OK-NET Arable Project

Challenges of Organic Arable Farming

2nd module: Fertilization strategies to enhance nutrient availability in organic arable crops





Module description and objectives

- Inadequate nutrients supply is often a factor limiting yields in organic farming. In addition to a short introduction of the topic, the course will offer innovative practices and tools allowing for a more efficient use of natural resources and processes in order to improve farm nutrient recycling and to optimize the use of nutrients into the soil.

- The objective of the module is to present the main problems related to the nutrient management in organic arable farming. Trainees will get information about tools and practices that can help them develop a sound nutrient management plan and enable them to participate in the discussion on this important topic. Some of the tools are site specific and this should be taken into consideration while evaluating them.

Module outline

1 - Challenges in nutrient management	
2 - Strategies to improve nutrient management	2.1 Legumes 2.2 Cover crops, green manure and intercropping 2.3 Livestock manure 2.4 Compost 2.5 Commercial mineral and organic fertilizers
3 - Calculation tools	3.1 Nutrient budget 3.2 Rotation planning
4 - Future prospects for nutrient sources	
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1. Challenges in nutrient management

The most important bottleneck for plant productivity in organic arable farming is **nitrogen**.

Mixed farms with sufficient livestock can best cope with nitrogen and result in high yields.

For **stockless farms**, mix- and intercropping with legumes is important.

Phosphorus deficiencies are a problem of stockless arable crop farms, especially longstanding ones. Worldwide, the commercially available phosphate resources, used to produce phosphorus fertilizer, are decreasing.

Improving the bioavailability of poorly soluble mineral sources of P (e.g. rock phosphate) through **fermentation or composting** with organic materials is becoming subject of research interest.

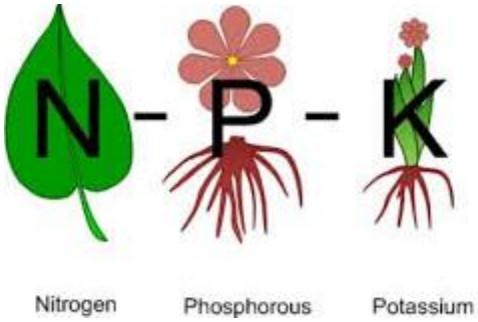
1. Challenges in nutrient management

Organic growing depends **first and foremost** on the mechanisms in the soils that convert nutrients from non-plant available to plant-available forms in the root zones.

Soil fertility → Plant nutrition

The **second** important mechanism is the recycling of organic material and nutrient elements, mostly on-farm, e.g.:

- Livestock manure
- Green manure
- Compost
- Field residues



Crop rotation covers all aspects above thereby affecting both, soil nutrient availability and plant nutrient uptake.

2. Strategies to improve nutrient management

Careful matching of secondary crops with the primary crop and growing conditions (e.g. root systems not competing but supplemental, combinations of nitrogen-fixing with non-fixing crops) is needed, based on plant appearance, timing of growth phases and complementarity of resource and nutrient use.

When developing a fertilization plan, several aspects should be taken into account. The example of nitrogen supply for winter oilseed rape shows differences in fertilization strategies depending on the following parameters:

- Farm with or without livestock
- Previous crop
- Timing of fertilizer application

Farmers can also create their own trial plots to test different fertilization strategies and to choose the best option for cultivation.

2.1. Legumes

Leguminous crops are an important source of nitrogen in organic crop production, in both mixed and stockless farms.

On **mixed farms**, the inclusion of leguminous crops in the rotation serves for:

- Fixing aerial nitrogen
- Improving soil fertility and soil structure
- Delivering feedstuff for ruminants

On **stockless farms**, legumes are mainly important for nitrogen fixation, soil organic matter improvement and soil fertility and are therefore called green manure.

2.1. Legumes

Stockless systems commonly use grain legumes as they have a cash value and the usage for feedstuff is economically less important in stockless systems.

Realistic **N-fixation** rates are between 17 and 200 kg N ha^{-1} $year^{-1}$ for grain legumes and between 63 and 236 kg N ha^{-1} $year^{-1}$ for temperate forage legumes.

Grain legumes have considerable higher fixation rates than forage legumes on temporary or permanent grassland but grain legumes consume most N for their own growth.

Forage legumes in grassland stands are stimulated by the N consumption of the monocotyledons (grass) and have higher fixation rates than in pure stands.

