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EDITOR LETTER

SUSTAINABLE SOIL MANAGEMENT: A 'BOTTLENECK' OR A TOOL FOR IMPROVEMENT?

The sustainability of soil pest management (nematodes and pathogens) has always been seen favorably for the opportunities it creates when applied, but some difficulties may arise initially at starting when adopted at farm level. Is it a 'bottleneck' or a tool for improvement? This was the provocative question that dr. A. Gamliel (Israel) put in the title of his invited presentation at the '*International Symposium on Soil Disinfestation 2014*' in Turin (Italy).

The topic was then widely discussed in the working sessions and in the group discussions during the meeting breaks, representing the leitmotiv of the Symposium.

Actually, sustainable soil management or soil disinfestation with an integrated approach, is now in principle accepted by all stakeholders such as research, extension, industry, professionals and farmers.

In addition, now at EU level, we have also in place from January 2014, the application of the Directive 2009/128/EC on the 'Sustainable use of pesticides', which implies the use of an IPM approach in crop protection.

However, to be successful in adopting an integrated soil approach, more efforts are needed and the following main steps required:

- accurate diagnosis through having reliable pest data, before deciding the control strategy;
- adoption of all possible agricultural practices to support the control strategy;
- integration of fumigants combined with alternative control methods;

- stewardship programme in place for the safe use of fumigants to protect humans (operators, residents and consumers) and environment;
- last, but not basic, a successful integrated approach should meet the economic expectations of the farmers.

The experts recognise today that soil disinfestation is a major pillar of any approach for effective management of soil-borne pests in intensive crops, such as protected vegetables, strawberries, carrots, baby leaf, etc.. However, the management of soil pests cannot be based only on a single measure, even a highly effective one, as fumigants generally are.

For that reason it is very important to have more available tools and an effective method of combining them.

Several new solutions for soil problems globally, like new fumigants, chemistry, plant extracts, biopesticides, etc. are already in development, from research level to application step. These, used alone and particularly combined in an integrated approach, will make a major contribution to sustainable soil management strategies in the future.

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NATURAL OCCURRENCE OF THE NEW SOIL FUMIGANT DIMETHYL DISULFIDE (DMDS)

Jacques Auger

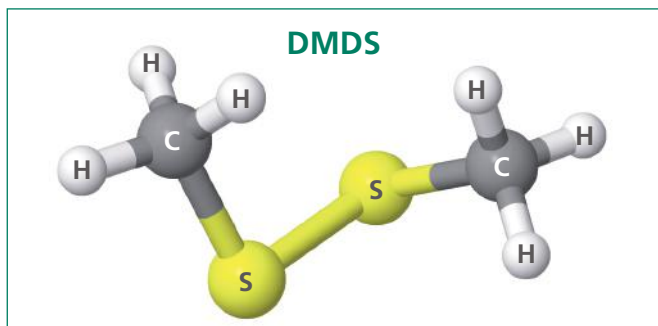
University of Tours François Rabelais, France



A collection of scientific peer-reviewed literature (2001-2011) on natural occurrence of DMDS, carried out by the University of Tours - François Rabelais, has identified 1978 references. DMDS reports in the collected papers were from a vast environment origin (air, soil, water) and several foods. A short summary is presented below.

DMDS production by plants

Sulfates are reduced by organisms mainly to the amino acids cysteine and methionine, which are incorporated into proteins.



Structural formula of Dimethyl disulfide (DMDS)

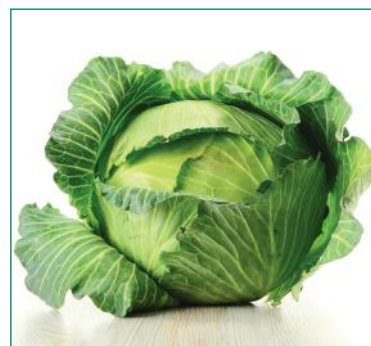
The breakdown of organosulfur compounds during fermentation and decomposition of organic matter is probably the most important mechanism for the release of sulfur volatiles. Sulfur compounds can be volatilized from living plant leaves, from decaying leaves and via the soil from root exudates, especially from *Brassicaceae* and *Alliaceae*. Volatile substances are enzymatically released when plant cell membranes are ruptured.

