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EPPO STANDARD - PHYTOSANITARY PROCEDURES

PM 3/93 (1) Management of phytosanitary risks for potato crops resulting from movement of soil associated with root crops and potatoes

Specific scope: This Standard describes the phytosanitary risks posed to potato by the introduction of potentially infested soil onto land that will be used to grow a potato crop. Such soil can result from the grading, packaging and processing of potato tubers and may contain tubers and other potato plant debris. It can also be soil associated with other harvested root crops, which have been grown on land that has previously been used to grow potato. This Standard provides recommendations to NPPOs to set rules for the return of soil to agricultural fields and to authorize its safe/appropriate treatment and disposal, based on a risk assessment carried out by the handling facilities. It also provides guidance for operators (growers and industry) to minimize the phytosanitary risks associated with soil along the whole production chain, from growing the crop to final packaging or processing. The risk posed by soil associated with plants for planting (including seed potatoes) and the case of soil known to be infested by a specific regulated pest are not covered by this Standard.

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Authors and contributors are given in the Acknowledgements section.

Definitions

Soil	Soil is defined as a growing medium that is naturally occurring, composed of the loose surface material of the earth and consists of a mixture of minerals and organic material (EFSA PLH, 2015). For the purpose of this Standard, the definition of soil also includes all foreign matter associated with the root crop after harvest (e.g. loose soil, stones, plant debris).
Handling facility	Any facility involved in sorting, brushing, washing, trimming, grading or packing potato and root crops for processes such as canning, freezing and frying (chips and crisps), and industrial purposes such as starch production or preparation for retail and wholesale. A handling facility may be a small facility at the farm level or a large facility at an industrial scale.
Root crops	Root crops are defined as any field crop of which underground parts are used as food or fodder (e.g. beets, carrots, sweet potatoes, turnips, endives, salsifies, leeks, etc.). For the purpose of this Standard, potatoes are excluded from this definition.

Other terms are used as defined in ISPM 5 (FAO, 2019a) such as commodity, pathway, pest, plant for planting, place of production and production site.

1 | INTRODUCTION

Naturally occurring soils harbour many organisms, some of which are beneficial to plants (e.g. mycorrhiza fungi), while others are pests of cultivated plants or pose a threat to biodiversity. Pests such as bacteria, fungi, insects, mites, molluscs, nematodes, viruses and weeds can be present in soil or in organic material mixed with the soil. Potential pests not yet known to science may also be present.

Whenever soil is moved, including with wastewater, it may act as a pathway for pests. However, when a soil-borne pest is discovered at a production site, it is not usually possible to identify the origin of the pest or when it was introduced. This is because for many pests, several host crops must be grown before the pest population increases to detectable levels in the soil or symptoms of the pest develop. Moreover, soils from different origins may have been mixed in the handling facilities before being returned to a production site.

The risk associated with soil on plants for planting, including seed potatoes, is not addressed in this Standard. Movement of soil with plants for planting is already regulated for many crop species (EFSA, 2015). For example, in the European Union (EU), field soil sampling and testing to demonstrate freedom from *Globodera rostochiensis* and *G. pallida* (potato cyst nematodes) is a pre-planting requirement for the production of seed potatoes and certain other plants for planting (EU, 2007). For production of seed potatoes, there is a general requirement of ≤1 or ≤2% w/w soil associated for seed potatoes and for high grades of pre-basic and basic material ≤1% w/w [EPPO Standard PM 8/1 *Commodity specific phytosanitary measures*: *Potato*, EU marketing directive for seed potatoes (EU, 2014a,b, 2019b)]. In addition, most root crops are grown from seed, which should be soil-free. There are also purity standards for inert matter and seed can be subject to testing for specific pests. Moreover, seed for some root crops, such as sugar beet, is produced within certification schemes which include crop inspection.

In contrast to plants for planting, soil associated with potatoes and root crops for packing or processing is mostly not regulated or only rarely [e.g. sugar beet in the protected zones for *Beet necrotic yellow vein virus* in the EU (EU, 2019a)]. Farm operations (e.g. the harvesting of root crops), the increasing use of the same equipment/machinery on multiple farms, the use of land at considerable distance from the main farm and the renting of land that belongs to different farms, are the main contributors to the spread of soil and its associated pests. In addition, the long-distance and cross-border movement of potatoes and root crops for processing and preparation for marketing has increased greatly in recent years due to more centralized and larger processing facilities, resulting in an increased risk of long-distance spread of pests.

Topsoil has a high content of organic matter and nutrients that maintains soil fertility. Soil is a limited resource and ideally should not be removed from the field. However, soil losses (harvest erosion) may reach 10 tonnes/ha in sugar beet, with an average of 5 tonnes/ha. With potato, the average soil losses are 2 tonnes/ha (Panagos et al., 2019). Potatoes and root crops delivered to processors are often associated with high levels of soil (usually between 2% and 10%, but it may be more). This represents a large quantity of soil, for example 2% soil on a 50 tonnes/ha crop means that 1 tonne/ha of soil requires management. As is it a limited and valuable resource, there is a need in certain countries to return soil to agricultural land. However, soil should only be returned to agricultural fields if the risk assessment concludes that the associated pest risk is acceptable.

As an example of the potential risk of pest introduction with waste soil, *G. pallida* was detected at a packing facility in north-east Germany handling potatoes from another country. This part of Germany is declared to be free from *G. pallida*. The pest was then found in potato lots received from a second country (Niere, pers. comm., 2018). Furthermore, in Slovenia, the first report of *G. pallida* was suspected to be linked to wastewater discharged onto grassland fields from the washing of ware potatoes imported from countries where the pest occurs (EPPO, 2012b). Similarly, spread of cysts can also occur with the movement of soil from infested zones to non-infested zones within the same country. Often soil-borne pests are extremely difficult to control, and eradication as well as containment is often not feasible, or may require decades of continuous action. For example, the potato cyst nematode eradication campaign in Australia continued for more than 20 years (DPIRD, 2018).

This Standard provides:

(a) A description of the pest risks involved with the movement of soil associated with harvested potatoes and root crops intended for grading, packing or processing (Section 2)

(b) Recommendations to NPPOs (Section 3):
- To raise awareness
- To require of handling facilities that only soil with acceptable risk is returned to agricultural fields
- To require that an assessment of the risk is performed by the handling facility
- To approve treatment methods and to audit the system

(c) A description of the role and responsibilities of operators (Section 4):
- To give guidance on how to reduce the phytosanitary risk of soil associated with potato and root crops
- To recommend how the risk assessment should be performed by handling facilities when soil is intended to be returned to agricultural fields
- To recommend how the risk should be managed by the handling facility.

Any recommendation in this Standard should not contravene/override local or national regulations on the disposal or transportation of soil. As this Standard was developed by the Panel on Phytosanitary Measures for Potatoes, the first version of this Standard focuses on soil associated with potatoes or soil associated with root crops grown on land which has previously been used to grow potatoes. The scope of this Standard may later be extended to cover the management of phytosanitary risks for root crops.

