BioGreenhouse

Handbook for Composting and Compost Use in Organic Horticulture

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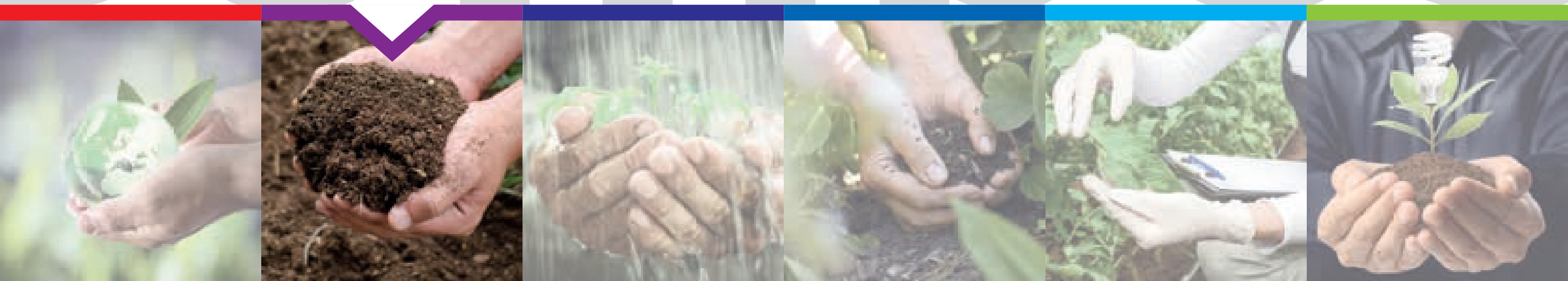
Compost



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Link to the Action: http://www.cost.eu/COST_Actions/fa/FA1105 and: http://www.biogreenhouse.org/

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Preface

In 2008, at the 16th IFOAM Organic World Congress in Modena (IT), about 25 participants expressed their interest in working together in the field of research and development for organic greenhouse or protected horticulture. A two-day workshop was organised in Cologne in 2009 to discuss the subject and to give further support to the collaboration. 45 people from across Europe and from Canada attended this workshop. It was decided to pursue joint efforts in the field of organic protected horticulture, with particular respect to planting material; soil fertility; composting; water management; disease and pest management; climate management and energy conservation; and sustainability. The group also agreed to submit a COST (European Cooperation in Science and Technology) Action on the same subject. The proposal ”Towards a sustainable and productive EU organic greenhouse horticulture” (BioGreenhouse) was submitted in mid-2011.

At the end of 2011, COST approved this proposal as COST Action FA1105 (see http://www.cost.eu/COST_Actions/fa/FA1105 and www.biogreenhouse.org), which set out to build a network of experts working in the field of organic protected horticulture. The aims of the Action are to develop and to disseminate knowledge of new and improved production strategies, methods and technologies for the support of sustainable and productive organic greenhouse/protected horticulture in the EU. This has involved coordinated international efforts and in total, 27 participating COST countries and two COST Neighbouring countries took part in the Action.

This Action offered the framework and funds for experts of the participating countries to meet and to work together in Working Groups focusing on the objectives of the Action. The objectives related to composting and compost use, were: to design strategies for making and using of composts and other amendments in order to improve soil fertility and to achieve disease suppression.

More than 10 experts from different regions and backgrounds worked together on this topic. They have approached their task with commitment by reviewing compost use for organic greenhouses and nurseries and by describing the composting process, various compost types, the microbiological background and the management of the compost process. Attention is also paid to the hygienic aspects of composting, to disease suppressiveness and to the use of compost in growing media; Compost is also compared with digestate and finally an explanation of how growers can assess compost quality and use is given.

Together they produced this publication:
“Handbook for composting and compost use in organic horticulture”

I believe this handbook will prove a unique source of information for all people involved in organic horticulture; for growers, compost producers, researchers, students, teachers, consultants and suppliers. This booklet could serve as a source to improve the composting process and the compost use.

On behalf of the COST Action BioGreenhouse, I want to thank the team of the authors for the work they have done, their cooperative spirit and their perseverance. This work will definitely contribute to better composting and better composts, and to an even more sustainable organic horticulture.

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5 Hygienization Aspects of Composting

Aad Termorshuizen and Beatrix Alsanius

In short:

- Compost use in agriculture always brings about the risk of introducing plant and human pathogens.
- The backbone of the hygienization process consists of temperature, moisture content and chemical compounds formed during composting and activity of antagonists.
- Compost produced by proper composting, i.e. a process that produces high temperatures during a sufficiently long thermophilic phase can be applied safely.
- Farmers should invest in good relationships with compost producers.