The first plant-produced sulfur compounds are thiosulfates (Ti), which are later rapidly degraded to disulfides in the soil. The major degradation products of leek and onion are dipropyl disulfide (DPDS) and dipropenyl disulfide (DPeDS) whereas garlic releases diallyl disulfide (DADS). Dimethyl

disulfide (DMDS) is also produced by onion and garlic but it is mainly present as a degradation product of crucifers (cabbage, radish).



Brassicaceae and *Alliaceae* are natural sources of DMDS



The second main group of plant-produced sulfur compounds comprises glucosinolates (GLU) and their derivatives. Most GLU have been found in the *Brassicaceae* family. In fact DMDS is the only sulfur compound identified and quantified in soils when various *Brassicaceae* plant materials were incorporated, up to 283 µg/g plant dry weight.

Like in *Allium* and *Brassicaceae*, DMDS is present in the flavor of many plants, asparagus, parsley, tomato, and neem. In *Brassicaceae*, the degradation of thiomethylated isothiocyanates, like sulforaphane in broccoli and erucine in *Eruca sativa*, produces DMDS. In mushrooms like truffles, DMDS of similar metabolic origin has also been reported.

Apart from DMDS production by decaying plant tissues involving soil microorganisms, intact sulfur rich plants like *Alliaceae* and *Brassicaceae* produce root exudates which are converted by soil bacteria into disulfides, like DMDS. Very little root production has been reported for other plant families like *Phytolaccaceae*, where DMDS can represent up to 35% of the volatile compounds.

The annual flux from crops ranges from 0,008 to 0.3 g sulfur/m². H₂S and DMS are the two primary emitted species but CS₂, COS and DMDS are also present, especially DMDS and other disulfides.

Other DMDS emissions

DMDS represent 2.5% of the terrestrial biogenic sulfur emissions exhibiting high variability. The emissions from paddy soils were higher than those from upland soils and DMDS can account for 75% of the sulfur compounds.

Interestingly other hot spots for DMDS emissions are wetland ecosystems like intertidal mudflats and salt marshes, whose contribution is estimated to be 2% of the total emissions.



Wetland ecosystems as important source for DMDS emissions

Coastal systems have the potential for large emissions of volatile reduced sulfur gases due to the availability of sulfate and organic matter. The marine bacterioplankton degrades dissolved DMSP leading to MeSH which is transformed in marine environment to DMDS. MeSH, DMS and DMDS are produced everywhere in oceanic waters and saline eutrophic lakes, but their distribution has been characterised by 'hot spots'. DMDS was identified also in forest and peat fires, sometimes as the major reduced sulfur containing gas, with maximum values of 113 ppb.

Sulfur volatiles (including DMDS) may play a role in the microbial ecosystem. In soil, sulfur volatiles from several sources (i.e. *Streptomyces* spp., *Trichoderma* spp, *Fusarium* spp. etc.) inhibit the growth of pathogens or may act directly or indirectly either to activate plant immunity or to regulate plant growth and morphogenesis. Among the consortium of plant growth promoting rhizobacteria (PGPR), the most important are *Serratia* spp. and *Achromobacter* spp. The major compound of one *Achromobacter* strain was DMDS (94% of the emitted volatiles) and it represents 2.5% for one *Serratia* strain.

Decomposition of municipal solid waste, biosolids from sewage sludge and livestock manure and feces through methanogenic fermentation produce biogas containing not only H₂S but also DMDS. In urban wastewaters H₂S, MeSH, DMS and DMDS can

originate from the fermentation of organic sulfur compounds (i.e sulfonates from surfactants) and proteinaceous material. DMDS was also identified as a major emission in cigarette smoke. DMDS is present in human odour produced by skin bacteria and saliva. DMDS is sometimes present in human urine, in human respiratory gas with an emission rate of 0.6 µg/h.

