Information sheet 1.06

Soil treatment

This information sheet is a supporting document to Appendix A ('Standardised checklist of risk reduction options') of the Guidance of the EFSA Plant Health Panel on quantitative pest risk assessment

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A. Description of the RRO

Management practices, such as use of crop rotations, cover crops and green manures, organic amendments, and conservation tillage, contribute to building active, diverse, disease-suppressive soil microbial and micro-arthropod communities. All these practices have been shown to effectively reduce major soil borne diseases in some situations (Larkin, 2015). However, in many cases this is not enough and additional RROs have to be put in place. Prevalence of many microorganisms living in the soil, including not only plant pathogens but also some worms, slugs, centipedes, insects and seeds can be reduced (ideally completely eliminated) by chemical (i.e., fumigants, other pesticides), physical (i.e., flooding, heat, mechanical removal) and biological (i.e. suppression, biofumigation) methods. Although methyl bromide was the fumigant of choice for many pre-plant soil applications in the past (Martin, 2003; Zasada et al., 2010), its phase-out triggered interest on chemical and non-chemical alternatives. Currently, there are only a handful of chemicals registered for soil treatment in the EU and the situation is constantly changing (EC, 2016). In addition to fumigation, the measures considered in this fiche include: heating, solarisation, flooding, soil suppression, augmentative biological control, and biofumigation (Martin, 2003; Zasada et al., 2010), which can be applied alone or in different combinations. Some of these measures can also be applied to growing media other than soil and also to tare soil, which is the soil attached to harvested products like ware potatoes, sugar beets, carrots or leeks (Overbeek et al., 2014; EFSA PHL, 2015).

a) FUMIGATION. Soil to be planted with high value crops, as ornamentals, fruit trees, strawberries, etc., is frequently treated with fumigants (e.g., Dazomet, Metam sodium, Metam potassium; EU, 2016) for control primarily of nematodes but also of soil borne fungi, as *Fusarium* and *Verticillium*, weeds and bacteria (Agrios, 2005; Klosterman et al., 2009).

b) HEATING. In some particular cases, e.g., greenhouses, and sometimes in seed beds and cold frames, soil can be sterilized by the heat carried in live or aerated steam, hot water or dry heat. For this method to be effective, soil moisture should be 50-85% of field capacity and soil temperature above 13°C at a 15.2 cm depth (Martin, 2003; Pennstate Extension, 2016).

d) SOLARISATION. Solarisation has been used for the management of soil borne pathogens since 1976 as a pre-plant soil treatment and is still widely used in many areas of the world. There may be limits to its effectiveness in some areas where warm temperatures coincide with rainfall since cloud cover and rain will reduce the effect of solar radiation under the plastic. However, selection of appropriate plastics for covering the soil may improve efficiency in these locations (Frank, 2003; Zasada et al., 2010).

e) FLOODING. Flooding is used as a standard agronomic practice in cranberry production, and its insecticidal value against a number of pests (i.e., cranberry fruit-worm, *Acrobasis vaccinii*, southern red mite, *Oligonychus ilicis*, and early-season cutworms) was recognized more than 70 years ago.
Similarly, flooding of vineyards for 40–50 days during the winter months has been shown to limit phylloxera, *Viteus vitifoliae*, populations (Granett et al., 2001). Flooding has also been used against soil nematodes (Spaull et al., 1992; Overbeek et al., 2014). This method can be effectively used against root-knot nematodes (*Meloidogyne* spp.) (Duncan, 1991), the stem nematode (*Ditylenchus dipsaci*) (Muller and van Aartrijk, 1988), the burrowing nematode (*Radopholus similis*) (Stover, 1979), and the potato cyst nematodes Globodera *pallida* and *G. rostochiensis* (Ebrahimi et al., 2016). This RRO can only be used where water is abundant and either in crops tolerant to flooding for a prolonged period (Vincent et al., 2003) or during the white period in between two crops.

f) SOIL SUPPRESSION. Suppressive soils hold considerable potential for managing soil borne pathogens. When suppression has a biological origin, identifying the causal organisms is the crucial step in realizing this potential. Identifying the key suppressive organisms may lead to the development of new tactics to create and maintain pest specific soil suppression (Borneman and Becker, 2007).