2 | PEST RISKS INVOLVED WITH SOIL ASSOCIATED WITH HARVESTED POTATOES AND ROOT CROPS

Soil associated with harvested potatoes and root crops is potentially infested with pests and can pose a threat if introduced onto land which is then used to grow a potato crop.

Such soil, which can result from the grading, packaging and processing of potato tubers, may also contain tubers, other potato plant debris and weed plants, which if returned to a production site may grow, thereby enabling the survival of many pest species. The management of potato volunteers [EPPO Standard PM 3/89 *Control of volunteer potato plants* (EPPO, 2020)] and weeds is a key element in the control of soil-borne pests.

Some soil-borne pests can persist in soil for a few years, whereas others can remain viable for decades. The association of important soil-borne pests with soil and their ability to survive in soil is described in Table 1. The list of pests in this table is a selection of soil-borne pests recommended for regulation as quarantine pests by EPPO. However, there are other pests which are serious soil-borne pests of potatoes and consideration needs also to be given to these pests (e.g. *Spongospora subterranea* and *Ditylenchus destructor*).

TABLE 1 Association of pests with the soil pathway and their survival in soil

Pests of potato	Taxonomic group	Categorization (EPPO lists)	Root crop hosts used in rotation with potato	Association with the soil pathway	Survival in soil without host
Clavibacter sepedonicus (CORBSE)	Bacteria	A2 List	*Beta vulgaris* (*)	The bacterium itself is thought not to survive well unprotected in soil.	The bacterium is capable of surviving 2–5 years in dried polysaccharide 'slime' that arises from infected potato tissue and adheres to the surface of materials and machines, e.g. on sacks, boxes, crates, bins, truck beds, cutting, harvesting and grading equipment, containers, storage walls, floors, etc. These serve as sources of continued contamination, even at temperatures below freezing (EPPO/CABI, 1997a). Cool and dry conditions promote long-term persistence, while repeated wetting and drying cycles decrease the ability of ring rot bacteria to survive (Elphinstone, 2010; Inglis et al., 2013).
Ditylenchus dipsaci (DITYDI)	Nematoda	A2 List	*Allium cepa*, *Allium sativum*, *Beta vulgaris*, *Allium porrum*, *Petroselinum crispum* (*,#)	Fourth-stage juveniles (J4) can survive for many years in soil or plant debris. The species is rarely found in soil when no infected hosts are present. Long-term survival is possible in a host or remaining parts of the host when many nematodes desiccate (anhydrobiosis) and form so-called eel wool.	Such nematodes can survive desiccation in soil (as fourth-stage juveniles) but are usually found in dried plant parts such as bulbs and seeds (EPPO PM 7/87).
Epitrix cucumeris (EPIXCU)	Insecta	A2 List	*Beta vulgaris*, *Allium cepa* (*,#)	Eggs, larvae, pupae and adult stages are associated with soil. Adult beetles overwinter in the soil near to their host plants, often at the field margin. Eggs are laid in the soil. Larvae feed on the roots and tubers for about 2 weeks and pupate in the soil. Pupation takes up to 13 days (EPPO, 2012a; EPPO, 2021a).	Overwintering adults can survive for months within the soil (CABI, 2018a). There is no information on how long eggs, larvae and pupae can survive in the soil with and without plant material (EPPO, 2012a).
Epitrix papa (EPIXPP)	Insecta	A2 List		Probably similar biology to *E. cucumeris* and *E. tuberis*.	Probably similar to *E. cucumeris* and *E. tuberis*.

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TABLE 1 (Continued)

Pests of potato	Taxonomic group	Categorization (EPPO lists)	Root crop hosts used in rotation with potato	Association with the soil pathway	Survival in soil without host
Epitrix tuberis (EPIXTU)	Insecta	A1 List	*Armoracia rusticana*, *Beta vulgaris*, *Raphanus sativus* (*,#)	Eggs, larvae, pupae and adult stages are associated with soil. Adult beetles overwinter in the soil near to their host plants, often at the field margin. Eggs are laid in the soil. Larvae feed on the roots and tubers for 2–6 weeks and pupate in the soil. Pupation takes up to 22 days (EPPO, 2012a; EPPO, 2021b).	Overwintering adults can survive for months within the soil (CABI, 2018b). There is no information on how long eggs, larvae and pupae can survive in the soil with and without plant material (EPPO, 2012a).
Globodera pallida (HETDPA)	Nematoda	A2 List	(#)	Soil can contain cysts with eggs and second-stage juveniles. Males may be present in soil only during the growing season of the host, and die after fertilizing the females. Males are not infective.	Cysts (with eggs) can survive for years (20 or more) whereas second-stage juveniles have a much shorter-time survival (weeks) when no hosts are present. Natural decline of *G. pallida* in fields after 1 year averaged 69% (50–85%) for sandy and peaty soils, but only 26% for loamy and clay soils (Been et al., 2019). Inundation (Ebrahimi et al., 2016) and heat (>50°C) (Viaene et al., 2019) reduce survival of cysts. Moisture also plays a role, dry cysts being much more resilient in high-temperature conditions (Viaene et al., 2019).
Globodera rostochiensis (HETDRO)	Nematoda	A2 List	(#)	Soil can contain cysts with eggs and second-stage juveniles. Males may be present in soil, only during the growing season of the host, and die after fertilizing the females. Males are not infective.	Cysts (with eggs) can survive for years (20 or more) whereas second-stage juveniles have a much shorter-time survival (weeks) when no hosts are present. Natural decline (in fields) of *G. rostochiensis* was slower than that of *G. pallida* (Been et al., 2019). Inundation reduces survival of cysts (Ebrahimi et al., 2016).
Pheletes californicus (LIMOCF)	Insecta	A1 List	*Beta vulgaris*	Infested soil may carry eggs, larvae, pupae and overwintering adults. Depending on the moisture, temperature, and firmness of the soil, the eggs are oviposited from just below the soil surface to depths of 15 cm. Once eggs hatch, larvae feed on roots, seeds or germinating host plants. Pupation occurs at depths of 5–10 cm in the soil. Adults overwinter in the soil and do not emerge until soil surface temperatures are around 10 to 13°C (CABI, 2018c; EPPO, 2005; Stone, 1941).	Eggs laid in compact soil or near the soil surface can suffer high mortality if rapid fluctuations in moisture and temperature occur (CABI, 2018c; EPPO, 2005). There is no information in the literature about how long larvae can survive in the soil without hosts. According to Campbell (1937), larvae avoided dry soil, soon dying of desiccation if they remained in dry soil, whilst saturated soil caused almost complete cessation of activity and sometimes death. Low temperatures induced larval dormancy (Parker & Howard, 2001). There is no information in the literature about how the temperature and humidity can cause mortality in pupae or overwintering adults.
Leptinotarsa decemlineata (LPTNDE)	Insecta	A2 List	*Daucus carota* subsp. *sativus* (*)	Fourth larval stage, pupae and adult stages are associated with soil. Adult beetles overwinter in the soil in areas adjacent to potato fields or in the fields themselves. The depth of adults in the soil depends on the temperature. In cooler climates, such as in Northern Europe, beetles will burrow 25–40 cm down into the soil. Fourth-stage larvae will also burrow into the soil to pupate (CABI, 2018d).	Overwintering adults can survive for months within the soil (CABI, 2018d), while pupation within the soil generally lasts 10–20 days (EPPO/CABI, 1997b). Overwintering survival by adults depends on a number of factors, including quality and quantity of food pre-diapause, soil quality and moisture content, depth of burrowing, and temperature (Costanzo et al., 1997; Hunt & Tan, 2000; Hiiesaar et al., 2006).