2.2. Cover crops, green manure and intercropping

A wide range of plant species belonging to different botanical families are used as cover crops and green manures. Species should be selected according to farmers' objectives (e.g. nitrogen fixation, organic matter increase, biofumigation, etc.).

Green manures can serve as powerful tool to balance nutrient supply for farms without livestock. This is particularly important when cultivating nutrient demanding plants (e.g. maize).

The cultivation of winter field peas and the incorporation in spring as green manure before maize can provide 100 kg of nitrogen to succeeding crops. Green peas are also used for intercropping. Barley as companion crop provides support for peas with significant increase in pea yield.

2.2. Cover crops, green manure and intercropping

Tailored use of cover crops as part of rotation can enable farmers to benefit the most of them. When choosing species for cover crops mixture we need to have information about them. Some examples:

- ✓ *Lolium perenne* is good for building soil structure, to enhance water infiltration and water-holding capacity.
- ✓ *Trifolium pretense* creates loamy topsoil, adds a moderate amount of N and breaks up heavy soil.
- ✓ *Medicago sativa* can be good even for arid areas as soil-saving and soil-building species, counting on its ability in N fixation and self-reseeding.
- ✓ *Vicia villosa* is recognized as an excellent green manure for dry conditions.

Based on extensive experiences with cover crops in Denmark, some general conclusions have been drawn for their management in arable rotations.

2.2. Cover crops, green manure and intercropping

"Green manuring" involves the soil incorporation of any field or forage crop while being green or soon after flowering, for the purpose of soil improvement. The difference between cover crops and green manures is that cover crop is any crop grown to provide soil cover, regardless of whether it is later incorporated.

The practical guide "Sort Out Your Soil", largely used in the UK, gives a wide overview of green manures with all details about the management and the benefits of their presence in crop rotation.

Even though most of organic farmers are familiar with benefits derived from green manure, still in some conditions their incorporation turns out to be a challenge and depends on the cultivation technique of the succeeding crop and the machine used. Here you will find some examples.

2.2. Cover crops, green manure and intercropping

Cover crops and green manures can be annual, biennial, or perennial herbaceous plants grown in a pure or mixed stand during all or part of the year.

Cover crop management affects the N content of legume cover crops and the contribution of N to the following cash crop. Early establishment of legume cover crops results in greater biomass production and N production.

The C:N ratio of **grass-legume mixtures** is usually intermediate to that of pure stands and this is seen as advantage of mixtures. Beside soil fertility building, cover crops provide ground cover (less erosion), help suppress weeds and reduce insect pests and diseases.

Leguminous leys are usually associated with N fixation but when species composition and management are well performed they can deliver additional benefits.

2.3. Livestock manure

The ***prototype of an organic farm is a mixed farm*** where livestock manure secures the productivity of the arable crops.

Nutrients concentration and quality of manure depends on its origin, composition (e.g. with or without straw), period and way of storage, season and moment of application to the soil.

An efficient use of nutrient derived from livestock manure requires the knowledge of crop-specific nitrogen demand. Considering nitrogen delivery from livestock manure, the supply varies from season of application and demand, according to the crop. Here, it is important to note that manure application affects actual and succeeding crops.

2.3. Livestock manure

At low stocking densities (<< 1 livestock unit per ha) the yield gap is much higher than at high stocking densities (>> 1 livestock unit per ha). The level of yields of organic arable crops receiving livestock manure is often between 80 and 90 percent of conventional crops.

As the farms have become more specialized in general, the regional cycles of livestock manure (**between livestock and crop producers**) are important to be organized.

Specialized stockless farms might run into a P deficit and this can threaten yields. Strategies to prevent this include

- Composts,
- Regionally available manures, and
- Commercial fertilizers based on rock phosphate.

2.4. Compost

The knowledge on the preparation and application of composts is very heterogeneous among European farmers and generally low. Excellent and easy-to-use information material in national languages is urgently needed.

Bio-waste (e.g. food and kitchen waste; waste from food processing plants) accounts for 88 million tons of municipal waste each year in the EU - **currently, only 23 % is effectively recycled.**

Composts play a crucial role in securing the productivity of crops in horticultural and in arable systems of organic farms in that they maintain and enhance the fertility and physical stability of soils.

2.4. Compost

Organic waste composts can be returned to soils as fertilizers or soil improvers.

Their sustainable use in agriculture reduces the need for mineral-based fertilizers, the production of which has negative environmental impacts and depends on imports of phosphate rock which is a limited resource.

