rearing farms).

2. Cereals

2.3. Maize as example

2.3.2. Potential solutions

The egg parasitoid *Trichogramma brassicae* is successfully applied to control *O. nubilalis*. Alternatively, *Bacillus thuringiensis* var. Kurstaki has been tested and reduced the number of *O. nubilalis* damage on the European corn by 35.4 to 45.9% (single application) and by 23.2 to 38.1% (two applications).

D. virgifera can be efficiently controlled using an appropriate crop rotation (a two-year break between maize is very effective).

Efficient strategies for wireworm management are still missing.

3. Legumes

3.1. Challenges and potential solutions

- Yield gaps are generally much smaller for legumes than other crop categories (about 5%). This can be partially explained by the reliance of these crops on fixed N derived from the symbiosis relationship with diazotrophic bacteria rather than inputs.

- Forage legumes are more common in organic than in conventional crop rotations and the yield gap between both systems is small. These crops require negligible inputs (i.e. there is no need for synthetic N fertilizer, while other nutrients are not usually limiting except in low potassium and phosphorus soils). Plant protection agents are not often used.

Table 2. Yield gaps between organic and conventional legumes.

Crop	Yield gap
Legumes in general	- 18% to NS
Soybean	-19% to +96%

Minus (-) indicate lower yield in organic crops.
NS: No difference.

3. Legumes

3.1. Challenges and potential solutions

- Grain legumes tend to yield more in conventional than organic production. Beans rarely achieved higher yield in organic than conventional crops, while organic soybean yield was 92% higher than the conventional one. Yield gaps may rise up, however, when inputs vary significantly.

- Weeds and diseases limit organic yields if appropriate biological-based strategies are not adopted.

- Besides pests and diseases, phosphorus deficiency is the main reason behind the depletion in legumes quality and quantity. Moreover, phosphorus (P) deficiency is a major limiting factor for legume–rhizobia symbioses particularly in acidic and calcareous soils.

- The organic production of forage legume seeds to meet the current seed certification standards is a significant challenge for seed producers.

3. Legumes

3.1. Challenges and potential solutions

- There are ongoing attempts to develop legume verities with higher ability to uptake phosphorus. Growing legumes cultivars that uptake P efficiently may improve P availability, especially in poor soils.

- Weed problems in seed fields can be managed by using a companion legume to suppress weeds and by developing an appropriate mechanical weed control system.

3. Legumes

3.2. Key pests and pest management

- Soy beans are attacked by birds, slugs and different larvae that belong to *Lepidoptera* order, while fava beans and peas can be infested by aphids and thrips.
- In addition to aphids, severe damage to fava beans and peas can be caused by the pea weevil (*Sitona lineatus* and *Sitona crinite*), especially in spring and early summer during hot-dry weather. Larvae of *Sitona* sp. feed on the roots of many cultivated and wild leguminous plant species, inducing a delayed growth.
- Larvae can be controlled by BT (*Bacillus thuringiensis*) application, while aphids and thrips usually remain below the economic threshold. Aphids can be controlled by neem oil applications.
- Intercropping peas with mustard or phacelia is effective in controlling the pea weevil. Damages can be reduced by an appropriate crop rotation, early sowing, additional chopping, application of silicate rock dusts or the use of exclusion nets.
- The colonization of legumes by the pea aphid can be reduced by mixed cropping with triticale, barley and oat.

4. Oil crops

4.1. Challenges and potential solutions

- Only few oil crops, such as oilseed rape, are practically very difficult to grow under organic conditions in regions where insect pests are present, while on the other hand, sunflower is a commonly grown oilseed crop whose organic yields can very easily reach conventional levels. Almost all oilseed rape production in central Europe is conventional (table 3).

- In many analyses, oilseed crops had the lowest yield gap between organic and conventional crops compared to all other crop categories, with the exception of fruits (Seufert *et al*., 2012, and Ponisio *et al*., 2014).
- Weed pressure on sensitive developmental stages is considered a decisive factor.

Table 3. Yield gaps between organic and conventional oil crops.

Crop	Yield gap
Oil crops (developed countries)	-1%
Oil crops (global average)	-26%

Minus (-) indicate lower yield in organic crops. NS: No difference.