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TABLE 1 (Continued)

Pests of potato	Taxonomic group	Categorization (EPPO lists)	Root crop hosts used in rotation with potato	Association with the soil pathway	Survival in soil without host
Meloidogyne chitwoodi (MELGCH)	Nematoda	A2 List	*Beta vulgaris*, *Daucus carota* subsp. *Sativus*, *Scorzonera hispanica* (*)	Second-stage juveniles and egg masses are present in the soil. Males may also be present in soil during the growing season of the hosts but are not infective. All juvenile stages and females are in the roots or tubers, or in pieces of roots/ tubers left in soil.	Egg masses are protected in a gelatinous matrix and survive the longest in the soil. Their survival was at least 24 weeks in normal (moist soil) conditions but was reduced (not zero) in dried soil after 12 weeks. Inundation influences the survival of all *Meloidogyne* stages (report Nemaspread- FOD project, 2016).
Meloidogyne fallax (MELGFA)	Nematoda	A2 List	*Asparagus officinalis*, *Daucus carota* subsp. *Sativus*, *Scorzonera hispanica* (*)	Second-stage juveniles and egg masses are present in the soil. Males may also be present in soil during the growing season of the hosts but are not infective. All juvenile stages and females are in the roots or tubers, or in pieces of roots/ tubers left in soil.	Egg masses are protected in a gelatinous matrix and survive the longest in the soil. Their survival was at least 24 weeks in normal (moist soil) conditions but was reduced (not zero) in dried soil after 12 weeks. Inundation influences the survival of all *Meloidogyne* stages (report Nemaspread- FOD project, 2016).
Nacobbus aberrans (NACOBA)	Nematoda	A1 List	*Beta vulgaris*, *Daucus carota* subsp. *sativus* (*)	Second-stage juveniles and egg masses can be present in the soil. Males may also be present in soil during the growing season of the hosts but are not infective. All juvenile stages and females are in the roots or tubers, or in pieces of roots/ tubers left in soil.	In laboratory tests, Jatala and Kaltenbach (1979) cited in EPPO/CABI (1997c) showed that *N. aberrans* survived 4 months in infested roots and soil at −13°C, and 8 months in air-dried soil (7–9% relative humidity). More recent results extend these periods to 12 months and 2 years, respectively (EPPO/ CABI, 1997c).
Ralstonia solanacearum (RALSSL)	Bacteria	A2 List	(*,#)	There are several ways in which *R. solanacearum* can arrive in soil habitats. The organism exudes from infected potato roots and tubers and infests the soil inside a matrix of protective polysaccharide (Shekawat & Perombelon, 1992). Infestation can also occur by irrigation with contaminated water or by infested plant debris or soil adhering to agricultural machinery, implements and vehicles.	Population densities in soil decline progressively over time, with a persistence observed up to 12 months. In microcosm experiments with bacterial cells added to different soil types, a gradual decline during 90 to 210 days was observed, which is sufficient to re-infest the next potato crop in the absence of rotation. Soil type affects the rate of population decline, with the greatest decline occurring in loamy sand soil. An accelerated decline to undetectable numbers occurred at 4°C and a single freezing-thawing cycle was sufficient to drop below the detection limit. Severe drought drastically reduced the populations in soils (van Elsas et al., 2000). Different soil amendments were also demonstrated to reduce viability (Messiha et al., 2009). The presence of plants debris and crop residues (e.g. roots) in the soil allows the bacteria to survive for longer periods.
Synchytrium endobioticum (SYNCEN)	Fungi	A2 List	(#)	Resting sporangia are released into the soil from decaying wart tissue. Infestation can also occur by irrigation with contaminated water.	Resting sporangia can survive in soil for decades depending on soil type and environmental conditions. Przetakiewicz (2015) found viable resting sporangia in soil 46 years after an outbreak.

(Continues)

TABLE 1 (Continued)

Pests of potato	Taxonomic group	Categorization (EPPO lists)	Root crop hosts used in rotation with potato	Association with the soil pathway	Survival in soil without host
Tecia solanivora (TECASO)	Insecta	A2 List		Infested soil may carry eggs or pupae (Povolný, 2004). Females prefer to deposit eggs in the soil (Barreto et al., 2003; Karlsson et al., 2009; EPPO, 2021c)	There is no information in the literature about how long larvae can survive in the soil without hosts, but it is expected to be a very short time because emerging caterpillars need to bore into tubers to complete their life cycle. According to Schaub et al. (2016) ,egg mortality was around 10% at temperatures of 10–25°C, increasing sharply at higher and lower temperatures, and reaching 100% at 5 and 30°C. According to Castillo (2005), at 10ºC pupae mortality amounted 100%, while according to Notz (1996) and Schaub et al. (2016), at that temperature there was pupa survival. Niño et al. (2002) confirmed there was no survival of pupae at 4.5ºC.
Thecaphora solani (THPHSO)	Fungi	A1 List	(#)	Forms galls on stems, stolons and tubers which contain spore balls (sori) containing two to eight teliospores, rarely one. Spore balls also formed within tubers. Infected tubers later dry to become a brown powdery mass containing many spores.	Spore balls are thought to be long lived in soil and tuber debris. Torres (2001) states that the fungus can survive up to 7 years in gall fragments. Nothing is known of about the infection process.

Note: * = other cultivated plant species host the pest; # = some wild/weed species also host the pest.

3 | ROLE OF THE NPPO

3.1 | Raising awareness

The NPPO should raise awareness amongst growers, inspectors and people involved in the potato supply chain about the risks posed by soil-borne pests and their potential introduction with soil. To reduce the phytosanitary risk, the first course of action should be to minimize the amount of soil removed from the field at harvest and to apply good hygiene practices (Section 4.1). Awareness campaigns (EPPO, 2019b; FAO, 2019b) should also highlight the importance of correctly managing the soil associated with potato and root crops at the farm level and at packing and processing facilities. Promotional activities can involve, for example, the internet, posters and workshops involving growers, potato traders and processors.

3.2 | General requirement on the movement of soil

The NPPO should require that only soil with an acceptable risk is returned to agricultural fields.

3.3 | Requirement for a risk assessment

The NPPO should require that a risk assessment is performed by the handling facility to analyse whether and under what conditions the soil can be returned to agricultural fields (Section 4.2). It is not necessary to perform this risk assessment when soil is to be deposited on land not intended to be used for crop production. The risk assessment should be formalized in writing and updated regularly or as soon as a significant change occurs, e.g. when contracting with growers in a new area or when the pest status of an area has changed following the report of a new emerging or regulated pest.

