Soil as a Resource
National Research Programme NRP 68

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Executive Stakeholder Summary

Project number	406840-143065
Project title	Applications of entomopathogenic nematodes for a sustainable control of soil insect pests
Project leader	Ted Turlings, University of Neuchâtel
Further project leaders	Fabio Mascher, Agroscope

Contribution(s) to thematic synthesis:

☒ Soils and Food Production	☐ Soils and Environment	☐ Spatial Development	☐ Soil Data, Methods and Tools	☐ Soil Governance

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Background

Nematodes are microscopic worms that occur in large numbers in terrestrial and aquatic ecosystems. Many nematode species are free living and feed mainly on bacteria and have no specific association with plants. Other species can be very detrimental to plants because they parasitize root systems and feed on plant tissues. However, there are also nematodes that can be of great benefit to plants because they parasitize and kill insects that are pests of plants. These so-called **entomopathogenic nematodes (EPN) have great potential to protect crop plants** from root-feeding insect and their application is a great alternative to the use of insecticides. Indeed, EPN are already commercially available and are applied to control pests in gardens and high value vegetables. For now, large-scale application in low value crops is considered not cost effective. This could be changed with good knowledge of EPN ecology, in combination with the development of more effective application methods.
The general knowledge of EPN in Swiss soils and their efficacy as pest control agents is poorly understood. Moreover, it is unknown if EPN are compatible with other beneficial soil organism. A good understanding of this and other factors that affect the presence and activity of EPN in Swiss agricultural soils could be of great value to enhance their efficacy as biological control agents. This is of particular importance at a time of climate change when new soil insect pests are invading and pose a threat to several crops in Switzerland.

Aim

In the context of our NRP 68 project we studied the occurrence of EPN in Swiss agricultural and natural soils and the factors that determine their occurrence and effectiveness as pest control agents. In collaboration with other NPRP 68 projects, as part of the Soil Biology Cluster, we also studied the compatibility of EPN with other beneficial soil organisms. The specific aims of the first phase project were:

1. To make an inventory of the EPN species composition and densities in different agricultural soils throughout Switzerland.
2. To determine the persistence and pest control efficacy of commercially available EPN in different Swiss soil types.
3. To evaluate the effect of agricultural management practices (mono-culture, mixed cropping, crop rotation, cover crops, and tillage) on the persistence and control efficacy of EPN.
4. To investigate and optimize the positive impact of EPN in combination with beneficial bacteria and fungi on crop performance in Switzerland.

Results

We developed improved molecular methods to measure EPN presence in soil samples. New molecular primer sets multiple EPN species were developed and after some fine-tuning the new methodology allowed for very precise identification and quantification of all of the different species obtained from soil samples. The new molecular techniques, as well as a conventional baiting technique were employed to measure EPN in annual cropping systems. Both methods revealed that EPN numbers were very low, also in plots at two long running Swiss field trials. In these trials different cropping strategies have been compared for over 30 years. No significant effects of cultivation practices were found, and again the numbers of EPN recovered from the different plots were very low.

We also investigated possible reasons why EPN numbers are so low in cultivated soils and we tested which agricultural practices might help to improve their persistence. None of the tested agricultural methods had any positive effect on EPN presence or persistence. The use of cover crops, which protect the soils and its fauna between planting seasons, had a minor positive impact on EPN persistence.

Further experiments implied that one of the main reasons for the low EPN numbers is the intense competition with associated organisms and strong pressures by natural enemies. An additional reason may be insufficient numbers of host insects for the EPN to reproduce, preventing them from building up a persistent population.

A very positive result was that EPN were found to be nicely compatible with application of plant beneficial bacteria and mycorrhizal fungi. In some cases these organisms had synergistic positive effects on plant performance. One field trial indicated a 30 % increase in maize yield after EPN and/or bacteria application. An additional trial will be conducted to confirm this effect.

