Focus Group SOIL-BORNE DISEASES

Mini-paper – *Anaerobic Soil Disinfestation and other techniques of 'non chemical' soil disinfestation techniques*

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1. Introduction

Soil-borne diseases can be suppressed in different manners, by means of one-target methods such as gene resistance or chemical fumigants, but also by multi-target techniques that can contribute to the general fertility/soil health and maintenance of the plant production, while avoiding the appearance of the mentioned diseases. The addition of decomposed or composted organic matter into the soil can be considered as a cultural practice that permits the control of several pathogens, as is shown in many examples. The result of this addition is variable and this variability is dependent on the decomposition state of the organic matter. In a recent review, Bonanomi et al. (2010) stated that extremely decomposed materials such as peats are very stable, showing slight suppresiveness or moderate conduciveness. On the other hand, undecomposed materials span all the possibilities between conduciveness and suppresiveness. The application method for the incorporation of easily-decomposable organic materials into the soil, as well as the features of these materials, is key factors in order to achieve success in the suppression of a soil-borne disease. In this regard, promising results have been achieved when organic matter is used as a disinfectant prior to plantation. The basis of this biological disinfection has its origin in the biocidal/biostatic effect of the volatile compounds produced during the decomposition of the organic matter as ammonia, plus additional effects provided by the release of non-volatile molecules to the soil, such asfatty acids (Arriaga et al., 2011; Runia et al., 2014). In this scenario, also the microbial communities can develop differentially than under a non-disinfected soil. To promote the biological disinfestation, i. e. the decomposition in soil of the organic matter, large amounts of water are required, as well as an upper layer to avoid losing the biodisinfectant gasses that are produced for a period ranging from 2 to 15 weeks. This layer is usually a transparent polyethylene plastic in the Mediterranean countries and soil is covered during summers, what comprises a soil solarization (Butler et al., 2012), but not transparent virtually impermeable film (VIF) is also used (Blok et al., 2000). Both actions favor the lack of oxygen in the soil at least for the first days after the watering. This depletion of oxygen gives name to the Anaerobic Soil Disinfestation (ASD), which integrates all the above mentioned techniques.

ASD is also termed "biological soil disinfestation", "soil reductive sterilization" and "reductive soil disinfestation", the term ASD is used to emphasize the anaerobic soil condition and to appropiately identify the soil as a soil disinfestation. This method implies the incorporation of easily decomposable organic amendments (ratio C/N: 8-20) into soil (wheat or rice bran, soybean flour, fresh crop residues, molasses, vinasses, agrofood residues,...) but also good results have

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been achieved with dehydrated plant tissues, compost and pellets from different organic matters (Klein et al., 2011; Melero-Vara et al., 2012; Gilardi et al., 2013).

2. Promising results on disease management.

There are many works testing the effect of these combination of techniques, as a part of the Montreal's Protocol works to search alternatives to methyl bromide, mainly in areas with the adequate climatic conditions. These works have been carried out on high value crops, such as strawberry, asparaghus, sweet pepper or carnation.

Asparaghus was the first crop to be studied under ASD in The Netherlands. This technique decreased *Fusarium oxysporum* f. sp. *asparagi*, *Rhizoctonia solani*, and *Verticillium dahliae* populations, even with relatively low temperatures (Blok et al., 2000).

For **Strawberry crop** several materials have been tested in different countries, showing promising results when applying biosolarization with available fresh poultry manure (FPM) to control fungi and nematodes (López-Aranda et al., 2012; Zavata et al.,2014).

For more than ten years, biodisinfection has been tested and improved to be implemented for greenhouse **flower growers** in the province of Cádiz (South of Spain). Initial trials showed a complete control of *Fusarium oxysporum* f. sp. *dianthi* when a mix of FPM and fresh flower plant residues was incorporated into the soil, deep irrigated and covered with high density polyethylene from 10th May to 10th June (García-Ruíz et al., 2012). Following trials repeated the success to control Fusarium wilt of carnation and *Meloidogyne incognita* when using only 5 kg/m^2 of FPM (Melero-Vara et al., 2012). It is worth noting that in these trials other treatments were tested comprising composted or pelletized material and results were not good until the third year repeating them on the same soil, or increasing the amount of composted material. Moreover, the temperatures did not reach lethal levels for those trials, so the effect of the solarization was not determinant in this case.

For more than 20 years, bell **pepper** crop has been subject of study of alternatives to methyl bromide, testing many different methods and products. Results of this long period of trials show the biosolarization as the best alternative to control *Phytophthora capsici* and *P. parasitica* as well as *Meloidogyne incognita* (Martínez et al., 2006; Ros et al., 2008). Also soil fatigue was reduced when applying biosolarization. The way biosolarisation was performed in these trials comprised the incorporation of easily available fresh sheep manure (FSM) mixed with fresh pepper residues and/or FPM. The dosage was reduced as the treatment is repeated year after year: FSM+FPM: 5+2.5 kg/m^2 (1st year), 4+2 (2nd year), 3+1.5 (3rd year), 2+0.5 (4th and later years) (Martínez et al., 2011). In this studies, the biosolarisation is highly effective when applied in Summer, with high temperatures inside the greenhouse. However, in trials developed in Northern Spain, results are also successful to control *Phytophthora* on sweet pepper, despite the lower temperatures and sun radiation (Núñez-Zofio et al., 2012). An interesting point of these trials was the use of previously sown mustard to get fresh organic matter from the same farm.