4. Oil crops

4.1. Challenges and potential solutions

- In seed production, oilseed rape can cross-pollinate with other *Brassicas* such as rutabaga, Chinese cabbage, broccoli rape, and turnip unless buffer distances are adequate. This problem is compounded in canola when it is grown in an area infested by mustard-family weeds.
- Oilseed rape is a sulfur demanding crop. Nutrient deficiency and lack of drainage might be serious issues.
- Choosing the right adaptive variety with balanced nutrient supply may solve the aforementioned problems. When sulfur is not sufficiently present (i.e. when it is not used as fungicide), Kieserite or Epsom salt might be used.

4. Oil crops

4.2. Key pests and pest management

- Crop resilience varies from farm to farm depending on the presence of bio-control agents.
- Pest insects of oilseed rape are more critical than diseases.
- Herbivore insects are the limiting factor in this category and there are not really effective organic methods for pest control, especially against the pollen beetle (*Meligethes aeneus*).
- Autumn pests, such as the flea beetle (*Athalia rosae*), are reduced by early sowing and by creating favorable conditions for a rapid plant development.
- The pollen beetle (*M. aeneus*) is the main pest insect in organic oilseed rape.
- Slugs mainly cause damages in autumn prior to the three-leaves stage.
- The rape stem weevils (*Ceutorhynchus napi* and *Ceutorhynchus pallidactylus*) are not usually perceived as problematic, but they might be a serious challenge for organic producers.

4. Oil crops

4.2. Key pests and pest management

- To avoid the feeding damage caused by flea beetle adult, *Psylliodes crysocephala* and silicate rock dusts can be applied.
- Slug damages are reduced by sowing under dry conditions and low sowing densities. Organic growers are allowed to use slug pellets based on ferric phosphate which are more expensive than products based on metaldehyde (forbidden in organic agriculture).

- The damage of *Ceutorhynchus* is lower in stronger and better developed plants.
- *M. aeneus* can be managed through sufficient N supply, selecting early flowering cultivars and applying silicate rock dusts. Spinosad can also be used but it has side effects on bees and other *Hymenoptera*. Therefore, the direct application before blooming is not recommended in organic farming.

- Although it is not sufficient, growing a mixture of oilseed rape with turnip as trap crops was used to control pollen beetles. However, this strategy is no longer recommended because it attracts higher numbers of stem weevils (Ludwig *et al.*, 2011).

5. Tubers

5.1. Challenges and potential solutions

- Starchy roots had the second highest yield gap between organic and conventional production. In 21 organic-conventional comparisons, all from Europe, de Ponti *et al*. (2012) found that organic potato yields were only 70% of conventional crops (table 4). In contrast, organic sugar beet and sweet potato yields were 105% of conventional crops.
- In potato, the primary yield-limiting factor is nutrient availability particularly Nitrogen. Pathogens such as *Phytophthora infestans* are another limiting factor.

Table 4. Yield gaps between organic and conventional tuber crops

Crop	Yield gap
Potato	-15 to -42%
Starchy roots (developed countries)	-11%
Roots/tubers (global average)	-26%

Minus (-) indicate lower yield in organic crops.
NS: No difference.

5. Tubers

5.1. Challenges and potential solutions

- Organic potato growers can monitor petiole N content throughout the season to determine N status. In general, early maturing varieties and those grown for early markets require less N than late maturing varieties.

- High N induces vigorous foliage, which can lead to an increase in vine rot diseases. In general, split applications of N are recommended for potatoes from both production and environmental standpoints. A portion of N should be applied before planting to be followed by other additions at emergence and hilling stages. Nitrogen uptake by potato is the highest during the tuber bulking stage.

5.2. Key pests and pest management

- Colorado potato beetles (*Leptinotarsa decemlineata*) and wireworms are the most damaging pests in potato production. The larval stage of click beetles (*Elateridae*) is also a serious soil dwelling pest.

- Late blight (*Phytophthora infestans*) may infect and destroy leaves, stems, fruits and potato tubers.

5. Tubers

5.2. Key pests and pest management

- Early maturing varieties and a quick emergence help preempt the infestation of Colorado potato beetle. Additionally, insecticides may be used to prevent economic losses in organic farming. The combination of Neem and BT had achieved good control on young larvae. This dual strategy minimizes the risk of developing resistance to the insecticides (Kühne *et al*., 2008).
- Ryegrass-clover mixtures in crop rotations provide many benefits (i.e. fodder production, nitrogen fixation and humification) but it increases wireworm populations.
- Agronomic practices such as the use of pheromone traps can reduce the damage of wireworms. The synergistic effect of some biological agents, such as entomopathogenic fungi together with the insecticide spinosad, against wireworms has been observed.
- Preventive (e.g. controlling all inoculum sources) and curative measures (e.g. minimizing the duration of leaf wetness by adjusting irrigation, stopping to oversupply nitrogen, controlling weeds, applying copper) are efficient to control the late blight.