The NPPO should require that information on the origin of the soil (Section 4.2.3.1.1) is kept by the handling facility for at least 3 years as part of the facilities quality control procedures and for external audits. If several batches are merged, the information may be provided only for the batch with the highest phytosanitary risk.

3.4 | Approval of the treatment, return of soil and disposal methods

When the risk assessment by the handling facility concludes that the risk of returning soil to an agricultural field is not acceptable, soil should be treated to allow its reuse as agricultural field soil or be disposed of safely.

All treatments applied to the soil (including wastewater associated with the part of the process related to raw potatoes or root crops) should be authorized by the NPPO. These treatment methods should be reviewed and

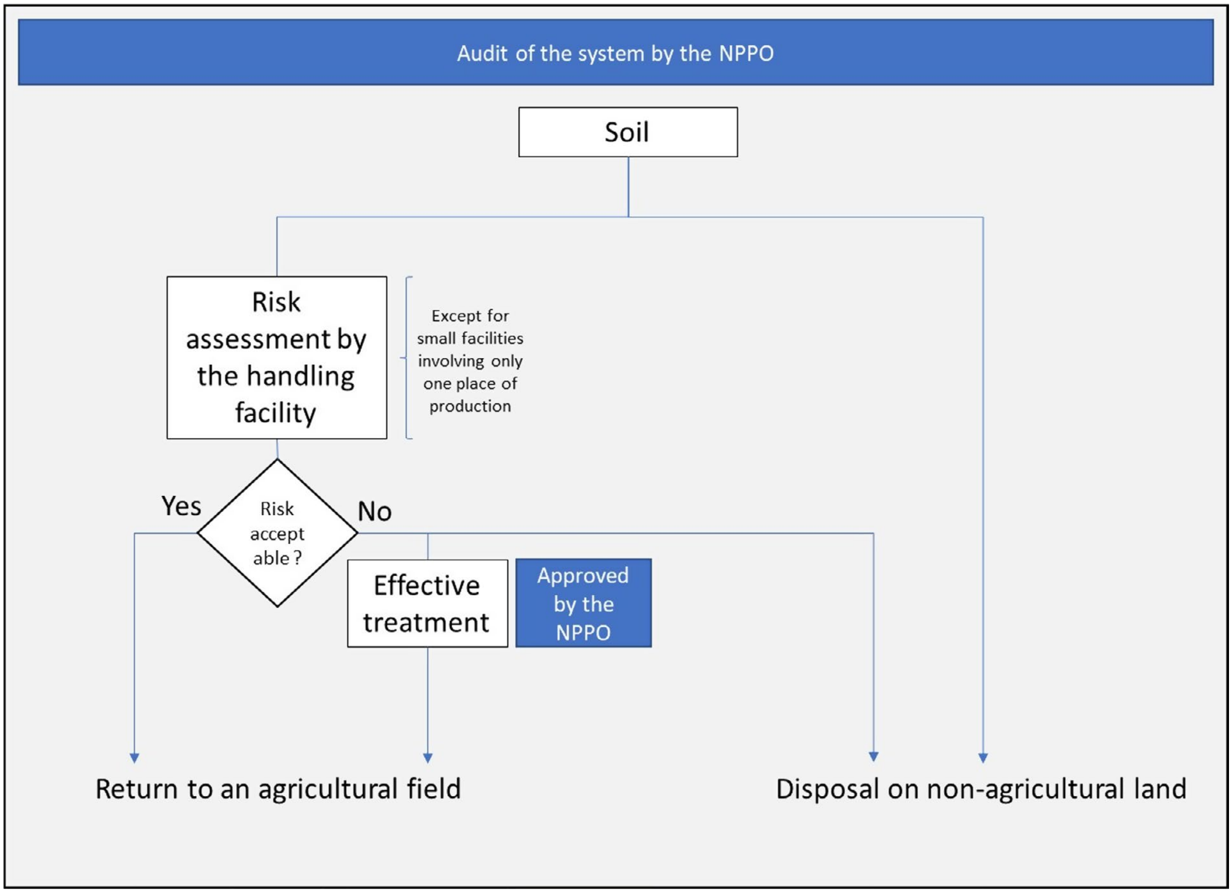

FIGURE 1 Flow diagram for the return or disposal of soil and role of the NPPO. Blue boxes indicate the role of the NPPO [Colour figure can be viewed at wileyonlinelibrary.com]

approved by the NPPO based on the information made available within the risk assessment. The NPPO should require that the handling facility keep records of the phytosanitary treatment(s) applied to the soil for at least 3 years as part of the facilities quality control procedures and for external audits.

When returning soil to fields or disposing of soil on non-agricultural land, specific requirements should be fulfilled (Section 4.3.4).

The NPPO should require that the handling facility keep records of the return or disposal of soil for at least 3 years as part of the facilities quality control procedures and for external audits. Traceability of soil transport and destination may be done by providing documents such as a CMR[1] consignment note to the NPPO when requested.

Official consent from the appropriate Government Agency or water authority should be required to discharge treated wastewater into a watercourse or into a public sewer.

[1]The CMR note is the standard contract of carriage for goods being transported internationally by road. CMR stands for Convention relative au contrat de transport international de Marchandises par Route (Convention on the Contract for the International Carriage of Goods by Road).

3.5 | Control

It is recommended that a regular audit of the system is performed by the NPPO, including a critical review of the risk assessment prepared by the handling facility.

Options for the return of soil to an agricultural field or disposal on non-agricultural land and the associated role of the NPPO are summarized in Figure 1.

4 | ROLE AND RESPONSIBILITIES OF OPERATORS

Handling facilities (e.g. packers or processors) also have a responsibility in raising awareness amongst growers and transporters about the risks posed by soil-borne pests and their potential introduction with soil (possible communication activities are mentioned in Section 3.1). They should encourage growers and transporters to minimize the phytosanitary risk.

To reduce the phytosanitary risk operators should apply good hygiene practices. In addition, for growers, the first course of action should be to minimize the amount of soil removed from the field at harvest. Transporters, packers and processors should minimize the mixing of soil (Section 4.1).

Before returning soil from handling facilities to agricultural fields, the handling facility should perform a risk assessment to analyse whether and under which conditions this can be done (Section 4.2).

If the risk is not acceptable, an appropriate treatment should be applied to ensure the phytosanitary safety of soil when returning the soil to agricultural fields. Alternatively, soil can be disposed of safely on non-agricultural land (Section 4.3 and Figure 1).

4.1 | Guidance to operators to minimize the risks related to soil associated with potato and root crops

Until the processing stage, operators are encouraged to take action to minimize the phytosanitary risk related to soil associated with potato and root crops.

4.1.1 | Guidance to growers/contractors at the place of production prior to, during or immediately after harvest (prior to transport outside the farm and processing)

In addition to using general phytosanitary farm hygiene practices, which helps prevent contamination from one production site to another, the priority should be to minimize the amount of soil removed from the field of production.