One of the major reasons for composting organic residues is the inactivation of plant pathogens and weeds that are normally present in these residues and, if manure is included, the inactivation of animal and human pathogens as well. The hygienization process during composting is based on temperature, chemical compounds and biological mechanisms. The heat generated during the composting process has to be sufficiently high and the thermophilic phase long enough to inactivate the great majority of these potential risk organisms. Thus, good compost process management is a precondition to minimize the risks connected with these pathogens. In this chapter, we focus on these risks and how composters and farmers may deal with them. A good compost management strategy comprises:

- Correct starting mixture;
- Temperature increase;
- Sufficient duration of the thermophilic phase (e.g. 1 Week >65 °c);
- Turning of the compost during the thermophilic phase;
- Avoidance of contamination risk (general organization of the work place);
- Proper storage of the mature compost.

For both the producers' and growers' sake, the process should be monitored and registered in a process protocol (dates of adding different input material, temperature profile in time, turning dates, dates for addition of water and water quality data).

The fate of pathogens during composting is described in several review articles [3, 7, 9]. We therefore focus more on the general approach composters can take to minimize phytohygienic problems.

5.1 Fate of pathogens during composting

The backbone of the hygienization process is a sufficiently high temperature linked with moisture content, pH, toxin and antibiotics formation as well as active antagonists[2]. Organisms posing a risk are pathogens capable of withstanding such conditions. Pathogens occur very commonly in feedstock organic residues, but the great majority, including pathogens of shoots and leaves (airborne pathogens), is inactivated during the thermophilic phase[7]. The short persistence of these heat-sensitive pathogens can be explained by leakage of nutrients through the thin cell walls. In addition, these thin cell walls are highly susceptible to attack by predators and antagonists. These mechanisms are also acvtive during the preheating and maturation phases of composting; but it is mainly the high temperatures prevailing during the heat phase of composting that inactivate most of the airborne pathogens[12].

Additional phytosanitary risks include some highly persistent soil-borne pathogens (see Table 5.1 for examples) along with animal and human (Table 5.2) pathogens[7]. Some of them are completely inactivated during proper composting while others may survive the composting process. On first sight, this renders the use of compost as too risky, but as we will show, these risks can be dealt with properly.

Generally, pathogens that are able to survive composting temperatures of >60°C can be considered as risk pathogens. The mere existence of risk pathogens does not mean that the use of compost leads to phytosanitary problems. The likelihood of phytosanitary problems occurring has to be based on local conditions, mainly:
The likelihood of occurrence of risk pathogens in the feedstock organic matter and the intended application of the mature compost[9]; in addition, for organisms pathogenic to humans, the mechanisms responsible for provoking infections as well as the infectious doses also need to be taken into account.

Cardinal points for selected human pathogens that may be transmitted by compost and probabilities for their inactivation during composting are presented in Table 5.3. However, their survival may also be improved in response to the matrix[1]. Feeding regime and the roughage type of the feed may affect the survival and transmission of human pathogens to vegetables; but survival patterns are pathogen dependent[6]. Also, heat shock treatment of E. coli O157:H7, *Listeria monocytogenes* and *Salmonella* spp. for one hour at 47.5 °C enabled their survival at temperatures above temperature maximum[8].

Thus, the presence of risk pathogens at a given location is context-dependent: the occurrence of risk pathogens is region-dependent; the pre-treatment of residues from the food or feed industry can be factory-dependent; and composting conditions will be composter-dependent. Many pathogens are host-dependent, thus proper rotation of crops can solve this problem. Quarantine pathogens (see e.g. www.eppo.org) have a special status, and handling protocols are usually enforced by law. These may include the possibility of composting infected residues.

