Focus Group SOIL-BORNE DISEASES

Mini-paper - *Green Manures and cover crops to reduce the pressure of soil-borne diseases in annual crops*

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Introduction

Soil-borne plant diseases are caused by numerous pathogens[1], which live in the soil and affect plant health by infection of the below-ground organs (roots, rhizomes, tubers) or in some cases above ground organs (stem bases, plant crowns or the vascular system). In Europe, the most important groups of such organisms are the oomycetes, fungi and nematodes while soil-borne diseases caused by bacteria, viruses or other microorganisms are less important. Soil-borne pathogens can be highly specialised or can affect a very broad host plant range. Another important point is the difference between purely biotrophic pathogens and those that can survive in soils as saprophytes.
Cover crops and green manures are grown with no intention of harvesting their biomass, either partly or completely, at the end of the cropping season. The difference between these two types of crops is their final use. The above-ground part of green manures is incorporated into the soil at the end of the growing period with the aim of returning accumulated nutrients (e.g., nitrogen) or useful secondary metabolites (e.g., glucosinolates) to the soil. Cover crops are grown for different reasons, such as to reduce leaching of nutrients (e.g., nitrate), avoid erosion, improve soil structure or suppress weeds. A combined use is also possible, a crop can serve first as cover crop (e.g., for weed control) and then be incorporated as green manure (e.g., for nutrient input) (Campiglia et al., 2009).

Non-host plants

One use of green manures/cover crops for control of soil-borne diseases is their role as a non-host crop as part of a crop rotation strategy. Even though the persistence of many soil-borne pathogens in the soil is often enhanced by long-term survival structures (such as chlamydospores, sclerotia, microsclerotia, oospores or cysts), populations of soil-borne pathogens increase rapidly in the field through the cultivation of host plants.
Knowledge on the range of host plants infected by particular soil-borne plant pathogens is plentiful. Often, the two major groups of plants, mono- and dicotyledons, are hosts to quite different groups of soil-borne pathogens. For instance, monocotyledons are not considered host plants of *Verticillium* spp. (Pegg & Brady, 2002) and *Poaceae*, the most important family of the monocotyledons, are not host plants to *Phytophthora* spp. (Erwin & Ribeiro, 1996). Other important soil-borne pathogens such as *Colletotrichum coccodes, Sclerotinia sclerotiorum* or *Thielaviopsis basicola* do not, or rarely infect monocotyledons. Pathogens which equally affect mono- and dicotyledons include *Rhizoctonia solani* or *Fusarium* species. In contrast, some soil-borne pathogens, such as *Gaeumannomyces graminis*, only infest mono- but not dicotyledons. However, the impact of asymptomatic host plants (Malcolm et al.,

[1] Nematodes are also considered as pathogens in this paper.

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2013) or resistant cultivars of host plants (Michel et al., 1996) on the populations of soil-borne pathogens should not be neglected and is often not well investigated.
Another important factor is the role of weeds as host plants for plant pathogens. Therefore, green manures or cover crops have to be established in a way to suppress weeds which could potentially act as sources of pathogen inoculum for crop plants, hence undermining their non-host effect.

Cover crops

Cover crops affect soil-borne pathogens in several ways. The roots can liberate a range of molecules (e.g., sugars, amino acids) during the growing period (Börner, 1960) and although the amount of these substances is too small to directly affect soil fertility, they can directly influence the community composition and biomass of soil microorganisms (Ladygina & Hedlund, 2010). Cover crops have been shown to influence the soil microbial biomass and composition more than soil temperature, moisture, pH, and texture in a tomato cropping system (Buyer et al., 2010). An increased microbial activity and diversity induced by preceding (rotational) crops such as canola, rapeseed, and barley were also shown to partly explain the reduction of several soil-borne potato diseases by these crops (Larkin et al., 2010).
A second way to reduce soil-borne pathogens through cover crops is the use of nematode catch crops, such as *Tagetes* spp. and *Brassica* spp. (Held et al., 2000). However, this control method is limited to a small number of crop x pathogen combinations.