4.1.1.1. Apply general phytosanitary farm hygiene practices

General phytosanitary farm hygiene practices include the regular cleaning of machinery, vehicles or equipment. In particular, cleaning is necessary when machinery, vehicles or equipment are used in different places of production, on newly rented fields or at different sites of production on the same farm if they have a different phytosanitary status. Cleaning may also need to be undertaken for a field where no potatoes have previously been grown to preserve the pest freedom of that field. In addition to cleaning, disinfection is necessary in high-risk situations, especially for movement of machinery between different areas of production with uncertainty about the presence of a quarantine pest (EPPO Standard PM 10/1 *Disinfection procedures in potato production*). Organizing farm operations according to the level of phytosanitary risk associated with the different fields will also reduce the associated risk (e.g. the least risky fields being harvested at the beginning of the day/harvesting period).

4.1.1.2. Reduce the amount of soil associated with plant products at the site of production: techniques applicable prior to and during harvest

Reduction of the amount of soil may not fully apply to ware potatoes or carrots, which need a thin layer of soil around the tuber or root to help protect them during storage.

Soil conditions during harvest can greatly influence the amount of soil removed with potatoes and root crops (Auersald et al., 2006; Ruysschaert et al., 2006). Harvest erosion is greatly influenced by soil type and soil moisture conditions (being generally greater during wet conditions). Good soil preparation before planting helps reduce the formation of forked sugar beet roots, thereby decreasing soil retention on the harvested crop. The quantity of soil associated with tubers may also be influenced by the potato cultivar (e.g. potato tubers with deep eyes tend to retain more soil) and the cultivar of root crop grown (e.g. development of sugar beets with a smoother surface and a diminished crease to retain less soil (Brendel et al., 2012)). Soil retention can also be influenced by the susceptibility of the cultivar to pests (e.g. high susceptibility to potato scab can result in rough patches of skin, which retain more soil). Furthermore, if present, weed plants can retain soil when potato or root crops are harvested.

As much soil as possible should be removed from potatoes or from root crops and left on the production site during harvest and when transferring root crops or potatoes directly from the harvester to the transport vehicle by using appropriate cleaning machinery. Recommendations to reduce the amount of soil are:

- Improve the soil structure: this may be achieved, for example, by increasing organic matter (using reduced tillage, intermediate crops or covering crops before planting) or by avoiding soil compaction (using appropriate machinery and low-pressure tyres, scheduling field operations and the use of machinery on land to avoid causing compaction, i.e. not going on soil when it is too wet).
- Use fields with light texture soils where possible, and avoid fields with too heavy soils or located in wet sites (e.g. not in the bottom of valley) or which are difficult to access in wet conditions.
- Use cultivars adapted to the soil texture (e.g. cultivars with shallow eyes reduce soil adherence to the tubers in clay soil).
- Use proper soil preparation before sowing/planting.
- Reduce the presence of weeds at harvest.
- Harvest in optimum conditions where possible (when soil is sufficiently dry).
- Use correct and well-tuned harvesting machinery (adapted to the specific soil conditions of each farm) with appropriate cleaning components/systems.
- Optimize the harvesting speed chain or increase staff at the sorting table.

4.1.1.3. Reduce the amount of soil associated with plant products at the place of production: techniques applicable after harvest (transporting to the farm, removing soil before storage or loading, washing)

Treatments after harvest to reduce the amount of soil associated with potatoes or with root crops in rotation with potatoes should be applied preferably before the harvested crop leaves the production site/place of production.

This can be achieved first by the temporary storage of sugar beets and other root crops in heaps on the field to dry before loading them onto a transport vehicle using a cleaner loader or by temporary storage in the place of production before loading. Ware potatoes and carrots are, however, not normally stored in the field. Further soil removal can be achieved by the use of a soil separator/destoner and then by sorting/grading.

The washing and brushing of root crops and potatoes at the place of production prior to marketing or processing will remove most of the soil from the consignment, which will be retained on the premises and therefore reduce significantly the risk of moving soil-borne pathogens with the potatoes and root crops. For some root crops, such as sugar beets, washing and brushing are necessary steps in the production process to guarantee the quality of the final product. Washing and brushing can be used to eliminate specific pests that are present. However, the purpose of this Standard is not to address pest-specific measures. Washing and brushing can be performed by mobile devices (e.g. this would be particularly useful for the management of *Epitrix* spp.). When washing and brushing are undertaken at a specialized facility, wastewater from potato tubers or root crops washing should be safely disposed of after receiving appropriate treatment (Section 4.3).

When washing of root crops and potatoes poses a problem because it reduces the shelf life of the product, it can be applied only to products to be marketed directly.

Further separation of remaining soil may also be achieved at each further step of handling the lot with the same procedures (use of well-tuned post harvesting machinery, e.g. soil separator, destoner, sorter, grading machine, etc.).

Potatoes in trade should be free from soil (with a maximum tolerance of 2% w/w) according to EPPO Standard PM 8/1 *Commodity-specific phytosanitary measures for potato* (EPPO, 2017a,b). Under certain conditions, e.g. prevalence of certain pests in an area, the proportion of soil needs to be lower.

4.1.2 | Guidance to operators during handling and transport prior to grading, packing or processing in other premises

Good hygiene practices applied during handling and transport prior to grading, packing or processing in other premises will help reduce the pest risks related to soil associated with potato and root crops.

When boxes or bags are used by different growers, these should preferably be cleaned between different places of production to remove soil and make sure that the soil from different origins is not mixed to prevent cross-contamination. When boxes or bags are not shared with other growers, or between different operational production sites, the risk of reusing these boxes or bags is normally considered to be acceptable.

In production areas where soil-borne quarantine pests are known to be present, it is recommended to clean the wheels of vehicles which entered the field before leaving the production site. It is also recommended to clean vehicles (including the wheels) before leaving the processing facility for another place of production. Washing should be done with care, possibly using a high-pressure steam cleaner and detergents. Routine hygiene measures, including disinfection, are described in EPPO Standard PM 10/1 *Disinfection procedures in potato production* (EPPO, 2006). Washing water should be treated and disposed of as specified in Section 4.3.3.

4.1.3 | Guidance to packers and processors during sorting, grading, packing or processing

During sorting, grading, packing or processing, soil associated with potato and root crops from different production sites, or failing that from different places of production, should preferably not be mixed, so that it can be safely returned to its site or place of production. Returning soil involves good traceability of the different batches until the delivery to and within the processing or packing facilities.

4.1.3.1. Apply general hygiene measures

General hygiene measures, including cleaning of the sorting, grading, packing or processing machinery, should be performed. Organizing handling operations according to the level of phytosanitary risk associated with the different potato and root crop lots will also reduce the associated risk (e.g. the least risky lots being first handled).

4.1.3.2. Separate the soil for each lot immediately after delivery

Handling facilities should preferably remove the soil attached to potato or root crops at reception in a soil separator/destoner and the extracted soil immediately returned to the supplier production site/place. However, this practice may not be applicable or possible for several root crops, e.g. sugar beets, due to the merging of batches into one continuous flow of material in the processing facility.

4.1.3.3. Handle soil from different origins separately
Different lots of potato or root crops with soil attached should preferably be handled separately. This can be done by using different lines or by handling these commodities at different times provided that the facility (including machinery) is cleaned (and possibly disinfected depending on the risk). However, it is currently not commercial practice and is rarely carried out.