5.2 Risk of pathogens and weeds present in residues offered for composting

Phytosanitary risks are absent if the incoming organic material does not contain any pathogens or weeds at all. This is not normally the case as airborne pathogens and weeds occur nearly everywhere, and some persistent soil-borne pathogens are also common or even very common, such as the wilt pathogen *Verticillium dahliae* (occurring in e.g. chrysanthemum) and *Rhizoctonia solani* (in e.g. lettuce). A compost producer who is not aware of the presence of these pathogens in a particular batch of residues will run into problems. Therefore, a worst-case scenario, that assumes the presence of regionally common soil-borne pathogens in a given batch, would need to be followed. This worst-case scenario can then be based on the composition of the incoming materials, which is normally known by the compost producer. For example, if woody materials or grass clippings enter the composting plant, the composter will know that only a few low-risk pathogens can be present, while in the case of e.g. potato residues a whole arsenal of intermediate to high risk pathogens can be present. Therefore, potato residues from the processing industry are not offered for composting in the Netherlands unless they have been cooked. On the other hand, tomato residues that are very common in Israel frequently serve as feedstock for composting due to their strong capacity to suppress several plant pathogens[10] (see chapter 6). The common *Fusarium oxysporum* may well occur on tomato residues and is rather heat-tolerant (Table 5.1) and therefore, high-quality composting is essential.

The main entry for human pathogens into feedstock material occurs through the addition of animal wastes. The spectrum of potential zoonotic organisms differs between different farm animals (Table 5.2) and also depends on national guidelines. For example, input of organic wastes from animal farms retrieved from conventional husbandry may be added to composts used in organic horticulture in some countries (e.g. in Switzerland).

The identification of sanitary risks of composting is a function of residue pretreatment. If untreated risk residues have to be dealt with, there are three options:
- Do not allow these into the composting process,
- Sell composts from these residues to non-risk applications or
- Perform an additional treatment to inactivate the pathogens.

The latter option is expensive and economically and environmentally unviable. Owners of such residues may also consider other applications such as the generation of biogas but then the fate of pathogens in the remaining digestate should be considered, as well[11] (see also chapter 7).

Pathogens without quarantine status that appear on lists of persistent, heat-tolerant pathogens, do not necessarily pose risks. To decide about this, detailed knowledge of the ecology of pathogens and of the local farming situation is important for risk assessment of the input material. Questions to be asked in this context are

- What are the cardinal points for inactivation?
- How is the pathogen transferred? Is it free-living or transferred by a vector?
- What is the biology of the vector?

Some issues on risk plant pathogens are illustrated in Table 5.1.

European legislation (EG 1069/2009; EG 1774/2002; EU 142/2011) is clear with respect to appropriate animal wastes or by-products introduced into compost. In the final product, *Salmonella* may not be detected in any sample and the average number of viable counts for *E.coli* or *Enterococcaceae* isolated from five representative samples shall not exceed 1000 CFU; of these only one of the five samples may have 1000-5000 colony-forming units (CFU). Reference to *E. coli* in such control programs stands for the organism as an indicator organism and not for pathogenic serotypes of *E. coli*. The presence of enterohaemorrhagic *E. coli* is not acceptable due to its very low infectious dose (<100 cells). As human pathogens may be unevenly distributed in the compost, compost producers need to be careful about the load of contamination in the animal based raw input material, reflect on their procedure to obtain representative samples, and reflect on the meaning of a negative result.

5.3 Quality of the composting procedure

Improper composting techniques may also contribute to a failure to inactivate pathogens, the most important being:

- Improper or infrequent turning of the compost.
- The margins of the compost may not be exposed to heat. Therefore, compost turning has to be done by trained personnel so as to ensure that the organic material situated at the margin of the compost heap is placed in the centre after turning and exposed to high temperatures.
- Improper use of machines.
- Shovels should not move from feedstock residues to mature compost as the mature compost can then become contaminated with pathogens. This is especially a risk for small-scale composters who may have only a single shovel available. In that case machine cleaning when moving from mature compost to untreated organic residues is essential.
- Recolonization of mature compost with pathogens.
- This risk increases with the storage duration of the compost and especially when it is stored outdoors, where notably animal pathogens could enter the compost from bird visits. Weed seeds can also infest such open piles.

Composting can be done at large or small scale (Table 5.4). Large-scale composting is usually done by professional compost producers, and small-scale composting usually by the farmers themselves or by farmers groups such as Kibbutzim in Israel. Large-scale compost producers usually have good control on the process conditions, but their control on the quality of the incoming materials is limited. Their preference to sell the compost as early as possible may also have a negative effect on its end-quality. On the other hand, in small-scale composting, control on the process conditions may be more limited, but there is a better control of the incoming materials. If farmers use the compost they produced themselves only on their own fields, they will not import new pathogens from elsewhere. There is, however, a possibility of spreading the farm’s own pathogens over multiple fields, which reduces the phytosanitary effect of rotation on soil-borne pathogens.