Composts from separately collected household bio wastes, when applied in recommended application rates, deliver 5 to 10 kg plant available N per hectare in the first year and 25 to 35 kg in the following ones.

In order to compensate for P and K exports from the farm, much lower compost applications are needed.

2.5. Commercial mineral and organic fertilizers in organic arable farming

Under the regulation of organic farming, the supply of mineral N fertilizers is restricted but there are commercial organic fertilizers available to farmers.

However, the high costs limit their use considerably as the costs of these fertilizers calculated for N content are about 5 to 7 times higher than the most popular conventional mineral N-fertilizers and about 23 to 29 times higher for liquid fertilizers as compared to urea.

The sources of commercial N fertilizers are animal feathers, horns, hoofs, meat-bones, wool, hides and others. An exception is vinasse, a by-product of the sugar industry which is a low cost source of N and K in most European countries.

2.5. Commercial mineral and organic fertilizers in organic arable farming

Purchased mineral and organic fertilizers should be seen as an addition to the nutrient elements acquired in the crop rotations and to the efficient use of on-farm organic materials (crops residues, manures, etc.).

For other macro elements like P and K, the most important sources are rock phosphate and potassium sulphate.

The application of phosphate rock is approved in organic agriculture and as the availability of phosphate rock is insufficient in many soils (e.g. soils with high levels of Fe- and Al-Oxides; acidic soil) research is undertaken to overcome this challenge.

3. Calculation tools
3.1. Nutrients budget

Nutrient budget is defined as the outcome of a simple nutrient accounting process, which details all the nutrient inputs from soil amendments, fertilizers, green manures etc. and outputs in exported products and crop residues to a given, defined system over a fixed period of time.

In organic forage systems, field level N-budgeting is recommended on a regular basis to ensure that legume-grass mixtures lead to a net gain of N that can be used by subsequent crops.

Many calculation tools are available and created to be user friendly. Nitrogen budget calculator does not require any priori software skills and enables them to quickly assess N fluxes in legume-grass mixtures.

3.1. Nutrients budget

Different crop and forage species have varying abilities to extract macro and micro nutrients from soil (Table 1) and this should be taken into consideration when making nutrients budget.

Table 1: Average micronutrient concentrations in flowers, leaves and stems of red clover, perennial ryegrass and timothy at the flowering stage (n=4) (Lindström et al. 2013).

Species	Component	Co	Cu	Fe	Mn	Mo	Ni	Zn
					mg kg^{-1} DM			
Red clover	Flower	0 08^{a}	4 6^{ab}	51^{c}	37^{b}	4 6^{a}	3 6^{a}	14 9^{b}
	Leaf	0 05^{b}	5 6^{a}	83^{ab}	56^{a}	1 5^{cd}	1 2^{b}	7 5^{cd}
	Stem	0 04^{b}	2 9^{c}	18^{e}	11^{d}	2 1^{c}	1 4^{b}	4 4^{e}
Ryegrass	Flower	0 02^{cd}	4 0^{abc}	25^{d}	18^{c}	2 2^{bc}	3 3^{a}	19 7^{ab}
	Leaf	0 04^{b}	3 6^{bc}	95^{a}	16^{cd}	3 6^{ab}	0 8^{b}	9 5^{c}
	Stem	0 01^{cde}	2 0de	13^{f}	15^{cd}	1 1^{d}	0 9^{b}	6 2^{cde}
	Leaf	0 01de	2 8^{cd}	43^{c}	12^{cd}	1 5^{cd}	0 4^{c}	8 0^{cd}
	Stem	0 01^{e}	1 3^{e}	9^{g}	12^{cd}	0 5^{e}	0 5^{c}	5 3de
Component effect		***	***	***	***	***	***	***
Species effect		***	***	***	***	***	***	***
Species x Component		***	**	***	***	***	***	*

*P < 0 05; **P < 0 01; ***P < 0 001. Values in the same column for each micronutrient followed by the same lowercase letter are not different at P < 0 05.

3.2. Rotation planning

Estimating N delivery from legumes to the following crops is of crucial importance. With the tool "**ROTOR**", a farmer or extension agent can compare different crop rotations regarding N-fluxes and impacts on the long-term humus balance of the soil. This enables farmers to plan in a long-term at field level to enhance nutrient supply and regulate weeds and diseases.