4.1.3.4. Minimize the discharge of wastewater
When water is used during the processing of potatoes and root crops, every effort should be made to minimize the discharge of wastewater (which may be contaminated) into the environment by recycling water whenever possible.

4.2 | Risk assessment to be performed by handling facilities

When the soil is to be returned to agricultural fields, the handling facility (e.g. packers or processors) should perform a risk assessment to analyse whether and under which conditions the soil can be returned to a place of production.

- If the soil is to be returned to its place or site of production of origin, the risk assessment should only consist of analysing whether soil from different origins has been mixed (Sections 4.2.1 and 4.2.2).
- If the soil is to be returned to another place of production, a full risk assessment should be performed (Section 4.2.1–4.2.3).

This risk assessment is not necessary for small facilities handling commodities only from one place of production and returning soil to this place of production (preferably to the same site of production). The risk may also be considered acceptable if the soil is to be returned to permanent wooded areas, grassland, pastures, orchards, short rotational plantations (e.g. fast-growing trees for biomass production) or Christmas tree production sites under the conditions described in Section 4.3.4.

4.2.1 | Traceability

Undertaking a risk assessment is reliant on the information (documentation and labelling) provided by the grower, trader or transport operator. This information should include at least the species and the origin of commodities (including the phytosanitary status of the place of production of origin when known, e.g. for *Globodera* species known to be present in other fields of the same place of production).

Traceability of transport may be achieved by providing documents such as a Phytosanitary Certificate with additional declaration, a CMR consignment note, an invoice, weighing notes, etc. Records of these documents should be kept so that they can be shown to the NPPO when requested.

4.2.2 | Assessment of the risk that soils from different places of production have been mixed

The first step of the risk assessment consists of analysing whether soils from different places of production have been mixed, either prior to the delivery or during the process. A strict application of the guidance to operators during handling and transport (Section 4.1.2) as well as during sorting, grading, packing or processing (Section 4.1.3) would minimize the mixing of soil from different places of production.

4.2.3 | Assessment of the risk related to mixed soils from different origins

When soils from different places of production have been mixed, the plant health risk of applying that soil to a place of production should be assessed (Section 4.2.3.1). The risk of introducing specific pests should also be assessed and recorded (Section 4.2.3.2).

4.2.3.1. Risk factors to consider when soils from different origins have been mixed
This section is intended to give guidance on the identification of risk factors related to potato and root crops with associated soil, e.g. when mixed from different places of production. The risks depend on the availability and reliability of information (Section 4.2.3.1.1) and on the origin of the commodity (e.g. handling in another production area, presence of soil-borne pest in the area of origin or use of different production practices) (Section 4.2.3.1.2).

4.2.3.1.1. Availability and reliability of information. The availability and reliability of information on the origin of potatoes and root crops handled in a facility, as well as information about the plant health status (and/or cropping history) of the site/place/area of production of these commodities, is a pre-requisite for the evaluation of the risk. In the absence of adequate information to allow an assessment to be made, the risk of introducing new pests should be considered as high.

4.2.3.1.2. Origin of the lots. In relation to the origin of the lots, the assessment should analyse whether the place of production where the mixed soil is expected to be returned has a different plant health status (same or better) as well as different production practices.

Difference in plant health status. The evaluation of the difference in plant health status at the places of production where the commodity was produced and where soil may be returned is based on the local pest status in the production areas as well as on the availability of surveillance data. Soil associated with potatoes or root crops produced within an area where a soil-borne quarantine pest is present is high risk if the soil is expected to be returned to a production area where the pest is not present. If potato or root crops are moved to new areas for handling (including movement through international trade), the associated risks of introducing new pests to these production areas may be greater than in the case of products moved and handled locally.

The assessment should also consider that, although potato and root crops may be produced on production sites which have been inspected for certain pests, even if the site is found free after sampling and testing there is a level of uncertainty concerning pest absence depending on the sampling method, sample size and the detection probability of the test.

When root crops or potatoes were grown in a specific pest-free area, this will give additional assurance of pest-freedom. However, these countries/areas should not only consider this specific risk but also other pests which may be present in that area and moved in association with soil.

Considering all these provisions, an accurate assessment of the relative plant health status is expected to be possible in only a very limited number of situations, such as

- when soil originates in a production area with homogenous phytosanitary status, and is expected to be returned to any of the fields in the same production area, or
- when the place of production where soil is expected to be returned is much worse.

Difference in production practices. Although an area may have the same plant health status, production practices can influence the pest risk.

A place of production located in a production area where potatoes have been grown on long rotation from certified seed potatoes would be classified as having different production practices compared to a place of production located in a region where potatoes are grown in short rotation, where farm-saved seeds are used or where seed potatoes are cut before planting.

In specific situations, e.g. where root crops or potatoes are received from a new potato production area with clear knowledge or evidence about the pest status based on surveillance data and good plant health management practices, the risk to return the soil to another place of production may be considered acceptable.

4.2.3.2. Association of pests with the soil pathway

When the risk of introducing specific pests is identified, their biology should be further considered to identify the level of risk of their introduction with soil. Some factors required to evaluate the risk from important soil-borne pests (e.g. association with the soil pathway, survival etc.) are given in Table 1. The risk of introducing specific pests is a key factor for the consideration of the most appropriate treatments and measures to mitigate the risks identified.

4.3 | Management of the risk at the level of the handling facility

4.3.1 | Decision support and general prerequisites

4.3.1.1. Decision support

Soil should only be returned to agricultural fields if the risk is considered acceptable. The following decision support scheme should be applied for the safe return or disposal of soil from the handling facility (Table 2).

Avoiding mixing soil and returning soil to the place/site of production can be achieved, e.g. when potatoes or root crops are unloaded by the growers themselves (or by a subcontracting carrier).

Returning mixed soil may be possible when soil from handling facilities is mixed on heaps and originated in a production area with homogenous phytosanitary status (e.g. for *Globodera* species) and similar production practices. In that case, the risk associated with returning this soil in any field of the area may be deemed acceptable.

Wastewater associated with the part of the process related to raw potatoes or root crops should always be treated before being released (Section 4.3.3).

4.3.1.2. General pre-requisites

All facilities handling potatoes (and root crops in areas where potato is grown in rotation) should be equipped with appropriate treatment facilities to minimize the risk of soil-borne pests in soil that cannot be returned directly to a site or place of production, or cannot be safely disposed of.

Plant residues resulting from grading and sorting (such as small and/or damaged tubers) should, as far as possible, be treated and disposed of separately from the soil according to EPPO Standard PM 3/66 *Guidelines for the management of plant health risks of biowaste of plant origin* (e.g. by composting, anaerobic digestion and/or direct heat treatment) (EPPO, 2008).