DMDS presence in food

DMDS is never present in the initial constituents of food: vegetables, mushrooms, meat, ... being produced from precursors like alkylcysteine sulfoxides in vegetables, through:

- enzymatic production caused by cutting of tissues, the enzyme like alliinase and myrosinase in *Allium* and *Brassicaceae*,
- microorganism production, especially in food from milk (cheese, butter...), from fish (sauces,...), meat (ham,...), and all types of fermented foods (soy sauces, wine, bread, beer),
- cooking production from Maillard and Strecker reactions on methionine and cysteine: coffee roasting, cocoa, peanuts, tea, extraction of essential oils.

DMDS is the major sulfur compound in extracts of the carob bean, and appears for instance as major factor in the perceived aroma of grapefruit. DMDS is present in the flavour of about all cooked foods like bread, fries, coffee and cocoa. During conservation of milk and butter the incidence of light on DMDS production is important so called 'light activated flavour'. Anaerobic storage conditions before cooking also have a great incidence.

Freshly distilled Cognac has a DMDS concentration from 50-500 µg/l, 5-6 times higher than that of Calvados samples. Great changes in DMDS level are linked to aging in 'Awamori', a Japanese beverage based in rice fermentation. DMDS was clearly identified and quantified in wines as well as in beers. DMDS also contributes to the flavour of all cheeses and numerous microorganisms have been identified for various pathways.

Conclusions

Measurements of biogenic sulphur emissions showed that DMDS is released into the atmosphere from different sources. Plants and soil microorganisms play a central role in DMDS emissions in marine environments, coastal wetlands and terrestrial ecosystems via rather well-known pathways.

CERTIS VISIONING ON PROTECTED CROPPING IN 2030

How can protected cropping contribute to a more sustainable food system in the future?

This and other hot questions were discussed during various workshops held by Certis Europe with industry experts. Certis decided to extend its perspective for development and strategic direction and to explore the role that the company might adopt in a sustainable future. Having identified critical trends Certis embarked upon an exercise to explore what the future of protected cropping might be and the contribution it could make to a sustainable food system in 2030.

By 2030 we can expect that food production will need to have increased by 70%, to feed 2.3 billion additional people. At the same time food production will be more vulnerable to extreme weather events as a result of climate change. Food security and food prices will be high up the political agenda. With these and other pressures to be considered, sustainability is an imperative for the future of our food system. Protected cropping is a major contributor of high value horticultural crops. It is a system that allows for a more sustainable approach to crop management, in particular pest control.

Certis Europe worked with Forum for the Future to develop four different but plausible scenarios in which to explore how protected cropping might change by 2030, with a focus on Europe: Silicon Farming, Factory Farming, Plastic Planet and Walled Garden. The scenarios are not intended to be predictions or visions of desired futures. They look at how global trends could combine to change our world, and what this could mean for protected cropping. Future scenarios are an invaluable tool for forward-thinking businesses to use when planning ahead. They help identify risks and opportunities, inform strategy development and

stimulate innovation.

The results of this work will enable Certis to open a dialogue with key stakeholders in the protected cropping sector, sharing and testing the scenarios we have created, as part of an exploration of their views of the future. From that dialogue we hope to develop our long term strategy for the sector and to start to identify the products and services we need to be evolving, as well as potential partners.

Certis is committed to its future as a major contributor to the sustainable production and supply of food and must therefore prepare its offering to the industry in a changing world.