When planning rotation, specific local conditions (e.g. type of soil, climate), selection of species according to several agronomic traits (e.g. N fixation rate, pH tolerance) and adaptation to environmental conditions should be considered. "**OSCAR**" toolbox, through a series of questions, helps farmers generate a set of plant profiles that fall within conditions indicated by farmers.

4. Future prospects for nutrient sources in organic arable farming

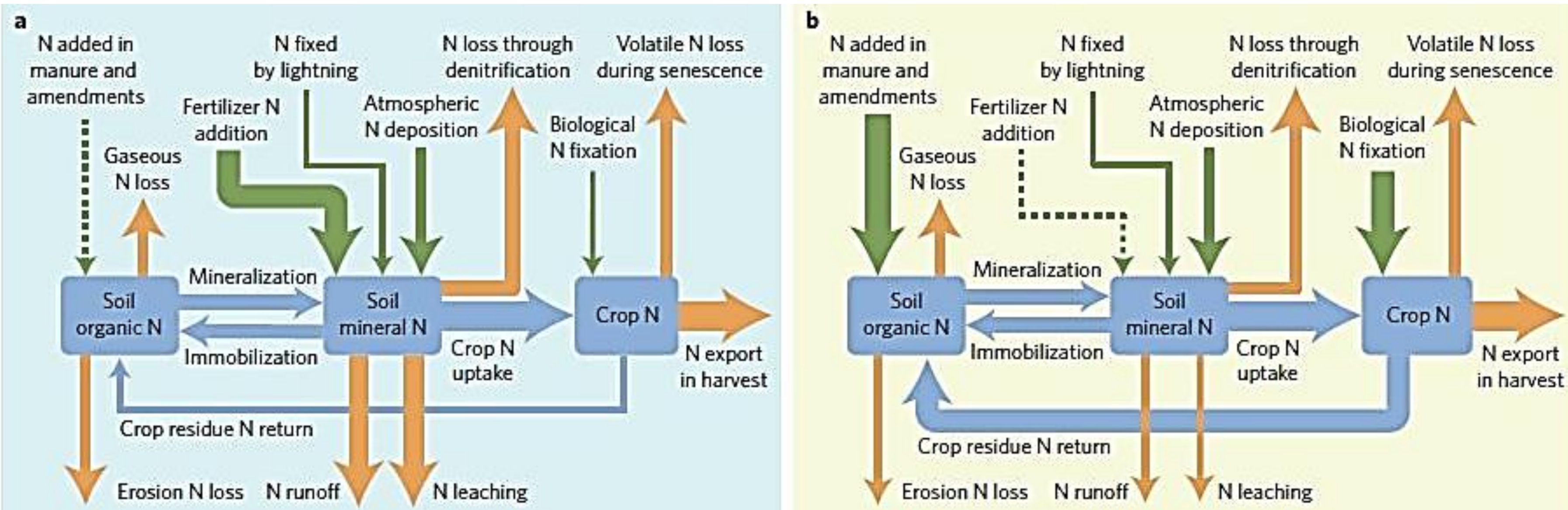
The future strategies of increasing productivity on organic farms will be found in the recycling of **sewage sludge**, although not accepted by the organic standards for the time being because of pollutants.

This is a hot spot of research and therefore technological solutions are already available and will be further improved.

In the far future, communal sewage systems will be based on an early separation of pollutants, liquid and solid human excretions which will make macro and micro nutrients available for agriculture.

5. Conclusive illustration on nutrient management (example of N)

Figure 1: Hypothetical nitrogen stocks and flows of two contrasting cropping systems



a) Cropping systems relying mainly on mineral nitrogen inputs have relatively higher nitrogen losses to air and water than…

b) Cropping systems with emphasis on biological N fixation, manure and other organic matter amendments, cover crops and perennial crops, and low reliance on mineral N fertilizer, such as organic and integrated systems (Reganold and Wachter, 2016).

- Arrows represent nitrogen inputs (green), losses (orange) and transformations (blue).
- The width of the arrows is relative to the size of the nitrogen flux.

Additional tools

Here are some additional tools, in the context of this module, available in other languages than English:

- Composting leaflet – agroecological approach at your farm / Dutch
- Nutrient management in farms in conversion to organic / German
- Web platform about nitrogen supply from different sources / German, French
- Green manure and cover crops in organic agriculture: guide to the choice of the species / French

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Enjoy the module!