All treatment, return and disposal methods need to be performed in compliance with the relevant national pesticide, biocide, environmental and waste legislation. Untreated liquid waste should not normally be returned to agricultural or horticultural land. It should also not

TABLE 2 Decision support scheme for the safe return or disposal of soil

Conditions				
Availability and reliability of information (Section 4.2.3.1.1)	**Mixing of soil (see assessment of the risk in Section 4.2.3)**	**Treatment (Section 4.3.2)**	**Origin (Section 4.2.3.1.2)**	**Return/disposal (Section 4.3.4)**
When information is available and reliable	When soil from different places of production has not been mixed	No need	–	Could be returned to the place of production, preferably to the same site of production
	When soil from different places of production has been mixed	When effective treatment applied	–	Could be returned to an agricultural field
		When not treated (or treatment considered not effective)	When there is no additional phytosanitary risk and similar production practices	Could be returned to an agricultural field
			When there is additional phytosanitary risk or produced with different production practices	Could be disposed of in permanent wooded area, grassland, pastures, orchards, short rotational plantations*, Christmas tree production sites, or for non-agricultural purposes, where the risk of spread to agricultural fields is very limited
When information is inadequate or not reliable	–	–	–	Should be disposed of in permanent wooded area, grassland, pastures, orchards, in short rotational plantations*, Christmas tree production sites, or for non-agricultural purposes, where the risk of spread to agricultural fields is very limited

Note: *e.g. fast-growing trees for biomass production.

be discharged directly into a watercourse or a sewage system without treatment to eliminate potential pests and official consent from the appropriate Government Agency or water authority (Section 3.4).

4.3.2 | Requirements for the treatment methods to ensure phytosanitary safety of soil

The assessment of the risk factors (Section 4.2) will help inform decision making about an appropriate treatment regime to mitigate risk. For example, if *Ralstonia solanacearum* may be present in potatoes being processed, then treatment to eliminate this pathogen from residual soil before its return to agricultural fields should be carried out.

Most of these treatments should be carried out at least at the handling facility but some could be also applied at the place of production.

Treatment methods for soil are listed below: they may not be applicable for routine use but may be applied to soil suspected to be contaminated. Treatment methods that are still under development are listed in Appendix 2.

4.3.2.1. Inundation of soil

Sedimentation basins may be used where water is used for washing or transporting of potatoes or root crops within a facility and their size adapted to the soil water volumes expected at the handling facility. Basin water should then be cleaned or treated so that it can be discharged legally into natural water courses (e.g. rivers) or sewage systems with consent from the appropriate government agency or water authority.

Measures to ensure the effectiveness of inundation need to be taken, e.g.

- Adding detergent to prevent flotation of potato cyst nematodes (PCN) on the water surface
- Using appropriate submersion time (at least 4 weeks)
- Amending soil with organic matter or agricultural waste.

Example 1: Examples of data on pest-treatments by inundation

- *Ditylenchus destructor* and *D. dipsaci*: these pests do not survive in inundated soil due to lack of oxygen, provided the soil is inundated long enough (the appropriate submersion time required depends on the temperature).
- *Meloidogyne chitwoodi* and *M. fallax*: inundation of soil when organic residues were added resulted in the death of all *Meloidogyne* stages after 6 weeks (report Nemaspread- FOD project, 2016).
- *Globodera rostochiensis* and *G. pallida*: Ebrahimi et al. (2016) indicates that it took 8 weeks of inundation of non-amended soil to reduce their survival by 72 %, while in soils amended with organic material, survival was reduced by 99.9 % after 4 weeks. Roughly 16 weeks inundation at a minimum temperature of 16°C would be needed to kill cysts and the submersion time can be shorter if organic material is added. The submersion time required also depends on temperature.

However, the effectiveness of inundation depends on the nature of the pest (see example 1).

In certain situations, inundation can also be carried out in crop fields. Guidance on how this is applied in the Netherlands to suppress PCN is available in Appendix 1 as well as in Ebrahimi et al. (2016) and Runia et al. (2014).

4.3.2.2. Chemical treatment of soil with an authorized product

Although there are some soil fumigants or alternative pesticides effective against a broad spectrum of pests and diseases which may be used in the field, no known products based on such treatments are available for treatment of heaps of soil.

4.3.2.3. Heat treatment of soil at temperatures effective in killing soil-borne pests

Although heat treatment is very energy intensive, at processing facilities excess heat may be available for use. The effectiveness of heat treatment depends on the pest (or group of pests). Distinction should be made between:

(a) dry heat
(b) steaming
(c) solarization.

Examples of time/temperature combinations and pests documented to resist heat treatments are given in Example 2.

Example 2: Examples of time/temperature combinations and pests documented to resist heat treatments

PM 3/66: The recommended time/temperature combination is 70°C for 1 h, preferably by wet heat. Heat treatment with this time/temperature combination will destroy most plant pests. Biowaste of plant origin known or suspected to contain any quarantine pests or heat-tolerant pests should receive a special heat treatment: 74°C for 4 h (Marcinisyn et al., 2003), 80°C for 2 h or 90°C for 1 h (Lorenz, 2006) using wet heat, either before or after processing.

Data on pest-treatments by heat:

Steinmöller et al. (2012) state that cysts of *Globodera rostochiensis* were killed by pasteurization for 30 min at 70°C. Viaene et al. (2019) state that cysts of *Globodera rostochiensis* in water were killed after 2 min at 70°C or after 20 min at 60°C. These conditions could be used for the treatment of wet soils but not for dry soils (a proportion of the eggs in cysts under dry conditions survived and hatched to produced viable juveniles after treatment at 110°C for up to 20 min).

Some quarantine pests are documented to resist heat treatments, for example:

- *Synchytrium endobioticum* is not killed by pasteurization at 70°C for 2 hours (Steinmöller et al., 2007), by pasteurization at 70°C for 90 min or by heating in a water bath at 80°C or in a dry oven at 90°C for 8 hours (Steinmöller et al., 2012).
- *Clavibacter sepedonicus* is not killed by pasteurization at 70°C for 2 hours (Steinmöller et al., 2007).

4.3.3 | Water treatment options for liquid waste associated with the processing of potatoes

During the process in the handling facility, potatoes, root crops or material can be washed, which would result in the presence of soil in wastewater. Such water should be treated before being released. An assessment of the risk factors (Section 4.2) will help inform decision making about an appropriate treatment regime to mitigate risk and to satisfy other possible environmental requirements associated with wastewater from potato processing. The only water presenting a risk is that associated with the part of the process related to raw potatoes and root crops (after steam peeling, the water is no longer considered to be a risk).

For example, if *Ralstonia solanacearum* may be present in potatoes being processed then treatment to eliminate this pathogen from wastewater before it enters any watercourse should be carried out. This is because the introduction of *R. solanacearum* into watercourses can result in the infection of *Solanum dulcamara* plants growing alongside waterways and the subsequent discharge of high numbers of this bacterium into the water. Outbreaks of brown rot in potato and tomato have occurred when contaminated river water has been used for irrigation (Danse, 1996).

The primary treatment of liquid waste such as that arising from the washing of potato tubers normally involves the removal of suspended solids by screening, sedimentation or simple filtration (examples are provided in below). A settlement tank or storage lagoon can be used for this purpose.

Example 3: Examples of use of filtration for specific pests

Filtration of liquid waste in a filter-flotation system enables separation of *Globodera* spp. cysts and winter sori of *Synchytrium endobioticum*.