Importance for research

The work generated new knowledge on EPN ecology and several surprising revelations about the factors that affect their presence. It was assumed that conventional farming with intense tillage would negatively affect EPN populations, also because organic matter is reduced in such modern farming practices. This was found not to be the case and organic farming had just as low numbers. Instead, we found that competition and natural enemies were key factors in impacting EPN populations. We also revealed a novel competition with free-living nematodes inside insect cadavers. These findings have resulted in several key publications that will have important implication for future ecological studies on EPN.

Practical signifiance

The main outcome of our project is that EPN presence in Swiss agricultural soils is insufficient to combat current and emerging soil pest problems. This deficiency cannot be overcome by altering agricultural practices. Only cover crops seem to slightly improve EPN persistence. This implies that for an effective control important root-feeding pests in problem regions will have to be supplemented with specific EPN. Current application methods are not cost effective and new methods need to be developed. Also because we found that EPN are nicely compatible with application of other beneficial organisms, it is crucial that we further explore the development of such methods.

Recommendations

One of the main conclusions from our research is that EPN levels are extremely low in Swiss agricultural soils, independent of agricultural practices. This can represent an important risk if new invasive soils pests arrive in Switzerland. One such pest is already causing problems in Ticino. It concerns the western corn rootworm (WCR) (*Diabrotica virgifera virgifera*), one the most devastating root pests of maize. In the United States it costs US farmers an estimated two billion US$ each year. In the early nineties, this pest was introduced into Europe, where it has rapidly spread and is causing significant damages to maize roots, now also in Switzerland. Pests like WCR are exceedingly difficult to control. Application of pesticides against soil insects is complicated and in cases where they may provide good protection they

can have disastrous effects on non-target insects. The same is true for native soil pests. In Switzerland some of the most persistent pests are the carrot and cabbage root fly. Since 2013 all larvicidal insecticides against root flies, such as organophosphates, have been banned in Switzerland. Only a few non-selective pyrethroids, which are sprayed on the leaves and target the adult stage, are allowed. They are only considered an interim solution until new control agents become available. The use of EPN would be an ideal, environmentally safe alternative.

The results from the project also show that EPN can be applied in combination with other beneficial organisms, such as bacteria that can promote plant growth and vigor and mycorrhizal that can provide plants with nutrients. Our **main recommendation** therefore is the application of EPN in crop fields with soil insect problems. The greatest obstacles to an effective application of EPN are the high costs of current application methods and a limited shelf-life. It is essential that these major obstacles be overcome. For this reason we currently use the knowledge obtained during the NRP 68 project to develop a novel application method that is based on encapsulation of EPN in alginate beads. The beads will be supplemented with useful plant-derived substances. Certain substances will put the EPN in a state of dormancy, which keeps them in good shape while they are embedded in the beads, and other substances will be used to attract and encourage the pests to feed on the beads. Both of these effects have already been demonstrated to work under laboratory conditions for certain target pests. The optimal bead could be applied in a cost effective manner to deliver the EPN to soils with pest problems. They can be planted with the seeds and the EPN would remain in the beads in good condition for long periods of time, and therefore be effective against the pests long after the seeds have been planted.

To summarize, the project greatly advanced our basic knowledge on the factors that limit the presence EPN in Swiss agricultural soils. EPN are nicely compatible with other beneficial organisms, such as plant beneficial bacteria and mycorrhizal fungi. We recommend that this knowledge now be extended to help find ways to improve EPN presence and efficacy. The above-described strategy is ideally suited to combat the important pest of maize roots that recently invaded Ticino. In addition, it will be an ecologically sound alternative to harmful pesticides that have thus far been used to fight root flies, which continue to be of major concern to Swiss carrot and cabbage growers. We see the farmers to be the main stakeholders in the success of our project. In addition, Swiss agro-companies, big (Syngenta) and medium-sized (Andermatt Biocontrol AG), stand to gain from novel pest control strategies and technologies.