Impact of soil management practices on soil fertility and disease suppressiveness

Lucius Tamm, Christian Bruns, Carlo Leifert, Jacques G. Fuchs, Barbara Thürig, Nicole Specht, and Andreas Fliessbach

Abstract **- Soil management practices are targeted to provide adequate crop nutrition and to ensure durable soil fertility and to avoid negative environmental impacts. Soil management also aims to reduce pest and disease pressure on crops. Organic farming is believed to increase soil suppressiveness towards soil-borne diseases as well aerial diseases. In this paper we will discuss the potential of soil management as a tool to improve disease suppressiveness in practice.**

INTRODUCTION

One of the principles of organic farming is to attain ecological balance through the design of farming systems, establishment of habitats and maintenance of diversity. Inputs should be reduced in order to maintain and improve environmental quality and conserve resources. However, there are still some 'technological' bottlenecks in organic production systems which potentially affect quality and safety in organic foods, the environment, as well as costs of production. These bottlenecks include insufficient and/or untimely availability of nutrients as well as occurrence of pests and diseases. Approaches to overcome such bottlenecks include improvement of soil properties, which may be relevant for plant nutrition and disease suppression towards soil-borne and foliar diseases.

Pioneers of organic farming have described the importance of the close relationship between soil and plant, which is summarized in the statement that 'a healthy soil is the prerequisite to grow healthy plants'. In this paper, we are discussing research, which is investigating the complex interactions between soil, crop, and diseases.

SOIL MANAGEMENT AND SOIL FERTILITY

Soil management (eg soil tillage, crop rotation, organic amendments) has an obvious impact on soil fertility as soil properties such as erosion stability, nutrient availability, water holding capacity etc are strongly affected. Microorganisms play a key role in soil quality and fertility as they are involved in nutrient cycling and transformation processes, as well as soil aggregate stability. Soil microbial communities are affected by short-term as well as by long-term management practices. In general, soil microbial biomass, activity, and diversity tends to be higher in organic than in conventional farming systems (Mäder et al., 2002).

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SOIL MANAGEMENT AND SOIL BORNE DISEASES

Soil properties do affect the occurrence of soil borne diseases. The extent of disease is the result of the abundance of disease propagules and the competition between crop plant, causal agent and interaction with antagonists. Crop rotation is widely used to reduce the survival of pathogenic propagules. The presence of specific antagonists or the addition of organic amendments to soil may suppress various soil-borne diseases such as *Rhizoctonia*, *Pythium*, *Fusarium*, *Gaeumannomyces* or *Phytophthora*. Several mechanisms of disease suppression have been identified, namely various specific antagonistic activities, competition for nutrients in the rhizosphere as well as induction of resistance in the host plant. In some cases, specific antagonistic species (eg. *Pseudomonas fluorescens*) or Plant Growth Promoting Rhizobacteria (PGPR) have been identified and the underlying mechanisms of disease control have been described in detail (Haas & Defago, 2005). Disease suppressiveness has also been related to high soil microbial activity.

SOIL MANAGEMENT AND FOLIAR DISEASES

There is evidence that soil properties are affecting the occurrence of diseases on foliar parts of the plant. For instance, wheat grown in organic fields showed less stripe rust and snow mould than comparable plants on conventional fields (van Bruggen, 1995). Several studies have shown that soil bacteria and fungi from the same genera protect plants from both, soilborne and airborne diseases. The active principle behind these effects is based on induced resistance of the plants. Induced or acquired resistance may be triggered by biotic or abiotic agents (van Loon *et al.*, 1998) and is effective against a broad spectrum of pathogens such as viruses, fungi and bacteria and has been reported to be also effective under field conditions. An inducing agent activates latent plant defense mechanisms without having a direct impact on the pathogen.

Several plant growth promoting bacteria such as fluorescent *Pseudomonas* spp. and non-pathogenic fungi from the genus *Fusarium* spp. are reported to induce systemic resistance (ISR) in various plant species (van Loon *et al.*, 1998).

Introduction of suppressiveness to foliar diseases has been attempted recently in the US in order to improve disease control in vegetable production systems. In this study, soil amendments had significant impact on *Pseudomonas* brown spot in snap beans. The authors found significant relationships between N-availability and disease expression, whereas the potential role of the soil microorganisms was not studied at all (Rothenberg et al, 2005).