Green manures

Green manures can potentially have the same effect on soil-borne diseases as cover crops as described above, up until harvest. Then, through the incorporation of the above-ground biomass of green manure crops, significant amounts of carbon, nutrients and secondary metabolites are added to the soil. The amounts of readily useable carbon in the form of organic amendments (fresh or dried plant material) added to the soil stimulates the general soil microbial activity (Stark et al., 2008; Michel & Lazzeri, 2011). Such increases in soil microbial activity can sometimes be correlated with a decrease in the number of soil-borne pathogens e.g., *Verticillium dahliae* (Michel & Lazzeri, 2011). However, the incorporation of fresh organic matter can occasionally also lead to a temporarily increase of certain soil-borne diseases (Hoitink & Boehm, 1999). Another aspect of incorporating high amounts of readily degradable organic matter is competition for oxygen in the soil, caused by the resulting intense macro- and microbial activity. Because of this, planting and especially sowing of a new crop immediately following the incorporation of the green manure should be avoided.
Some green manure plants contain specific metabolites that may be toxic to various plant pathogens. Biofumigation is based on the use of cruciferous plant species with a high content of specific glucosinolates which upon incorporation into soil are converted to toxic isothiocyanate compounds (Kirkegaard, 2009). *More information on this control method is presented in the corresponding minipaper.* Other plant species widely used as green manures, mainly belonging to the Poaceae family, contain also metabolites that are transformed into toxic substances during their decomposition (Widmer & Abawi, 2002; Putman & DeFrank, 1983). Plants containing essential oils are another group of green manure crops that can also be used for the control of soil-borne pathogens (Gwinn et al., 2010).
Similar to cover crops, green manure crops also influence the soil microbial activity and community composition (Elfstrand et al., 2007). For instance, specific groups of microorganisms, such as *Streptomycetes* spp., stimulated by the incorporation of green manure crops directly increased the health and yield of alfalfa and potato (Wiggins & Kinkel, 2005a).
The incorporation of significant amounts of nutrients contained in the organic matter of green manures could also influence the populations of soil-borne pathogens. Fresh organic material is quite rapidly mineralized and different forms of mineral nitrogen can affect certain pathogens in the soil (Huber & Watson, 1974). An indirect effect of the nutrients released after the incorporation of green manure plants on the following crop may also increase plant health and yield.

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Efficacy

Green manures and cover crops have a lower efficacy in controlling soil-borne plant diseases compared to soil disinfestation with chemical substances, heat or steaming, at least in the short term. However, a reduction of the disease pressure and, perhaps more importantly, an increase in the yield and improvement of crop quality can be achieved with the use of green manures/cover crops (Larkin et al., 2007; Wiggins & Kinkel, 2005b). Incorporating the above-ground biomass i.e., using a crop not only as cover crop but also as green manure can also enhance the efficacy of this control method (Motisi et al., 2009).

Current Situation

The cultivation of green manures and cover crops varies widely across Europe. In Germany, green manures (Gründünger) were grown in summer by 50% and in winter by 62% of the growers (Anonymous, 2010). The amount of arable land (Ackerland) covered by green manures was 11% in summer and 16% in winter. In Lithuania, in contrast, green manures are rarely grown, mainly due to technical (no specific equipment), environmental (no time between harvest and start of winter) and financial (additional costs) reasons. In France, a survey on the use of control methods of soil-borne diseases in vegetable crops revealed that green manures, used alone or combined with soil solarisation, are the most widespread alternative to chemical control methods (Janvier & Ade, 2013). Interestingly, green manures were used more in protected crops (by 21 of 36 growers) than in field crops (by 9 of 41 growers). In Switzerland, green manures or cover crops are mostly grown during the winter season, mainly to avoid nitrate leaching. It is part of the ecological measures to obtain the Integrated Production (IP) label and is financially supported by the government.

Conclusions

The use of cover crops and green manures has some potential to control soil-borne diseases of field and horticultural crops. However, their immediate efficacy is lower compared to more radical methods, such as chemical soil disinfestation or heat treatments, and hence they have to be used in a more preventive and longer–term way. The choice of a green manure or cover crop also depends on multiple factors other than the control of soil-borne diseases such as weed suppression, reducing erosion and nitrate leaching, and improving soil structure.

