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PRACTICE ABSTRACT No. 6

Increasing Arbuscular mycorrhizal fungi (AMF) colonisation in wheat

Arbuscular mycorrhizal fungi (AMF) form a symbiotic association with the roots of most crop plants with the potential to contribute to sustainable agricultural production via the reduced use of mineral fertilisers and pesticides.

Benefits of AMF:

- enhanced nutrient acquisition of P, N and Zn
- increased tolerance to biotic and abiotic stresses
- enhanced soil structure through aggregation
- provide a marker for soil health and quality

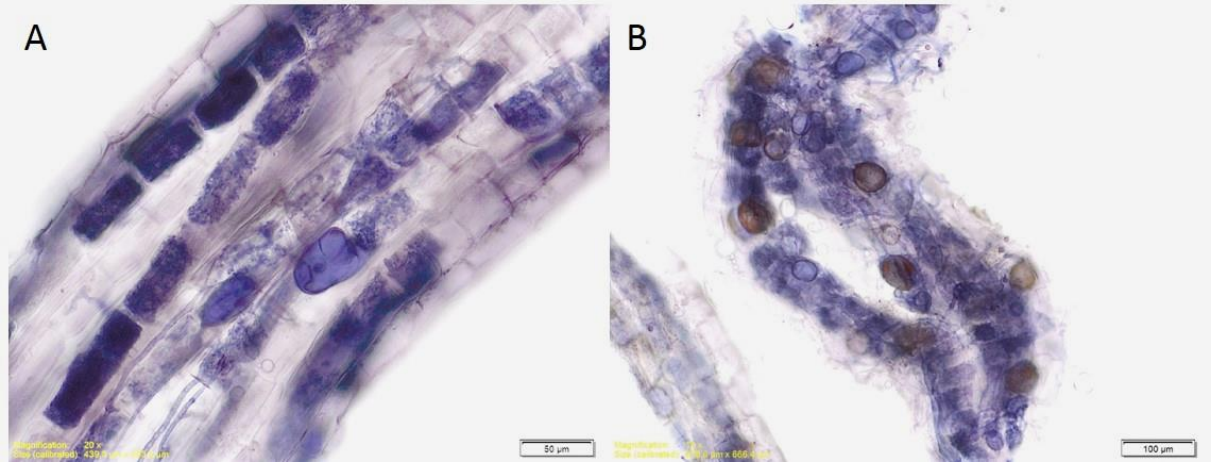

Fig. 1: Arbuscular mycorrhizal structures in wheat roots from field samples stained with ink and vinegar: cvs. 'Aurelius' (A) and 'Arminius' (B).

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SOLUTIONS:

- AMF have been shown to be more abundant in soils with reduced tillage
- AMF have been shown to be more abundant in organic than conventional soils where pesticides and mineral fertilisers are not permitted
- Numerous studies have shown genetic variation in wheat for AMF colonisation (Hetrick et al., 1996; Zhu et al., 2001)
- Wheat varieties with the potential for increased colonisation efficiency are being screened in the ECOBREED project
- Breeding for AMF colonisation offers clear long-term potential for sustainable agricultural production

PRACTICAL RECOMMENDATIONS:

- Promote the use of soil management strategies which support native AMF such as reduced tillage and reduced fertiliser input.
- Biostimulants containing AMF either applied as a seed dressing or directly to crops have the potential to increase colonisation in soils poor in native AMF.
- Promote the use of healthy functional soils through increased organic matter, soil health and soil microbial communities.
- Further research is required for the optimisation of AMF in wheat production to provide an economic return to farmers.

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ECOBREED CONSORTIUM

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PRACTICE ABSTRACT No. 7

Cover crops: the potential for reducing pest and disease in potato (*Solanum tuberosum*)

The role of cover crops:

Cover crops have the potential to enable us to move towards more sustainable farming practices by:

- Reducing soil erosion and losses of P to water
- Reduced leaching of N to the environment and thereby increase the supply of N to the following crop
- Improving soil organic matter content, soil structure, soil health, water infiltration and nutrient retention/supply
- Reducing pest and disease levels

PROBLEMS

Potato growers have a clear reliance on the use of extended rotations, soil fumigants, and granular nematicides to control pests and disease but due to the increasing cost, reduced efficiency as well as the withdrawal of an increased number of active ingredients in recent years the use of cover crops has increasing potential.

SOLUTIONS

Cover crops are usually planted as a mixture of species including brassica, legume, and cereal species, whereby the synergistic effects of variation in above and below ground growth of individual species can be matched to their function. A number of cover crop species have been identified to have roles in the reduction of pest and disease in potato:

- Biofumigation crops like Indian mustard (*Brassica juncea*) and oil radish (*Raphanus sativus*) and their role in the control of potato cyst nematode (PCN) (Ngala, 2015).

- Sticky nightshade (*Solanum sisymbriifolium*) and black nightshade (*Solanum nigrum*) in the control of PCN (Ellis & Cook, 2016).
- Oilseed rape (*Brassica napus*) in the control of early blight (*Alternaria solani*) (Runno-Paurson et al., 2019).
- Mustard *(Brassica juncea*), Sudangrass (*Sorghum bicolor*), rye (*Secale cereale*), oilseed rape (*Brassica napus*) in the control of common scab and black scurf (Larkin et al., 2010; Larkin et al., 2014).
- Vetch (*Vicia sativa*) and brassica species in the control of *Rhizoctonia solani*.