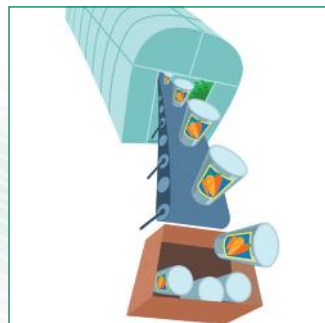
For more information visit www.certiseurope.com

Nicola de Tommaso
European Portfolio Manager, Cleanstart

Silicon Farming



Factory Farming



Plastic Planet

famine
global shortages
processed food
biological pest control
stagnant economies
extreme weather
reduced expectations
Africa booming
big business
low cost industry
free trade
cheap labour

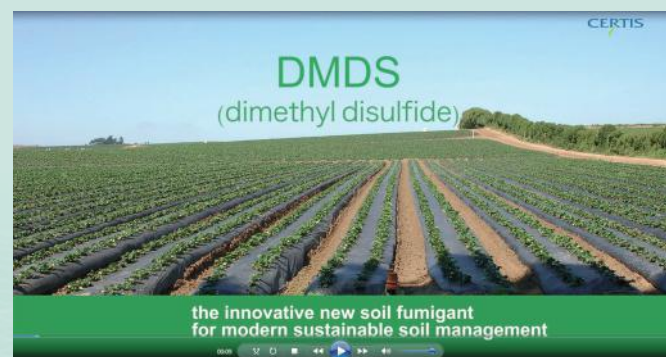
Walled Garden

unrest
trade restrictions
fresh is luxury
high production costs
high-cost food
expensive labour
shortages
investment for security
vertical integration
constrained growth
colonial domination

Stewardship videos launched

In the framework of the CleanStart programme Certis recently created two stewardship videos, with the objective of visually explaining best practice for field management of DMDS and giving precise instructions in case of product spill or leak.

This effort is well appreciated by market stakeholders and product users as a way to support their field activity; these videos are intended to be used for training operators and explaining best practice to market stakeholders.



**CERTIS EUROPE - IFAPA (HUELVA, SPAIN):
A COLLABORATION TO FIND NEW SOLUTIONS FOR SOIL PROBLEMS OF STRAWBERRY**

Since 2002/03 the Andalusian Institute for Research and Training in Agriculture, Fisheries, Foods and Organic Production (IFAPA) has started a series of field trials with chemical and non-chemical alternatives for soil disinfestations in Huelva, which is a major reference for the Mediterranean strawberry industry. So far, more than 20 fumigant combinations have been evaluated in this series of experiments, shank-applied, or drip-irrigated under mulched (VIF and LDPE film) pre-formed beds, or incorporated into the soil (such as dazomet).

Certis has, in its Cleanstart portfolio, several products to be used in strategies to give solutions for the strawberry industry. Thanks to the collaboration with IFAPA (Fig. 1), Certis has recently tested several technical solutions from the CleanStart programme for strawberries in Spain.



Fig. 1 IFAPA and Certis group in strawberry trials

The following have proved to be successful Cleanstart solutions for strawberry:

- Basamid in broadcast application, before bed conformation, at 350 kg/ha applied in situations where a stronger fungicide effect is needed (already in practice).
- Basamid in broadcast application (20 g/m²) applied before bed conformation plus DD90 at 30 g/m² applied by drip irrigation in bed. Used in situations with high need of fungicide and nematicide effect (already in practice).
- Basamid in broadcast application (20 g/m²) applied before bed conformation plus DMDS at 30 g/m² injected under pre-formed raised beds, under black VIF sheets. To be used in situations of high pressure of nematodes and pathogens requiring high fungicide and nematicide activity. The results of this new strategy combining MITC gas with DMDS are very promising (Fig. 2).