Outlook

Standard easy-to-apply solutions, such as the application of methyl bromide, do not exist for the use of green manures and cover crops. Their use has to fit the specific situation of each individual grower and has to be adapted to the agricultural, ecological, political and economic environment. Attention to the control of soil-borne diseases only once they are an important production constraint is not appropriate when green manures and cover crops are used as control method and hence they must become part of an integrated control concept and be applied preventively.

Fail factors

- The most important fail factor is the preventive nature of green manures/cover crops. Their cultivation uses resources (time, money, space) with no immediate visible return.
- The second fail factor is the limited efficacy of this method, which is insufficient under high disease pressure.
- The possibility that green manures or cover crops may be a host plant of a soil-borne pathogen is the third fail factor. For example, *Brassica* species are not accepted as green manures by Swiss vegetable growers as the percentage of cruciferous species in their rotation is important.
- The relatively high price and low availability of seeds of specific green manures varieties e.g., brown mustard with high content of glucosinolates, are further fail factors.

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- The lack of knowhow and equipment to grow green manures (grown as a field crop) by horticulturists can also hinder the adoptation of this method.

Implementation

Important points for the implementation of green manure/cover crops are:

- Good extension service to provide accurate advice to individual growers
  Growing green manures is not a new technique, but traditionally is not used to control soil-borne diseases. In contrast to the use of chemical or heat-based control methods, it is more complex. The grower should not be confronted with new problems caused by the cultivation of green manures or cover crops. Therefore, non-biased advice should be provided to him by an extension officer who knows the local conditions well.
- Easy accessible and reliable information on host status of green-manure/cover crops
  Knowledge on the host status of the green manures/cover crops but also of the crop before and after their cultivation is most important for a successful use of this control method. Easily accessible (i.e., web-based) and reliable (i.e., established by public research and extension organisations) information are essential for the implementation of green manures/cover crops.
- Specific cultivar with high content of secondary metabolites and intrinsic resistance to diseases and pests
  With the specific goal of reducing soil-borne pathogens, cultivars that produce a high amount of potentially toxic compounds are important. They should also be resistant to the most important soil- and air-borne pathogens and pests to facilitate their successful cultivation.
- High quality seeds of such cultivars
  A rapid establishment of green manures or cover crops is important for control of weeds, but also to ensure a good production of the needed fresh organic matter.
- Political encouragement to grow green manures and cover crops (including financial support)
  In Switzerland, the obligation to cover the soil during the fall season (15.9. – 1.11.), when the risk of nitrate leaching is highest, is softened by a financial contribution. In contrast, if such an obligation is enforced without financial compensation, it will be difficult to be implement. Therefore, at least the costs for the sowing and incorporation of the green manures should be covered by the government.

Data needed

Research is needed for two areas:

- The long term effect of different types of green manures and cover crops to control soil-borne diseases should be investigated in field and greenhouse trials. Conventional (chemical, heat) and alternative (Anaerobic soil disinfestation (ASD), solarisation, biological control agents (BCA), biofumigation, grafting) control methods have to be included in these trials. They should be run at different locations in Europe, to take into account the regional differences but also to serve as demonstration trials for the transfer to the practice.
- The costs and benefits of the use of green manures and cover crops as a control method should be evaluated by surveys in different regions of Europe. Such data can be used to define the (eventual) financial support by the government but also to evaluate the economic competiveness of this method.

References

Anonymous, 2010. Zwischenfruchtanbau in Deutschland. Statistik und Berichte des Bundesministerium für Ernährung und Landwirtschaft. www.bmelv-statistik.de/de/statistischer-monatsbericht/a-landwirtschaft/