SOIL FERTILITY MANAGEMENT TECHNIQUES AND DISEASE REDUCTION

The systematic use of soil fertility management techniques to reduce diseases is an intriguing concept in theory, but it is not widely used in practice (e.g. Stone et al, 2003), partly due to the lack of understanding of the underlying principles. Despite the claims made by some organic farmers, we still find no evidence that reduced foliar disease susceptibility is a typical feature of plants grown in organic farms.

In 2000, we started to study the impact of soil properties in fields on foliar diseases. The aim was to assess the suppressiveness level in organic farms. In this preliminary study, 15 potato fields in Switzerland were selected and soil samples were taken immediately before planting. As a test system for foliar resistance we selected the *Phytophthora infestans*/tomato bioassay. To test suppressiveness to soil-borne diseases, the *Pythium*-cucumber assay was used. In this empiric study we found positive correlations between disease suppressiveness and parameters which describe soil microbial biomass and activity (Cmic, basal respiration). We also found correlations between suppressiveness and macro-/micronutrients (Berner et al, 2003).

As a major outcome of this study we found that (i) differences in suppressiveness exist in practice and (ii) bioassays are able to quantify the level of suppressiveness. However, causal relationships between soil properties and supppressiveness were not identified and the relative importance of site-specific as opposed to cultivation-mediated parameters was unknown.

Within the framework of the QLIF project, the working groups of FiBL, Kassel University and Newcastle University started a research project in 2004 in order to elucidate the influence of soil properties on soil suppressiveness and to quantify the relative importance of site-specific *vs*. cultivation-mediated soil properties.

More specifically, the study's aims were to (i) develop and optimize bioassays, which show the direct effect of organic matter based fertility inputs on soil and air-borne diseases and to (ii) quantify the effect of selected soils on these parameters. So far, we focused on the following hypotheses: (i) Differences in suppressiveness are relevant (i.e. >20% disease reduction), (ii) suppressiveness depends on site-specific parameters, (iii) suppressiveness is influenced by agronomic practice, (iv) soil amendments influence suppressiveness in the short and long-term, (vi) suppressiveness is universal (i.e unspecific), (vii) suppressiveness is durable (viii) suppressiveness is linked to microbial activity, and (ix) may be enhanced by high organic matter input that leads to high soil microbial activity.

A total of 4 field sites have been selected in Switzerland, Germany and the UK to identify site-specific differences, the impact of long-term farming practice, and the impact of short-term organic soil amendments. At each site, soil samples were taken from selected treatments in the properly replicated field trials. All samples were submitted to in-depth soil analyses (chemical, physical, and microbiological) and studied for suppressive properties in 4 bioassay systems (*Rhizoctonia*/ basil, *Pythium*/ cucumber, *Phytophtora*/ tomato, and *Pseudoperonospora*/ *Arabidopsis thaliana*.

Preliminary data analysis indicates that differences in suppressiveness may be quantified and related to soil properties. Furthermore, site-specific factors, which cannot be influenced by agronomic practices, were found to have a greater impact than cultivation-specific effects within the same site. The ongoing research is focussing on verifying hypotheses that aim to identify the underlying correlation between suppressiveness and selected soil properties.

CONCLUSION

The investigation and understanding of the effect of the soil compartment on plant-pathogen relationships is a challenging task. One of the major difficulties is the inherent spatial and temporal dynamic of soil processes. For instance, there is always a delay between soil sampling and the establishment of analyses and bio-assays that is possibly influencing soil properties and that has to be coped with. Moreover, the massive disturbance of the soil in the sampling process may change soil conditions, in a way that they can not be compared to undisturbed field conditions. In addition, crop plants (as well as model plants used in bio-assays) release specific or unspecific root-exudates that may substantially influence soil microbial communities. In such a setting, isolated results are of limited value and generalizations of results are difficult. From an applied point of view, effects that are practically relevant need to be universal, robust, and durable. Therefore, we are looking for soil parameters and interactions that show consistent effects among a broad variety of host-pathogen-systems. For practical use, we also focus on soil parameters that can be manipulated by agronomic measures.

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