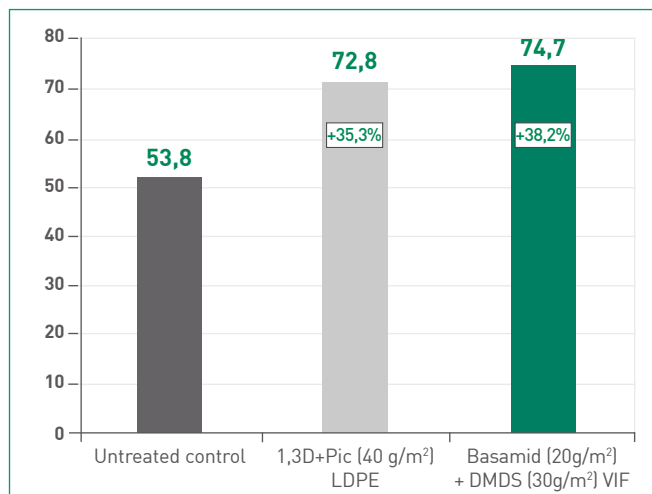


Fig. 2 Production of 1st quality strawberries (MT/ha) in Spain (IFAPA: average of 4 trials in 2012 and 2013)

Another new combined technical solution (DMDS 30g/m² + Metam-Na at 60g/m² both applied by drip irrigation under the beds), is being tested with good expectations of being easily adopted by growers in the future.

According to the expert José Manuel López - Aranda, 'adoption of alternatives by strawberry growers for prolonged and extensive use will depend on the European legislation, consumer responses, scientific explanations for current results, changes to machinery and cultivation practices, and the ability of growers to adopt procedures for using new technologies'. IFAPA has also tested alternative solutions, such as chemistry, but also non-chemical and mixed, to cover the needs of several types of strawberry production: conventional, IPM and organic.

Considering that strawberry cropping in Huelva is already under the new European Sustainable Directive 2009/128 EC and the more restrictive Andalusian specific Regulation for IPM, Certis has tested Tusal, a mixture of strains of Trichoderma (T11+T25) as a 'biological fungicide' to be applied on strawberry crops after transplant by drip irrigation against *Phytophthora* spp. Tusal, as well as Basamid, is listed in the Andalusian Regulation for Integrated Production. Only registered products formulated with Trichodermas are allowed against phytophthora.

Our stewardship programme and the efficacy and yield results of Cleanstart strategies have been very promising, making Certis a reference company in this sector related to Integrated Soil Management for strawberry.

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EMERGING SOIL-BORNE PATHOGENS ON VEGETABLE CROPS IN ITALY

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The vegetable crop sector is particularly exposed to the risk of the emergence of new diseases as a consequence of its dynamism and intensive cropping systems. During the past few years, many new diseases caused by soil-borne pathogens have been detected in Italy, also as a consequence of the changes undergone in soil disinfestation. Many of these pathogens are transmitted through seeds.

In the case of leafy vegetables (both in open field and under greenhouse) several *Fusarium* wilts have recently been observed in Italy on lettuce, wild and cultivated rocket, lamb's lettuce and endive. *Phytophthora tentaculata* was consistently isolated from chicory plants grown in field. Increased attacks of *Rhizoctonia solani* causing losses in yield and quality under favorable conditions on lettuce, wild and cultivated rocket, chicory, endive and leaf beet were recently observed. Leaf spot necrosis caused by *R. solani* has frequently been detected at the harvesting marketable stage on chicory and endive. This pathogen is becoming serious also on tomato rootstocks. Damping-off caused by several species of *Pythium* is considered one of the most important problems on several vegetables, such as spinach, lettuce, rocket, leaf-beet, lamb's lettuce. *Sclerotinia sclerotiorum* and *S. minor* are among the most devastating and widely distributed pathogens on different vegetable hosts.



Fig. 1 *Fusarium* wilt of wild rocket



Fig. 2 Severe attacks of *Rhizoctonia solani* on lettuce grown in tunnel

Among the fruiting vegetables *Phytophthora capsici* is also widespread in almost all areas in which *Solanaceous* (tomato, bell pepper) and cucurbit (zucchini, squash) crops are cultivated. This pathogen can also infect other species such as lima bean and even weeds (*Solanum nigrum*). *P. nicotianae* is reported on tomato hybrids and is an emerging problem on tomato grafted on rootstocks belonging to *Solanum lycopersicum* x *S. hirsutum*.