Current research:

ECOBREED partners in the UK and Slovenia are currently evaluating the impact of a range of cover crop species, i.e. brown mustard (*Brassica juncea*), oil radish (*Raphanus sativus*), lucerne (*Medicago sativa*), black oat (*Avena strigosa*), vetch (*Vicia sativa*), and a mixture of all five species on the performance and pest and disease levels of 4 potato varieties.

Fig. 1: ECOBREED cover crop trials in Slovenia (green cover crops in autumn 2020 and over-wintering cover crops in spring 2022).

The knowledge arising from ECOBREED will assist farmers in selecting cover crop species with the potential to control pests and diseases in potato.

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PRACTICE ABSTRACT No. 8

Wireworm biocontrol strategies

Wireworms (Coleoptera: Elateridae) are the soil-dwelling larvae of click beetles and are one of the most important pests of potatoes. Within the ECOBREED project field experiments on wireworm biocontrol strategies were established at Kmetijski inštitut Slovenije in 2020 and 2021 evaluating several preparations based on entomopathogenic fungi of the genus *Metarhizium*. The knowledge arising from ECOBREED will assist farmers in the control of wireworms in organic potato production.

PROBLEMS:

- Wireworms damage potatoes by tunnelling into the tubers while feeding, reducing their market value rather than yield.
- Even a small population of wireworms can cause significant economic losses.
- Wireworms have a very long development cycle (3-6 years), which makes them difficult to control in both organic and conventional production systems.

Fig. 1. Potato tubers damaged by wireworms

SOLUTIONS:

- Biological control with entomopathogenic fungi (EPF) of the genus *Metarhizium* whereby these beneficial cosmopolitan soil fungi successfully kill root feeding herbivores such as wireworms.

- By increasing the concentration of entomopathogenic fungi in the soil, we can increase the frequency of fungal infections of wireworms.
- Attracap® is a granular bioinsecticide for wireworm control in potato and asparagus crops that works via the "attract and kill" principle. The granules contain starch, yeast and EPF M. brunneum. When the capsules come into contact with soil moisture, they start to release CO_2. Wireworms are attracted to the CO_2 sources and thus come into contact with the entomopathogenic fungi in the capsules and die within a few days.

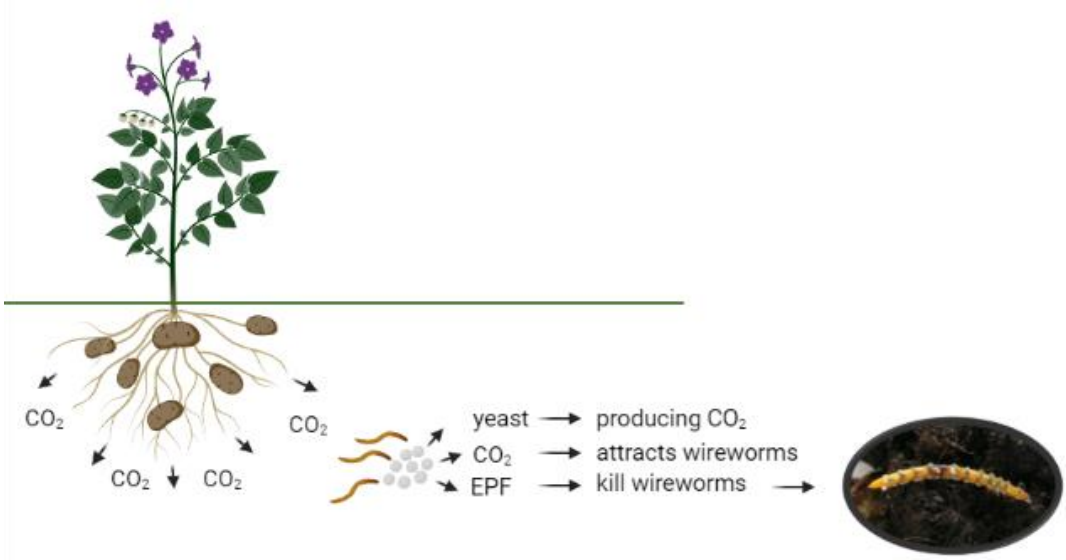

Fig. 2. Baker's yeast, starch, and entomopathogenic fungi are encapsulated in Attracap® granules. Yeast produces CO_2 that attracts the wireworms away from the plant.Wireworms come into contact with the entomopathogenic fungi in the capsule, become infected and die (photo:BioRender.com).

PRACTICAL RECOMMENDATIONS:

- The use of entomopathogenic fungi is a suitable biological control method for certified organic potato production.
- For long-term effects, it is recommended that entomopathogenic fungi are used over several consecutive seasons.
- Caution is advised as entomopathogenic fungi are sensitive to UV light, so their efficacy is reduced if they are exposed to sunlight for too long.
- It is recommended that entomopathogenic fungi are applied to the potato field at the time of planting.