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Börner H., 1960. Liberation of organic substances from higher plants and their role in the soil sickness problem. Botanical Review 26:393–424.
Buyer J. S., Teasdale J. R., Roberts D. P., Zasada I. A., Maul J. E. 2010. Factors affecting soil microbial community structure in tomato cropping systems. Soil Biology & Biochemistry 42:831-841.
Campiglia E., Paolini R., Colla G., Mancinelli R. 2009. The effects of cover cropping on yield and weed control of potato in a transitional system. Field Crop Research 112:16-23.
Elfstrand S., Båth B., Mårtensson A. 2007. Influence of various forms of green manure amendment on soil microbial community composition, enzyme activity and nutrient levels in leek. Applied Soil Ecology 36: 70-82.
Erwin D. C., Ribeiro O. K. 1996- *Phytophthora* diseases worldwide. APS Press, St. Paul MN, USA:
Gwinn K. D., Ownley B. H., Greene S. E., Clark M. M., Taylor C. L., Springfield T. N., Trently D. J., Green J. F., Reed A., Hamilton S. L. 2010. Role of essential oils in control of *Rhizoctonia* damping-off in tomato with bioactive monarda herbage. Phytopathology 100:493-501.
Held L. J., Jennings J. W., Koch D. W:, Gray F. A., 2000. Economics of trap cropping for sugarbeet nematode control. Journal of Sugar Beet Research 37:45-55.
Hoitink H. A. J., Boehm M. J. 1999. Biocontrol within the context of soil microbial communities: A substrate-dependent phenomenon. Annual Review of Phytopathology 37:427-446.
Huber D. M., Watson R. D. 1974. Nitrogen Form and Plant Disease. Annual Review of Phytopathology 12:139-165.
Janvier C., Ade C., 2013. Proposer des solutions techniques pour la gestion des bioagresseurs telluriques en cultures légumières : bilan du projet Prabiotel. Innovations Agronomiques 28 :87-99.
Kirkegaard J. 2009. Biofumigation for plant disease control – from the fundamentals to the farming system. Pages 172-195 in: Disease control in crops. Biological and environmentally friendly approaches. Walters D., ed. Wiley-Blackwell, Oxford, UK.
Ladygina N., Hedlund K. 2010. Plant species influence microbial diversity and carbon allocation in the rhizospere. Soil Biology & Biochemistry 42:162-168.
Larkin R. P., Griffin T. S., Honeycut C. W. 2010. Rotation and cover crop effects on soilborne potato diseases, tuber yield and soil microbial community. Plant Disease 94:1491-1502.
Larkin R. P., Griffin T. S. 2007. Control of soilborne potato diseases using *Brassica* green manures. Crop Protection 26:1067-1077.
Malcolm G. M., Kuldau G. A., Gugino B. K., and Jiménez-Gasco M. M. 2013. Hidden host plant associations of soilborne fungal pathogens: An ecological perspective. Phytopathology 103:538-544.
Michel V. V., Hartman G. L., Midmore D. J. 1996. Effect of previous crop on soil populations of *Burkhoderia solanacearum*, bacterial wilt, and yield of tomatoes in Taiwan. Plant Disease 80:1367-1372.
Michel V., Lazzeri L. 2011. Green manures to control *Verticillium* wilt of strawberry. IOBC/wprs Bulletin 70:81-86.
Motisi N., Montfort F., Faloya V., Lucas P., Doré T. 2009. Growing Brassica juncea as a cover crop, then incorporating its residues provide complementary control of Rhizoctonia root rot of sugar beet. Field Crops Research 113:238-245.
Pegg G. F., Brady B. L. 2002. *Verticillium* wilts. CABI Publishing, Wallingford, UK.
Putman A. R., DeFrank J. 1983. Use of phytotoxic plant residues for selective weed control. Crop Protection 2:173-181.
Stark C. H., Condron L. M., O'Callaghan M., Stewart A., Di H. J. 2008. Differences in soil enzyme activities, microbial community structure and short-term nitrogen mineralization resulting from farm management history and organic matter amendments. Soil Biology & Biochemistry 40:1352-1363.
Widmer T. L., Abawi G. S. 2002. Relationship between levels of cyanide in sudangrass hybrids incorporated into soil and suppression of *Meloidogyne hapla.* Journal of Nematology 34:16-22.
Wiggins B. E., Kinkel L. L. 2005a. Green manures and crop sequences influence alfalfa root rot and pathogen inhibitory activity among soil-borne *Streptomycetes*. Plant and Soil 268:271–283.
Wiggins B. E., Kinkel L. L. 2005b. Green manures and crop sequences Influence potato diseases and pathogen inhibitory activity of indigenous *Streptomycetes*. Phytopathology 95:178-185.

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