Fig. 3 *Phytophthora capsici* on zucchini (*Cucurbita pepo*)

Colletotrichum coccodes affects the root system with considerable necrosis deteriorating both the old and young roots on grafted and non-grafted tomato and sweet pepper. A globally emerging disease is 'Vine decline' caused by *Monosporascus cannonballus*: in Italy it is present on watermelon, melon and cucumber.

The presence of these emerging pathogens in the Italian vegetable industry must be critically considered in order to take suitable prevention and management measures.

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INTERVIEW WITH DR. JUAN JESÚS MEDINA MINGUEZ, DIRECTOR OF IFAPA-HUELVA

The Andalusian Institute for Research and Training in Agriculture, Fisheries, Foods and Organic Production (IFAPA) of Huelva, is a reference centre for strawberry production in Spain. It is a very important research and extension centre for farmers, with long experience in testing chemical and non-chemical alternatives for soil disinfection of strawberry.

This work is carried out together with other centres of the Institute located in Alcalá del Río (Sevilla), Churriana (Málaga) and Granada.



1. What is the economic importance of strawberries grown in Huelva for Spanish agriculture?

Nowadays, 93% of the strawberry crop grown in Spain is located in Huelva, Andalusia. The strawberry area grown in Huelva province is about 7,500 ha with a production

of about 300,000 MT. Cultivation started in the area in the 1960s and this is now the main area of European cultivation and the fourth globally, behind the US, Mexico and Turkey, becoming a worldwide reference.

2. What has been the evolution of the crop and what are the key trends of strawberry cropping in Spain?

The crop has evolved over the years working on genetic improvement programmes that have allowed the development of a number of cultivars adapted to different climatic and soil conditions and more resistant to diseases. At the moment, the most common cropping system (over 85% of the area) is based on an annual crop, grown on beds with chemically disinfested soil covered by black mulching. Plants are protected under plastic film tunnels, transparent thermal polyethylene sheets. Another trend is the implementation of IPM, covering around 70% of strawberry cultivation in Huelva. Currently we also have about 200 ha of soil-less cultivation, but the main problem of this system is the lack of suitable varieties.



General view of strawberry cultivation in Huelva

Also, it is important to note that the strawberry farms grow three or four varieties, which are planted and harvested at different times, allowing the continuous supply of European markets from December to June.

3. What are the main soil-borne pathogens that affect strawberry production in Huelva?

The main phytosanitary problems that affect the crop are *Phytophthora cactorum*, *Verticillium dahliae*, *Rhizoctonia solani*, *Fusarium oxysporum*, *Colletotrichum acutatum*, *Macrophomina phaseolina* and nematodes, such as *Meloidogyne hapla* and *Pratylenchus penetrans*.

4. How the pathogen picture is evolving year after year? Are new soil problems appearing?

During recent years outbreaks of new pathogens and the re-appearance of others that were practically eradicated from strawberry cultivation have been observed in various countries. Many experts associate this fact with the changes of products used in soil disinfection and how they are applied (e.g. phasing out of Methyl Bromide). Charcoal rot, caused by *Macrophomina phaseolina*, is an emerging disease that severely affects strawberry.

Considering that many times the level of lethal inoculum of soil-borne pathogens is very low, it is necessary to consider the phenomenon of 'soil fatigue' in intensive monoculture, as in Huelva, where the plot size and specialisation of growers do not allow rotation with other crops.

5. How do you consider the future of soil pest management? Will sustainability be considered a priority?

Several soil treatment techniques without chemicals have been tested: hydroponics, anaerobic soil disinfection, steam, solarisation, biofumigation, biosolarisation, etc.. These techniques could be considered for strawberry as viable alternatives to fumigants only if they allow effective control of the main pests and adequate yields. Non-chemical alternatives are considered viable as they can be repeated season after season in the same plot.

Moreover, it is necessary to consider the important regulatory restrictions in the EU for the use of fumigants. Anyhow, I do not think that the use of chemical treatments will decrease dramatically in a medium-term future. I believe that it is realistic to think about the use of different chemical solutions and methods of application, alongside the non-chemical alternatives.

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