5.4 Conclusion

On first sight, it seems straightforward to reject any residue for composting if there is even only a tiny phytosanitary risk. However, this is an unnecessarily cautious approach, possibly rendering most, if not all, residues unfit for composting. This is therefore an unwanted approach, since application of compost is one of the few possibilities for management of agronomic soil quality. As we explained here, most risks can be dealt with, providing a proper composting procedure has been followed. In many cases apparent risks may be absent, e.g. if the pathogen of interest is not occurring in a certain region, or if it is not present in the feedstocks. It is, therefore, of importance to consider the real existing risks and to have a clear plan for their management. An individual farmer has to weigh the pros and cons of own home-composting against those of professional, large-scale composters (Table 5.4). If compost is to be obtained from the latter, it is important that farmers build a good relationship with composters.

Table 5.1

Examples of some (potential) risk plant pathogens. Instead of attempting to present a full list of pathogens, we would rather like to make the point here that reasoning about the phytosanitary risks of allowing certain residues for composting is context-dependent. An longer list of potential risk pathogens can be found in (7).

Organism	Host	Remarks	Approach	References
Cucumber Green Mottle Mosaic Virus (CGMMV)	cucumber, (water) melon	heat-resistant, persistent in soil and contact-transmitted	risk material not to be applied in cucumber/melon cropping systems	13
Fusarium oxysporum	various, including tomato and basil	inactivation temperature about 60 °C	composting conditions are crucial	14
Olpidium brassicae, vectoring two viruses	lettuce, cucumber	inactivation temperature 53 °C (3 wk)	problematic only if belowground plant tissues are offered for composting, e.g. bulb materials.	15
Tobacco Rattle Virus (TRV)	various	highly heat resistant	considered unproblematic as it is vectored by heat-sensitive nematodes	2
Tomato Mosaic Virus (TMV), Tobacco Mosaic Virus (ToMV)	various	heat resistant	heat resistant, but probably sufficiently reduced during composting	16,17
Verticillium dahliae	many, including chrysanthemum	heat-sensitive; however common in temperate regions and able to cause disease at low levels of inoculum	avoid bulk feedstocks from *Verticillium*-contaminated residues	2

Table 5.2

Dominant microbial hazards introduced through animal wastes (4).

Cattle	Pig	Chicken	Sheep
Salmonella			
Shiga-toxin producing *E. coli*	*Salmonella* spp.	*Campylobacter* spp.	Shiga-toxin producing *E. coli*
Listeria monocytogenes	*Campylobacter* spp.	*Salmonella* spp.	
Campylobacter jejuni	*Yersinia enterocolitica*	ESBL	
	ESBL[1]		

[1] ESBL=extended spectrum betalactamase-producing bacteria.

Table 5.3

Cardinal points for temperature, pH and water availability of some human pathogenic bacteria and probability of their inactivation during composting. Ranges may vary in relation to the matrix used. Figures for cardinal points and for probability of inactivation have been extracted from (1) and literature therein and from (5), respectively.

Organism	Temperature (°C)		pH		Water availability	Expected inactivation by composting
	Minimum	Maximum	Minimum	Maximum	Minimum	
Bacillus anthracis						-[2]
Bacillus cereus	5	46	4.4	9.3	0.93	-
Campylobacter jejuni	27-30	45	4.9	9.0	0.98	NI
Clostridium perfrigens						-
Escherichia coli O157:H7	8	43	4.0-4.4	9.0	0.95	+
Listeria monocytogenes	-18 (survival) 0-4 (growth)	44	4.6	9.0		NI
Salmonella spp.	6	46	4.0	9.5	0.94	++
Shigella spp.	7	46	4.9	9.3	0.98	NI
Yersinia enterocolitica	0	44	4.4	9.6	0.97	NI

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[2] ++: total inactivation; +: inactivation; -: survival; (PI): no information on process but predicted inactivation of pathogen; (-) no information found, but predicted survival of pathogen, NI: no information found

Table 5.4

Pros and cons of small-scale composting by individual farmers against large-scale composting by professional compost producers.

Scale of compost producer	Monitoring of the composting process	Pathogen presence in the to-be-composted material	Feedstock (e.g. manures)
Large-scale	generally high standards	generally more pathogen species	better availability
Small-scale	varying from low to high standards	generally less pathogen species; but higher risk of introducing high quantities of pathogens occurring on crops grown by the farmer	lower availability

Figure 5.1 *Machinery can cause contamination if they move directly from handling fresh residues to cured compost; this bad practice is not shown in this illustration, though. Photo: Paula van Ommen.*

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