Recent trials in greenhouses cultivated with **tomatoes** or **cucumbers**, has shown comparable results to those exposed above. Soil fatigue, knot-root nematodes, *Phytophthora parasitica, Fusarium solani* f. sp. *cucurbitae* and *Fusarium oxysporum* f. sp. *radicis-cucumerinum* are some diseases that have been controlled by means of incorporate fresh organic matter (mostly mix of plant-crop residues and fresh manure) followed by a deep irrigation and tarping with transparent polyethylene or VIF. Trials have been developed in summer and winter conditions with good results. Some growers are sowing mustard and other *Brassicae* in their own farms to mix with fresh manure and/or crop residues, and in many cases the biodisinfection is performed only on the plantation rows, what reduces the consumption of plastic and organic matter (Martín-Expósito et al., 2013; Pérez-Hernández et al., 2014).

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3. Soil health promotion and soil fatigue correction.

It is a common argument for intensive growers that a soil reaches fatigue after continuous monocropping. This fact can be related to the concept of soil health. A fatigued soil is a non-healthy soil. It is accepted that soil fatigue can present three origins: chemical (the origin is a phytotoxin or alhelopatic substance), mechanical (due to an inadequate soil structure), or biological (soil microbiota affects the normal development of plants without showing parasitism.The prove for the biological fatigue is shown when a grower who applied soil disinfectants in soils without pathogens, leave to apply the disinfectant for one or two years and the yield of the crops diminish without any soil-borne disease. We can find good examples for strawberry or sweet pepper and methyl bromide in Spain. For these cases, the substitution of methyl bromide for biological disinfection was enough to avoid the apparition of fatigue for those soils without pathogens (Tello et al., 2010).

4. Success and fail factors

The ASD has shown to be a practical technique that permits the management of pathogenic nematodes and soil-borne fungi for different high value crops. This fact would allow growers to consider the use of costly methodologies, but the profitability of the technique is a key factor to take into account. Part of the success of ASD is based on the feasibility of the technique to substantial differences adapted to each crop system. Success factors that can be numbered are:

1- The **recycling of plant residues** from the same field (this can include the proper crop, even infected plants, or specific crops such as mustard or cabbage). This avoids growers to pay for the management of plant residues.
2- ASD **increase the fertility** of the soils. Growers have to reduce the application of fertilizers to avoid an excess of nutrients in soil (saving money again).
3- **Soil fatigue** is minimized, allowing growers repeating the same crop year after year.
4- **Irrigation requirements** are reduced.
5- **Extremely high temperatures** during ASD are not strictly necessary.
6- Commonly a **relatively cheap source of fresh organic matter** is available.
7- **It really works** for nematodes and parasitic fungi.
8- Growers are incorporating this technology after participatory research programs.

Some fail factors to be considered:

1- Plant residues can carry **plastic materials** for guiding the plants that need to be removed (for some growers this is not a real problem). One solution is the use of biodegradable materials that substitute those made of plastic, but price has to be take into account.
2- **Abundance of water** is required to initiate the microbial activity.
3- Sometimes **the time required** before planting is too much.
4- A **temperature** higher or at least similar to growing is required, and this implies one season without crop when there is no time.
5- **Plastic tarping** is required to achieve the best results.
6- **Incosistent results have been found**

5. Crossfeeding with other growing systems

ASD is ideal for intensive crops because of the "intensive" requirements of organic matter and plastic. For extensive crops an organic amendment can turn to a biodisinfection, just taking some considerations: using fresh organic matter, incorporating it when temperatures in soils did not stop the beginning of the microbial activity to decompose the organic matter (usually fresh manure has a high temperature by itself), applying sufficient water to promote the microbial activity, and covering with any plastic or mulch to avoid the liberation of gases for at least two weeks (not thinking on a solarization, just to keep the initial gases in the soil). Making this, the differential cost between an amendment and a biodisinfection should not be very high.

6. Research necessities.

As has been stated, there are numerous works dealing with trials in soils with commercial crops, that have allowed growers to apply ASD with beneficial effects. These works are not easily reproducible because the factors influencing the effect of ASD on the pathogen populations are diverse and not always explored:

- Temperature increasing plays an important role, but in fact this effect is not important under the lower zones that are normally explored by the roots. Lack of oxygen is also important, but the dynamics of this element at different depths is also unknown. So, studies involving samples at deeper soil fractions seem necessary.
- Soil microbial populations that can play a role to induce suppressiveness have not been studied sufficiently. Promising works aim to explore these aspects (Martinez et al., 2011; Klein et al., 2013) There are methodologies commonly used to study natural soils microbial populations that could be interesting to amplify this knowledge. Indicators of such suppressiveness are also necessary.
- Decomposition of organic matter is not always complete when applying ASD, but disease reduction can be observed. On the other hand, non-fresh organic matters have shown efficient as amendments for ASD. This heterogeneity shows a complex interaction between the components of the ASD. It would be possible a standardization for these matters?

With regard to the extension that biological control is getting, the management of ASD to maintain or increase the presence of those biological control agents in the soils needs to be considered.

Secondary effects can appear because of the incorporation of the required amounts of organic matter for ASD. Dosage calculation methods when repeating ASD should be established.

The presence of difficult-to-degradate materials together with the crop residues makes difficult to convince growers to incorporate their own residues into the soils, so new materials have to be checked.

5. Referred literature.

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