g) AUGMENTATIVE BIOLOGICAL CONTROL. When soil suppression can be attributed to the effects of individual or selected groups of microorganisms and is transferable, these microorganisms can be added to soil, seedlings, growing media, etc. prior to transplanting using different methods. One of the best-described examples occurs in take-all decline soils. In Washington State, take-all decline results from the build-up of fluorescent *Pseudomonas* spp. that produce the antifungal metabolite 2,4-diacetylphloroglucinol (Weller et al., 2002; Borneman and Becker, 2007).

h) BIOFUMIGATION. The practice of incorporating brassicaceous plant material into the soil to control soil borne organisms has been coined biofumigation. When a field of brassica plants is mechanically chopped and quickly incorporated into the soil, a flush of isothiocyanate can be released in sufficient concentration to impact plant-parasitic nematode populations and a few soil borne fungi including *Verticillium* spp. (Klosterman et al., 2009; Zasada et al., 2010; Wei et al., 2016).

All the RROs exposed above can affect the probability of the pest being associated, spatially or temporally, with the pathway at origin, where these RROs may have a direct effect on the prevalence of the pest in the crop.

B. Risk factors

Table 1. Points of application of measures.

RROs	Place of production at origin		Processing at origin	Export	Transport	Entry point	Destination
	Pre-harvest	Harvest	Post-harvest			Import	
Fumigation	X		x			x	x
Heating	X		x			x	x
Solarisation	X						
Flooding	X		x			x	x
Soil suppression	X						
Augmentative BC	X						
Biofumigation	x		x			x	x

C. Parameters to consider regarding effectiveness of the RRO

EFSA PLH Panel (2015) extensively reviewed the risks to plant health posed by EU import of soil or growing media. The Panel found that the 'prohibition of import' is the only phytosanitary measure with a very high effectiveness and a low uncertainty. The panel considered, though, that several measures included in this RRO could be highly effective (i.e., heating, fumigation). However, their effectiveness depends on several factors, especially on the characteristics of the growing medium, the type of harmful organisms and the procedure of application. Because of the variability in their effects, the effectiveness of these RROs to mitigate risks posed by the import of soil or growing media is highly uncertain.

D. Applicability / feasibility of the RRO

The main technical limitations for the implementation of these RROs are listed in the synoptic table at the end of this fiche. For instance, presently authorised fumigants (EC, 2016), the methyl isothiocyanate generators Metam sodium, Metam potassium and Dazomet are very effective against nematodes and are widely used. However, although these are broad spectrum biocides, their performance is inconsistent because of inadequate volatility, which results in poor soil distribution and a relatively poor capability to penetrate and kill old woody roots or tubers (Zasada et al., 2010).

Some relevant examples for this group of RROs include:

a) International Standards for Phytosanitary Measures. ISPM 36. Integrated measures for plants for planting (FAO, 2016).
Appendix 1: Examples of pest management measures to reduce the pest risk of plants for planting at a place of production.

Examples of measures that may be applied to reduce the pest risk of plants for planting at a place of production categorized by pest group.

Pest Group	Available measures
Soil-borne pests able to colonize the plant	• Isolation from sources of infestation (e.g. buffer zone or geographical distance from other host plants, physical isolation using a glasshouse or polytunnel, growth of plants on raised benches, temporal isolation) • Derivation from mother plants that have been tested and found free from the relevant pest • Production within a specified certification scheme or clean stock programme • Testing of samples of the plants for freedom from pests • **Pre-planting soil treatment** or testing for freedom from pests such as fungi, nematodes, viruses transmissible by nematodes • Use of soil-less growing media.
Soil-borne pests in soil attached to plants	• Isolation from sources of infestation (e.g. buffer zone or geographical distance from other host plants, temporal isolation) • **Pre-planting soil treatment** or testing for freedom from pests (especially nematodes, fungi) • Pesticide treatment (e.g. drench or fumigation) prior to export • Roots washed free from soil (and repotted in **sterile growing medium** in a sterile container).

b) Council Directive 2000/29/EC[1] on protective measures against the introduction and spread into the European Union territory of organisms harmful to plants or plant products.

