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CROP ROTATION: PRACTICAL INFORMATION

This factsheet contains complementary information to the Best4Soil video on Crop rotation: practical information
https://best4soil.eu/videos/12/en

INTRODUCTION

If the same crop is grown in the same field for a long time, the yield level declines. Important causes are diseases and nematodes, soil borne pests that need a susceptible host plant to survive and multiply. Since the roots of one crop always explore the same soil layers and demand the same proportion of different nutrients, the soil gets exhausted while pests such as nematodes can survive and multiply on the host plant. Although pest and disease management requires a multi-action approach, the basis for a healthy soil is a good crop rotation: a planned order of growing specific crops on the same field (fig. 1) in order to prevent diseases and pests, while also increasing and maintaining soil health.

WHY CROP ROTATION?

Crop rotation is one of the oldest and most effective strategies to control soil borne diseases and pests. The final result however – higher economic benefit – depends very much on the choice, frequency and order of the crops in the design, adjustment to local conditions and integration of other management practices., crop rotation forms the basis for pest and disease control. In a good crop rotation soil health is maintained for the long run and disease and pest pressure is maintained low, resulting in sufficient yield of high-quality crops. Additional reasons to apply a good crop rotation are to maintain a good soil fertility and structure.

Each year it is a challenge to grow the type of crops in the quantity needed to ensure the farm profitability while the soil quality is maintained for a long-term productivity. Another challenge is to prevent specific pests and diseases while also not promoting other pests or diseases when planning the sequence of host- and non-host plants. In the following paragraphs you learn how to do that, with examples of good crop rotations.

Fig. 1: Scheme of crop rotation. Crops of the different botanical families are grown alternately.

Table 1 shows the importance of applying a good crop rotation with enough time between the first and second time that the same crop is grown on the field (advised minimum frequency in years).

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Table 1. The balance between soil health and main crop groups, their minimum frequency and possible consequences if the minimum requirement is ignored (A minimum frequency of 1:5 means one crop is grown once in the 5 years at the same field.)

CROP FAMILY	ADVISED MINIMUM FREQUENCY	HIGH RISKS IF CROP IS GROWN MORE TIMES THAN THE MINIMUM FREQUENCY
Solanaceae (e.g. potato, tomato)	1:5	Potato cyst nematodes *Verticillium dahliae* *Sclerotinia* *Alternaria* *Phytophthora* (oospores) *Rhizoctonia*
Alliaceae (e.g. onion, garlic)	1:6	White rot *(Sclerotium cepivorum)* *Fusarium* *Ditylenchus dipsaci* Onion fly *(Delia antiqua)* *Pratylenchus penetrans*
Apiaceae (e.g. carrot, parsley)	1:8	Soil borne fungal diseases (e.g. black spot disease, *Sclerotinia)* Carrot fly *(Chamaepsila rosae)* *Pratylenchus penetrans*
Beta vulgaris (e.g. sugar beet, red beet)	1:5	Beet cyste nematode *(Heterodera)* *Cercospora* *Rhizoctonia solani* *Verticillium*
Hordeum vulgare (barley)	1:2	*Rhynchosporium secalis* Net blotch *(Pyrenophora teres f. teres)* *Heterodera avanae* *Meloidogyne naasi* *Wheat balb fly (Delia coarctata)*
Triticum (e.g. winter wheat, summer wheat)	1:2	*Gaeumannomyces graminis f. sp. tritici* *Meloidogyne naasi* *Pyrenophora tritici-repentis* *Wheat balb fly (Delia coarctata)* *Pseudocercosporella herpotrichoides* *Saddle gall midge (Haplodiplosis marginata)*
Leguminosae (e.g. pea, broad bean, field bean)	1:6	Soil borne fungal diseases (e.g. foot rot diseases, *Sclerotinia)* *Pratylenchus penetrans* *Ditylenchus dipsaci*
Cruciferae/ Brassicaceae (e.g. rapeseed, cabbage)	1:4	*Sclerotinia sclerotiorum* *Verticillium dahliae* *Phoma lingam* *Plasmodiophora brassicae*
Zea mays subsp. mays (maize)	1:3	Soil borne fungal diseases *(e.g. Fusarium, Pythium)*

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STEPS TOWARDS A GOOD CROP ROTATION

The design of a crop rotation is determined by local conditions but general steps apply, as explained in the Best-4Soil video (https://best4soil.eu/videos/12/en). Planning the rotation is balanced by management decisions at farm and field level on an annual and multi-year basis. Normally, a crop rotation is made for each field based on the biology (e.g. nematode infestation levels) and then adjusted at farm level:

- to the amount of products you want to harvest from each crop in a year;
- to spread the risk evenly (income depending on multiple crops);
- to meet the market demand.

The following general steps apply:

- Determine whether you have problems with nematodes. Consider to apply soil analysis to determine the **infestation level of plant parasitic nematodes.**
- Consider the **fungal pathogens** you expect, since only a few can be analysed.
- **Decide which cash crops** you want to focus on and which varieties. Some **varieties** of the same crop can be less susceptible or even resistant for certain pests and diseases while others even multiply a nematode species.
- Make **a first design** in which you grow each crop preferably above the minimum frequency (table 1). Include the rotation of the past years.
- Use the Best4Soil online tool (https://www.best4soil.eu/database/en) to see which nematodes and soil borne fungi are related to your crops and adjust your scheme:
    - **Alternate a host-plant by a non-host-plant** for at least 1 crop cycle. Growing a crop which is sensitive to an expected or already present nematode after a non-host plant, lowers the risk that the concerned nematode prevails.
    - If you have a **high infestation level** of a certain nematode, consider how to reduce this. For some nematodes you can grow specific crops which eliminate the species
    - Be aware that certain species can be good prevention against one nematode or disease, but at the same time be susceptible to another.
- **Consider crop characteristics.** Crops with specific characteristics can benefit from each other if planned wisely, such as a legume crop which fixes nitrogen in the soil, which is later consumed by a high nitrogen demanding crop.
- **Integrate** other best practices in your management to maintain and improve soil health, such as cover crops.