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PRACTICE ABSTRACT No. 9

Wheat breeding for organic farming

PROBLEMS:

- The area under organic cultivation in Europe has been growing steadily.
- The choice of wheat varieties adapted to organic farming is more limited than for conventional farming.
- The demands made on an organic wheat variety differ in part from those of conventional varieties. There are a number of characteristics, mostly complex, that have a higher priority in organic farming.
- Rising input prices, the increasing impact of climate change and the need for sustainability are creating a large opportunity for breeding wheat varieties adapted to organic farming.

Fig. 1: High weed presure from Galium aparine in winter wheat with low weed suppression. Ecobreed trial 2021 Feldkirchen, Germany.

SOLUTIONS:

- Screening of parental and breeding lines for characteristics which are important for organic farming, like weed suppression, early and rapid seedling development, high soil coverage, disease resistance and high N use efficiency.
- Crossing of varieties with known traits which are important for organic farming.

PRACTICAL RECOMMENDATIONS:

- Direct selection of quantitative traits (e.g., yield, quality) influenced by Genotype x Environment interactions should be performed under organic conditions. For example, weed suppression, soil coverage, yield, end-use quality, N use efficiency.
- The use of marker assisted selection (MAS) can increase success in finding resistance genes to leaf, ear, and soil-borne diseases. Overall, promising applications of MAS in organic breeding will be to identify QTLs associated with complex traits, e.g., weed competition under different environmental conditions. Fortunately, methods are emerging that can improve the efficiency of selection for complex characters (Wolfe *et al.* 2008).

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PRACTICE ABSTRACT No. 10

Seed inoculation (soybean)

PROBLEMS:

- Unfavourable conditions for rhizobia (symbiotic nitrogen-fixing bacteria) that result in decreased nodulation include (i) low soil pH, (ii) high or low temperature, (iii) insufficient soil moisture, (iv) high soil nitrogen content etc.
- Rhizobia are living organisms that may lose their viability and effectiveness to colonise plant roots under unfavourable conditions.
- Soils on which soybean has not been grown previously usually do not contain the specific strains of rhizobia, hence, it is necessary to provide them through seed inoculation.

SOLUTIONS:

- Soybean has a special role in crop rotations through its ability to fix and utilise atmospheric nitrogen from the air to support growth.
- Bacteria that form nodules in symbiosis with soybean are *Bradyrhizobium japonicum*, *Bradyrhizobium elkani*, *Sinorhizobium fredii*, etc.

Fig. 1. Inoculated soybean seed. Photo credit: Institute of Field and Vegetable Crops, Department of Soybean

- Nitrogen fixation takes place in nodules which are globular structures located on the roots. The process of nodule formation starts during early root formation and development, with the nodules becoming fully active during the latter part of the plant's growth and development.

- Application of inoculants and biostimulants enables successful; nodulation of plants, better nitrogen fixation from the atmosphere, stimulation of plant growth, increase in biomass and nitrogen content in the plant, as well as yield and grain quality.

PRACTICAL RECOMMENDATIONS:

- Inoculation of soybean is required prior to sowing.
- It is important to use inoculated seeds on the day they are treated as because viability is reduced by exposure to light.
- It is important to handle the product in the shade since the bacteria might lose vitality if exposed to direct sunlight.

Fig. 2. IFVC Inoculant for soybean NS-Nitragin. Photo credit: Institute of Field and Vegetable Crops Novi Sad

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PRACTICE ABSTRACT No. 11

Sheep grazing of autumn-sown cereals

PROBLEMS:

- Early drilled cereal crops can often develop high disease inoculum levels over winter which can pose a challenge for organic production systems.
- Early drilling can be used to increase the compretitiveness against weeds depending on location and weed species.

SOLUTIONS:

- Grazing of autumn-sown cereals during the winter months can bolster the winter feed supply for farmers with minimal effects on grain yield. Grazing with sheep over the winter months, has shown that wheat yield can be increased, by around 0.5t/ha in places (Virgoona *et al*., 2006).

Fig. 1. Grazing of winter wheat with sheep in the autumn at Thornton Farm in the UK

- By eating diseased leaves, this can reduce the disease inoculum levels and the crop can grow away cleanly in the spring. The reduction of biomass also encourages the plant to tiller more and increases root growth (Virgoona *et al.*, 2006). In addition to eating off some of the weed burden, the sheep manure can add to the soil nutrient supply and soil biology. Depending on location tillering can be very high which increases crop susceptibility to lodging.

PRACTICAL RECOMMENDATIONS:

- Grazing is best suited to fast developing varieties that have been drilled early to help control weeds in organic production systems. However, the situation is very different depending on location so farmers should trial a small area initially to see whether grazing works in their environment.
- It is key to remove the sheep before the plants reach the start of stem extension i.e. GS30 (Zadoks *et al*., 1974) to limit potential damage to the developing ear. A large number of sheep for a short period of time is preferred with careful monitoring essential to avoid over-grazing and poaching. Sheep can also help consolidate the soil surface which can help reduce the risk of crop-heave with winter barley being more susceptible than wheat.

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