Annex IV. Part a. Special requirements which must be laid down by all Member States for the introduction and movement of plants, plant products and other objects into and within all member states. Section I. Plants, plant products and other objects originating outside the Community.

Plants, plant products and other objects	Special requirements
34. Soil and growing medium attached to or associated with plants, consisting in whole or in part of soil or solid organic substances such as parts of plants, humus including peat or bark or any solid inorganic substance, intended to sustain the vitality of the plants, originating in: — Turkey, — Belarus, Estonia, Latvia, Lithuania, Moldavia, Russia, Ukraine, — non-European countries other than Cyprus, Egypt, Israel, Libya, Malta, Morocco, Tunisia	Official statement that: (a) the growing medium, at the time of planting, was: — either free from soil, and organic matter, or — found free from insects and harmful nematodes and subjected to appropriate examination or heat treatment or fumigation to ensure that it was free from other harmful organisms, or — subjected to appropriate heat treament or fumigation to ensure freedom from harmful organisms, and (b) since planting: — either appropriate measures have been taken to ensure that the growing medium has been maintained free from harmful organisms, or — within two weeks prior to dispatch, the plants were shaken free from the medium leaving the minimum amount necessary to sustain vitality during transport, and, if replanted, the growing medium used for that purpose meets the requirements laid down in (a).

E. Other RROs that may lead to similar effects

Any RRO aimed at reducing the pest prevalence at origin (field treatments, e.g., use of resistant cultivars) or in the consignment (post-harvest, e.g., irradiation) may lead to similar results.

F. Combinations of RROs that include this RRO

Depending on the type of pest and commodity under scrutiny, a soil treatment can be a "stand-alone" measure. However, it may be combined with many other RROs, and should be combined with supporting measures such as visual inspection and/or laboratory testing.

G. Conclusion

This family of RROs may have a direct effect at origin on the prevalence of the pest in the crop (in field treatments) but also in tare-soil (post-harvest treatments). The main technical limitations for the measures included in this RRO may be related to the availability of authorised products (fumigants, suppressive soil, biological control agents), inadequate volatility (fumigants), soil accessibility, temperature and moisture (fumigants, heating), compatible weather conditions (solarisation), and water availability and crop tolerance (flooding). One of the main advantages of this RRO family lays on its compatibility with many other RROs.

[1] Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organism harmful to plants or plant products and against their spread within the Community.

Synoptic table for the RRO.

Measure	Target	Area of application	Expected effect	Main technical limitations of use	RROs with similar effects / most often in combination
Fumigation	Soil-borne pests	In the field (open or protected cultivation) and in post-harvest.	Reduction of the prevalence of the pest or of its vector in the soil, including tare soil.	Availability of authorized active substances. Inadequate volatility.	Any other measure in this table.
Heating	Soil-borne pests	In the field (open or protected cultivation) and in post-harvest.	Reduction of the prevalence of the pest or of its vector in the soil, including tare soil.	Soil accessibility, soil temperature and moisture.	Any other measure in this table.
Solarisation	Soil-borne pests	In the field (open or protected cultivation).	Reduction of the prevalence of the pest or of its vector in the soil.	Coincidence of warm periods with sunny days. Congruence with cropping calendar/rotation.	Any other measure in this table.
Flooding	Soil-borne pests	In the field (open or protected cultivation) and in post-harvest.	Reduction of the prevalence of the pest or of its vector in the soil, including tare soil.	Water availability. Crop tolerance to flooding.	Any other measure in this table.
Soil suppression	Soil-borne pests	In the field (open or protected cultivation).	Reduction of the prevalence of the pest or of its vector in the soil.	Availability of suppressive soils.	Any other measure in this table.
Augmentative BC	Soil-borne pests	In the field (open or protected cultivation).	Reduction of the prevalence of the pest or of its vector in the soil	Availability of registered biological control agents.	Any other measure in this table.

Biofumigation	Soil-borne pests	In the field (open or protected cultivation) and in post-harvest.	Reduction of the prevalence of the pest or of its vector in the soil, including tare soil.	Congruence of brassica cultivation with existing crop rotation.	Any other measure in this table.

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