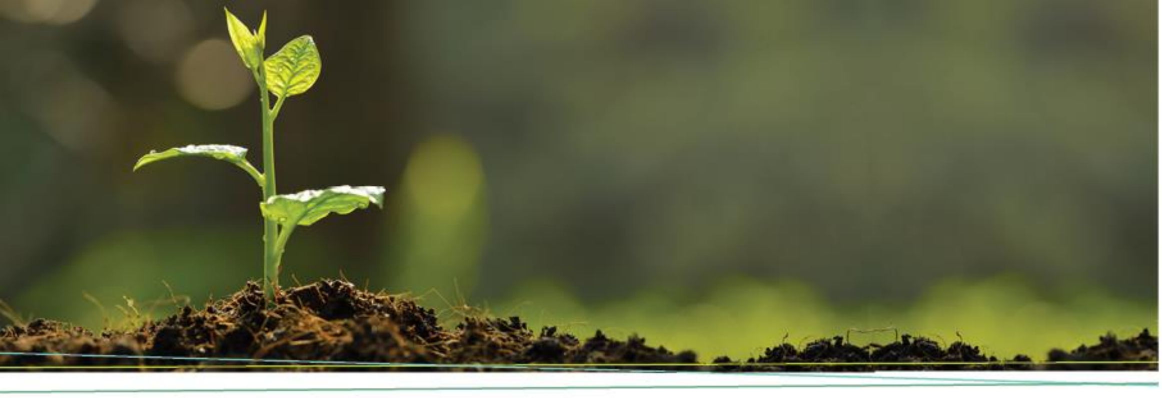

Focus Group SOIL-BORNE DISEASES

Mini-paper - *Organic Matter, Compost*

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Introduction:

Soil-borne diseases (SBD) are one of the main problems in many modern plant production systems. Compost (COM), especially as source of organic matter (OM) provides different soil functions and can be one of the strategies to reduce the impact of SBD in agriculture. Other sources of OM as green manure can provide such functions, too.

Compost and organic matter derived from compost:

Definition:
COM is a product, that results from microbial decomposition of OM under aerobic conditions. Depending on composting method, size, intensity of the operation and the input material, a large range of qualities can be produced. Most regulations in the EU only apply to the nutrient and heavy metal content, beside of some other chemical characteristics (pH level, electrical conductivity etc.). For the issue of SBD the most critical ingredient is the OM (including humic substances, humic and fulvic acids) and the microbial community and its activity.

Compost suppressiveness related to soil-borne diseases:

The suppressive capacity of COM against soil-borne pathogens has been demonstrated in several studies, and, consequently, the use of disease suppressive COM can reduce crop losses caused by SBD and benefit growers (Hoitink and Fahy, 1986; Hoitink and Boehm, 1999; Noble and Coventry, 2005; Hadar, 2011). COM showed to be the most suppressive material, with more than 50% of cases showing effective SBD control, compared to other amendments such as crop residues and peat (Bonanomi et al., 2007).
In field trials COM showed, in most experiments, to be suppressive when at least 15 t/ha were applied. Lower applications has also been reported to be sufficient for reducing some diseases. Suppressive effect of COM is generally proportional to the inclusion rate in soil. However, different results can be obtained by different COMs on the same pathosystem. Soil type and conditions, like texture, pH and moisture, can also influence suppressiveness to soil-borne pathogens (Bruehl, 1975).
In container experiments using soil or sand, COM derived from green wastes and/or dairy cow manure generally showed a disease suppressive effect on Pythium spp. and Rhizoctonia solani, but results from these container experiments could not always be repeated in the field (Noble and Coventry, 2005). COM suppressiveness also showed to be dependent on the type of wastes used for preparation.
Low rates of COM in growing media are more indicated to avoid negative growth effects and phytotoxicity caused by high pH and electrical conductivity, and other phytotoxic compounds present in COMs (Sullivan and Miller, 2001). However, it is generally necessary to include at least 20% v/v of COM in containers for having a suppressive effect, and lower rates were applied

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successfully for few specific cases, like Ralstonia solanacearum and Rhizoctonia solani (Voland and Epstein, 1994; Islam and Toyota, 2004). Cases of COM used in containers increasing disease severity have also been reported. Among soil-borne pathogens, Rhizoctonia solani is considered to be the most difficult one to be controlled with COM (Scheuerell et al., 2005; Bonanomi et al., 2007). Variability also depends on the pathosystem.
Success or failure of COM for disease control depends on the nature of the raw materials from which the COM was prepared, on the composting process used and on the maturity and quality of the COM (Termorshuizen et al., 2006). Fortifying COM with beneficial microorganisms is one possible factor that can help in the success of COM use, increasing the efficacy and reliability of disease control (De Clercq et al., 2004). OM amendments, COM as one of the best, are suggested as a promising tool for the management of plant-parasitic nematodes, although some reports point to an increase of these nematodes after the use of OM. Thode et al 2011 suggest possible mechanisms for a stimulation of plant-parasitic nematodes as well as mechanisms that might be causing a reduction of them, elucidating that proliferation of non-pathogenic free living nematodes have a positive effect over this reduction..