6. Fruit trees

6.1. Challenges and potential solutions

- During the conversion to organic agriculture, orchards might suffer from new pests and/or nutrient deficiencies.
- Hormones are prohibited and thinning blossoms is therefore a big challenge in organic fruit production.
- In addition to organic common amendments such as manures and composts, other nitrogen sources (e.g. feather meal and blood meal) and phosphorus sources (e.g. rock phosphorus) can target a specific nutrient need. Growers can also include authorized foliar sprays, such as fish emulsion, in the fertilization plan.
- Manual thinning is a common practice in organic farming. However, thinning with a rope thinner, lime sulphur, additional pruning and some foliar fertilizers can be used as well.

6. Fruit trees

6.2. Key pests and pest management

Some key pests follow:

- Spotted Wing Drosophila (*Drosophila suzukii*)
- Western Cherry Fruit Fly (*Rhagoletis indifferens*)
- Stinkbug (*Halyomorpha halys*)
- Fire Blight (*Erwinia amylovora*)
- Powdery mildew (*Erysiphe cichoracearum*)
- Apple scab (*Venturia inaequalis*)

6. Fruit trees

6.2. Key pests and pest management

General measures include:

- Pruning. It is the most efficient practice to remove dead/diseased branches, leaves, and twigs. The disposal of infected debris should be done far from trees to avoid re-contamination of any diseases.
- The mere presence of a pest does not always indicate a problem, or a need to apply controls. It is important to understand what to use, when and where to use it.
- Kaolin clay is a natural mineral that creates a physical barrier between leaves and fruit, and different fungus and parasites. Regardless of some dispute in the effectiveness of Kaolin, many organic tree growers have reported positive results.
- Pheromone traps (for monitoring and mating disruption) are highly selective to the pest species being targeted for disruption without causing secondary pest outbreaks due to the elimination of biological control agents. Coloured traps coated with tangle foot can provide effective control of pests such as *Rhagoletis Ronsheim pomonella* on apple.

7. Conclusions

- Productivity is the primary purpose of agriculture and farmers try to optimize crop yields. However, this is not the only concern in organic farming but other aspects (e.g. non-commodity ecosystem services, the efficiency use of non-renewable resources and being aware of social costs to society) are considered.

- The current average yield deficits do not threaten the advantages of organic agriculture. Yet, there are many challenges not be dismissed. To overcome these challenges, a tailor-made strategy that fits each crop or crop group should be constantly developed.

- Chemically-synthetized products are used for different aims in conventional agriculture, while in organic agriculture the absence of such products rise up challenging tasks.

7. Conclusions

- Being an integrated approach, organic farming invests many practices to meet different crop needs (e.g. using leguminous cover crops as biological control agent hosts, weed control tools and nutrients sources).

- Crop groups might have many common practices that suit crops of the same group or even crops from different groups. In some cases, it only requires to adjust the dose, the timing or sowing method to fit different categories. However, it is always vital to search for measures that meet crop needs in the best possible way considering the variety, the area, the weather conditions, etc.

- Organic movement must grow and organic practices should become the norm rather than the exception in order to make the difference.

Further tools

Here there are some further tools within this module available in other languages

- Organic Cultivation of Green Peas (leaflet) / German.
- Organic Cereals (leaflet) / German
- Organic quality wheat production (leaflet) / German
- Control of wireworms in organic potato cultivation (video) / German
- Processing Quality of Organic Wheat (Video) / French
- Potato Crop Management (leaflet) / Dutch

Linkography

1- General:

Facts and figures on organic agriculture in the European Union

Crop Rotation on Organic Farms: A Planning Manual

2- Orchards:

Planning the Organic Orchard

Organic Stone Fruit Orchard Floor Management

Transitioning to Organic Management of Orchards

Growing Organic Apples

A Grower's Guide to Organic Apples

Managing Pests & Diseases in an Organic Apple Orchard

Organic Tree Fruit Certification

Linkography

3- Vegetables:

Organic Vegetable Organic Vegetable Production Research

Breeding organic vegetables

Vegetable Production Technologies and Organic Production

Organic Vegetable Production

ORGANIC FOOD – food quality and potential health effects

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