When considering the risks from table 1, depending on your region a good crop rotation can be designed like the examples given in table 2 and 3 for farms in The Netherlands and Spain. Here you also see how local factors influence your rotation, such as economic reasons. In table 2 for example, there was decided to grow the main crop potato with a frequency of 1:4 instead of the advised minimum of 1:5 because of its relatively high profit and a low risk was expected based on nematode analysis result. In table 3 the rotation was mainly based on the nutrient requirements.

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Table 2. Example of a good crop rotation for a farm on a light silty loam soil in The Netherlands, with potato, carrot, sugar beet, winter wheat and onion as main cash crops (GM = green manure). From a nematode analysis from this field follows there is a high risk for Trichodorus. Some fields have more light soils (sandy) and others heavier soils (more clay), resulting in a slightly different rotation.

SOIL PROPERTIES	FIELD	YEAR 1		YEAR 2		YEAR 3		YEAR 4		YEAR 5		YEAR 6		YEAR 7		YEAR 8	
Clay	A1	Potato		Sugar beet	Wheat	Wheat	GM grass	Onion	GM Mustard	Potato		Sugar beet	Wheat	Wheat	GM grass	Onion	GM Mustard
Clay	A2							Carrot								Carrot	
Clay	B1	Onion	GM Mustard	Potato		Sugar beet	Wheat	Wheat	GM grass	Onion	GM Mustard	Potato		Sugar beet	Wheat	Wheat	GM grass
Clay	B2	Carrot								Carrot							
Sandy	C1	Wheat	GM Radish	Sugar beet	Wheat	Wheat	GM grass	Onion	GM Mustard	Wheat	GM Radish	Carrot		Potato	GM mix	Sugar beet	Wheat
Sandy	C2							Carrot				Onion	GM mix				
Sandy	D1	Sugar beet	Wheat	Wheat	GM Radish	Onion	GM Mix	Potato	GM mix	Sugar beet	Wheat	Wheat	GM Radish	Carrot		Potato	GM mix
Sandy	D2					Carrot								Onion	GM Mix		

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Table 3. Example of a good crop rotation for one year of a farm on a sandy soil in South of Spain. In red = main crops (high nutrients requirements). In green = secondary crops (low nutrient requirements). In black = Green manure.

YEAR 1		YEAR 2		YEAR 3		YEAR 4	
Cauliflower	Green manure	Pepper	Onion	Melon	Cabbage	Tomato	Carrot
Corn	Lettuce	Potato	Carrot	Green bean	Green manure	Eggplant	Onion
Peanut	Chard	Corn	Lettuce	Potato	Watermelon	Lettuce	Green bean
Pumpkin	Broad bean	Green manure	Cabbage	Pepper	Onion	Corn	Lettuce

MANAGING DISEASES AND PESTS WITH CROP ROTATION

Important pests to manage with a rotation are nematodes, tiny worms living in water (either in rivers, seas, soil or animals). There are thousands of soil borne nematodes, which are fortunately not all harmful. Whether nematodes become a problem depends on:

- Host range: Nematodes need specific host plants to survive and multiply. The range of host plants vary from very wide to narrow
- Mobility: Nematodes can be introduced and spread through the soil, water bodies, machinery, human or animals entering the field
- Persistence: Different species can be very sensitive to very persistent to survive
- Damage: Nematodes harm crops by feeding on them but also by spreading diseases

Managing diseases and pests successfully requires information on:

- How long a pathogen survives in the soil
- How the pathogen can survive: on which crops and how they survive between susceptible crops
- How it spreads or can be introduced
- Which other plant species can be affected by the disease or pest

If you recognize the damage (figure 2) of pests and diseases you have a better starting position to:

- Take samples to check for nematodes or diseases
- Cure the spot in the parcel where the damage is observed. For the current season it is mostly too late to solve the issue, but for the next season this is important information.

Figure 2. Damage to crops by pests and diseases: a) Fusarium in onion (middle onion plant), b) Verticillium in strawberry, c) Rhizoctonia solani solani in lettuce, d) Sclerotium cepivorum in onion.

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MANAGEMENT PRACTICES WITHIN THE ROTATION

You can utilize your crop rotation also for other reasons, e.g. to enhance soil fertility. By choosing certain crops, especially green manures and cover crops, you can focus on the following to enhance soil fertility:

- Use of perennials
- Cover crops and green manure
- Deep-rooting crops that bring back nutrients from deeper soil layers
- Permanent soil cover to prevent leaching and erosion
- Legumes to fix nitrogen
- Cash crops with additional benefits (e.g. wheat)

Furthermore, a rotation design can include weed management. For example soil cover between the main crops can prevent weeds to germinate. Also the weed species should be considered in the rotation since they can be host plants for nematodes.

A GOOD ROTATION: A COMBINATION OF PRACTICES, INSIGHT AND FLEXIBILITY

Planning a crop rotation can be very simple but planning a good one in which high economic profit is reached along with maintaining a healthy soil is a challenge. Integration with best practices, knowledge on the site-specific situation and smart use of tools like the Best4soil databases however form a good basis for a healthy crop rotation, ensuring productive soils on the long run.

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