Mechanisms of action of soil-borne disease suppression:

Disease suppressiveness depends on soil or substrate properties, including both abiotic (physicochemical) and biotic parameters (Mazzola, 2004; Janvier et al., 2007).
A loss in the disease suppressive effect of COMs following sterilization or heat treatments has been demonstrated in several papers (Hoitink et al., 1997; Cotxarrera et al., 2002; Reuveni et al., 2002; Chen and Nelson, 2008; Pugliese et al., 2011). A declining of microbial activity after long periods of maturation and, consequently, a reduction of disease suppression has been also reported (Zmora-Nahum et al., 2008).
Also the use of water extracts from COMs showed to suppress several soil-borne pathogens (El-Masry et al., 2002), indicating a predominant biological component rather than chemical or physical in the suppressive effect. COM acts as a food source and shelter for the antagonists that compete with plant pathogens or parasitize them, for those beneficials that produce antibiotics and for those microorganisms that induce resistance in plants: high-quality COM should contain disease-suppressive microorganisms (Noble and Coventry, 2005; Hadar, 2011).
Bacteria belonging to genera Bacillus spp., Enterobacter spp., Pseudomonas spp., Streptomyces spp., Penicillium spp., as well as several Trichoderma spp. isolates and other fungi, have been identified as biocontrol agents (BCAs) in COM-amended substrates (Chen et al., 1987; Boehm et al., 1993; Hoitink et al., 1997; Boulter et al., 2002; Pugliese et al., 2008).
The presence of toxic or volatile compounds in COM, sometimes correlated with changes to the physical properties of the growing medium or soil or to soil pH and electrical conductivity, are other possible mechanisms (Noble, 2011), suggesting COM use as alternative to chemical fumigants for managing soil-borne pathogens, also integrated with soil solarization (Katan, 2000).
Investigating a wide range of biological and chemical characteristics of COMs and COM-peat mixtures in relation to plant disease suppression, Termorshuizen et al. (2007) demonstrated that only pH increase resulting from COM amendment showed a consistent relationship with the suppression of some diseases, such as Fusarium oxysporum, but that there is no single factor conferring suppressiveness to COMs.
Several approaches were used to monitor COM suppressiveness, microbial activity and related effects after organic amendments application to soil and substrates, including analysis of phospholipid fatty acids (PLFAs), enzymatic activities and DNA-based techniques (Noble and Coventry, 2005). Overall, enzymatic and microbiological parameters, rather than chemical ones, are considered much more informative for predicting suppressiveness (Bonanomi et al., 2010). In future, new insights could be given by novel analysis, like COM metagenomics. Metagenomics deals with the isolation of genetic material directly recovered from environmental samples and such approach can better elucidate to understand the genetic diversity of a microbial population, the population structure, and the ecological role played by the microbial communities in a soil.

Compost quality in relation to soil-borne diseases depend on:
- Resources
- Production process
- Production technology
- Management and process controlling
- Storage conditions
- Use and application

Sources of OM for COM are numerous: urban organic wastes, industrial wastes, manure, crop wastes, etc. Very important for all them is begin the process with a high C/N rate, increase the plant fiber content to increase this rate and to obtain a final product rich in humic substances. However, probably the most important subject related with quality will be the absence of different physical, chemical and microbial contaminant.
However, it is possible to make COM locally or at farm level using simple methods. This process contributes to a sustainable agriculture production.

Functions of compost in respect of soil-borne disease:
COM properties can be divided in three groups: biological, physical and chemical properties.

Biological properties:
- Micro-organisms (e.g., bacteria, fungi, protozoa, nematodes): COM acts as a food source and shelter for the antagonists that compete with plant pathogens or parasitize them, for those beneficials that produce antibiotics and for those microorganisms that induce resistance in plants
- Macro-organisms (e.g., earthworms) breed microorganisms in their gut and feed them through mucus: They also provide physical properties like porosity and biological fixed soil aggregates. The chemical characteristics (availability of nutrients for plants, plant growth substances etc.) of their fecal is changed compared to the input material.
- …

Physical properties:
- Soil texture and structure (porosity, water storage capacity) significantly influence the development of root disease. Well-aerated, well-drained soils create conditions that discourage root diseases. Soils that drain poorly, however, tend to favor the survival and distribution of soilborne pathogens such as Pythium and Phytophthora. Only a few root diseases are favored by drier soils (for example, common scab of potato caused by Streptomyces scabies).

Chemical properties:
- pH, EC: for example clubroot disease of crucifers caused by Plasmodiophora brassicae is a major problem in acidic soils (5.7 pH or lower). The disease is dramatically reduced when the pH rises from 5.7 to 6.2 and is virtually eliminated at soil pH values greater than 7.3 to 7.4. Similarly, common scab of potatoes is favored by a pH of 5.2 to 8.0 but is reduced dramatically by soil pH values lower than 5.2.
- micro- & macronutrients. High levels of soil nitrogen increase the growth rates of crops, prolong the plants vegetative phase and enhance the growth of succulent plant tissue. Plants in this condition are more vulnerable to attack by some soilborne pathogens. On the other side, low levels of soil nitrogen weaken plants and may predispose them to attack by some pathogens.

- organic carbon
- …

These three groups of properties are interconnected and in interaction and can be responsible for SBD suppression based on two modes of action:

Direct inhibitory effect on SBD:

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- Competition for nutrients
- Humic substances content
- Toxic volatiles
- victim-predatory relationship
- …

Indirect effect on SBD via the plant:
- Plant growth (COM delivers nutrients for the plant)
- Reduction of common plant stress
- Induced resistance for plants
- enhanced soil structure
- …

COM, or other OM amendments, contributes to recover the health of soil. The soil is enrichment in nutrient compound, in microbial population, and in physical properties. All these characteristics enhance plant development, and consequently avoid SBD. On the other hand, soil-borne pathogens are reduced by the antagonistic effect of microorganisms added to soil, enhanced the suppressive effect of the COM.

Concerns with composting and compost application:

- Physical-chemical properties (pH, CE, CIC, OM content, humic substances, porosity, C/N rate, nutrient content, …): all this properties are very important for plant growing, microbial developing, plant pathogen survival, and relation with other factors very important for all these mentioned, such as water drainage, temperature soil control, or macro and micronutrients disponibility.
- Microbial properties (microbial richness, diversity, …): it is a quality parameter for SBD suppression, and for movement or recycling OM, induced resistance to plant pathogen in plant.
- Absence of Human pathogens: It is a quality parameter of COM to be added in crop soil, overall when products are consume as fresh products. This is from food security point of view. Very important when compost is made with urban organic wastes or manure.
- Absence of Plant pathogens: It is a quality parameter of compost to be added in crop soil, when it has been made with plant wastes
- Limits of heavy metal contamination: It is a quality parameter since environmental and food security point of view, very important in COM obtained from industrial and urban organic wastes)
- Limits of chemical contamination (pesticide residues) It is a quality parameter since environmental and food security point of view,
- Solid contaminants (glass, metal, plastic, etc.). They are contaminants for the soil, environment, and food product chain.

Other concerns with COM application:
- Costs for process and application
- Costs for technical equipment
- Pollution of the environment (smell, germs, runoffs) during COM production
- Soil compaction during application
- Availability (in EU over 10 million tons are produced every year, but this amount is not sufficient for the total cropping area)
- Criteria of resource selection
- Quality control and certification
- Knowhow

Use of COM and OM against SBD by the farmers

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Farmers' willingness to use compost is strictly connected to various quality aspects of compost. It is mainly applied for improving soil fertility and secondary to control soil-borne pathogens. Dosages for soil applications may vary from 5 to 30 t/ha, or be applied as growing media, generally mixed with peat, at 10-20% v/v. In some cases COM is applied by farmers in integration with other strategies, like soil solarization, grafting, and anerobic soil disinfestation.
The application of compost requires specific and suitable machineries, and consequently farmers must need assistance for a proper application of compost.

OM derived from other resources then from COM:

OM can also be provided by other resources, then COM. The decomposing process then takes places directly in the soil and similar functions can be expected. The OM acts as a food resource for the soil food web and drives the microbial activity. Because of the lack of hygenisation (which is performed by the duration of hot temperatures during composting), the control of SBD and other plant pathogens cannot be guaranteed. Although in most cases, this is not a problem, because of antagonistic effects.

Among criteria on how to produce effective composts, various aspects should be considered, including the resources from which the compost was prepared, the composting process and the maturity and quality of the compost. Effective composts should be stable and contain, or being fortified with, microbial antagonists. On the contrary, if compost is used in integration with solarization or anaerobic soil disinfestation, and not completely mature compost is much effective because it can better release toxic compounds against soil-borne pathogens.

Resources of organic matter, other than compost:

- Root exudates
- Crop residues – Green Manure (Cover Crop)
- Manure
- Residues from food processing
- Organic waste
- Mulch
- Organic fertilizer and soil amendment
- By-products from biogas and biofuel industry

Recommended research:

- Recognition of SBD through plant communication in an early stage
- COM extracts in relation to SBD

- Allelopathy
- Micro application of COM and COM extract (e.g. seed coating)
- Prediction of SBD suppression ability of COM. Which parameters can predict the SBD suppression ability of COM or OM?
- Metagenomic research of COM and OM
- direct and indirect effect of the interactivity of the biological, physical and chemical properties of COM and OM

Know how transfer:
- Best practice and research farms
- Webinars
- Tours

e.g.: soil practitioner training for different kind of farmers in Austria, Germany, Czech Republic, Slovakia, (8 days training)

Healthy soil

Although COM and OM are important for soil health, there are also other factors contributing to soil health.

Methods related to soil health:
- Tillage system
- soil compaction (avoidance technics)
- soil contamination (pesticide)
- Crop rotation/waiting periods
- Cover crop/green manure use
- Incorporation of organic methods
- COM production and use
- Reconsidered plant protection methods

Environmental impacts related to soil health:
- Climate change (drought, flooding, soil erosion)

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funded by European Commission