Secondary treatment usually involves biological oxidation by filter beds or oxidation ditch systems (activated sludge).

Solid substances obtained after the primary or secondary treatment must be treated (Section 4.3.2) or disposed of (Section 4.3.4).

The clarified liquid waste can be heat treated or disinfected with an approved method (examples are provided in below) to allow re-use.

Example 4: Examples of pest specific disinfection methods for clarified liquid waste

Disinfection methods for clarified liquid waste that are proven to control the bacterial pathogens, *Ralstonia solanacearum* and *Clavibacter sepedonicus*, include:

- Injection of peroxygen compounds (e.g. peracetic acid formulations giving a residual level of at least 4 mg per litre of peracetic acid measurable over at least a 2-minute reaction time).
- Chlorination (e.g. injection of chlorine dioxide giving a residual level of at least 0.1 mg per litre of residual chlorine dioxide measurable over at least a 2-minute reaction time).
- Ozonation (e.g. injection of ozone giving a residual level of 0.4 mg per litre measurable over at least a 4-minute reaction time).

UV irradiation is only effective when the quality of the liquid being treated is such that it allows efficient penetration of the UV light. As a guide, it has been determined that irradiation at 300 J/m^2 of UV light at a wavelength of 254 nm was reliable provided a transmission of at least 50% of the UV was recorded at all times through the liquid (to a depth of 1 cm) within the reaction chamber.

4.3.4 | Requirements for return or disposal of soil to minimize spread of pests to potatoes

The availability of a risk assessment, the assessment of the risk factors (Section 4.2) (when a risk assessment is available), as well as the potential treatment and its efficacy for a specific pest risk will help inform decision making about an appropriate return or disposal method for the soil (i.e. return to agricultural fields or disposal in a non-agricultural area), its destination (in areas with specific phytosanitary status) and its mode of transport (e.g. closed containers, open trucks) to mitigate the risk.

National boundaries should not be crossed (unless by agreement between the countries).

Safe return or disposal of soil may be achieved by the methods described in Sections 4.3.4.1–4.3.4.2.

Transport of soil for return or disposal should be documented and recorded through the entire supply chain (from producer to producer/end-user via the processing unit).

4.3.4.1. Return of soil to agricultural fields

Conditions for returning soil to a place of production used to grow potatoes or root crops are detailed in Section 4.3.1.1.

Erosion (wind or water) may lead to local spread of pests present in such soil. Therefore, the soil should not be deposited in area where soil may be subject to wind erosion or water could run off to the rest of the field or adjacent fields, or in area prone to flooding.

Mixed soil may be re-used in, for example, orchards, Christmas tree production sites or short rotational plantations (e.g. fast-growing trees for biomass production) which are not and will not be used for arable crop production, or in permanent wooded area, grassland or pastures.

4.3.4.2. Soil disposal for non-agricultural purposes

Soil may be re-used for non-agricultural purposes such as for reforestation areas, for the reclamation of open (e.g. coal) mining areas or for the construction of embankments and infrastructure (roads, sound walls, parks, etc.) in areas sufficiently separated from agricultural production.

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APPENDIX 1 – INUNDATION OF ARABLE FIELDS AS A CONTROL MEASURE AGAINST POTATO CYST NEMATODES AND DISEASES (AS APPLIED BY THE NETHERLANDS FOOD AND CONSUMER PRODUCT SAFETY AUTHORITY, NVWA)

Introduction

The underlying principle of the inundation method is to make the soil anaerobic and thereby kill off the nematodes. This method, which consists of (partially) flooding a field, requires a sufficiently long anaerobic period. In general, the higher the temperature, the quicker the soil becomes anaerobic.

This method is based on laboratory and greenhouse tests in which multiple variables were measured under controlled conditions. Research has shown that the inundation method reduces the presence of viable cysts by more than 99%. If properly executed, this method has the highest rate of reducing the nematode population of all methods that are currently available.

However, this method can only be used on fields with minimal variation in altitude.

Information

The research report 'Effectiveness of inundation to control *Globodera pallida* and *Verticillium dahliae*' (December 2012, Lelystad, PPO-AGV) provides a detailed description of the method and how it should be applied, its effects on the potato cyst nematodes and the soil, and its costs. More information can be found at the following link: https://upload.eppo.int/download/1015o8d7d639b7.

Execution

The method for the inundation is described in the manual provided at: https://upload.eppo.int/download/1016obb268c6a4.

Points of interest

- The method is based on cutting off the supply of free oxygen to the soil, causing the nematodes to die. Making the soil anaerobic requires the activity of bacteria. When the soil temperature is lower than 16°C, these bacteria are not active.
- The field needs to be cleared of weeds. Weeds sticking out of the water prevent the soil from becoming anaerobic.
- The field needs to be continuously and sufficiently submerged so that even windy conditions cannot cause dry spots. The anaerobic period (at least 12 weeks) at a minimum temperature of 16°C should not be interrupted.
- The embankments have to be constructed in such a way that they do not cave in under the pressure of the water, even under windy conditions.

Notification

The inundation measure has to be notified 14 days prior to the actual flooding of the field. Notification is done by means of the notification form '*control measure PCN*'. It needs to be ensured that there is sufficient time to carry out the inspection visits.

The NVWA assesses the following criteria:

- The NVWA's assessment is limited to the plots of inundated land that were designated as infested.
- Declaration of infestation: the arable land must not be subject to any other declarations of infestation (especially regarding brown rot).
- Inundation in an area where crop irrigation is prohibited is considered a risk for the production of seed potatoes (considering the possible use of water contaminated with brown rot). Seed potatoes produced in the first year after the field was inundated receive a high-risk status and consequently fall under the integral inspection regime of one sample per 25 tonnes of potato produced.
- Period of execution: the inundation can only start when the average bottom temperature (soil + water) is expected to be at least 16°C for the next 12 weeks. In the Netherlands, this is usually in June.
- Flatness of the terrain: no more than a 50 cm variation in altitude.
- The field that was designated as infested should be submerged by at least 5 cm of water at the shallowest point (prevent drying by the wind, add water if necessary).
- Drains must be closed.
- Duration of the inundation: the infested field should be continuously flooded for a period of 12 weeks.
- Location of the infested field: if the embankment for the larger part (e.g. alongside the entire length or width of the field) is made up of soil from the field that was designated as infested, it should be subjected to separate control measures. In all other cases, a number of things have to be evaluated by and discussed with the NVWA inspector. For example, when a small infested surface of land is used as an embankment, there is no need for additional measures or sampling of this embankment.

In all other cases, a different disease control measure has to be applied.

After the inundation was carried out, there is no waiting period to conduct sampling. As soon as it is possible to walk in the field and sampling thus becomes possible, an official soil analysis may be conducted.

APPENDIX 2 – OTHER TREATMENT METHODS UNDER DEVELOPMENT TO ENSURE THE PHYTOSANITARY SAFETY OF SOIL

These methods are still experimental and are not used on a wide scale.

Composting of soil

Composting is usually done with plant residues and therefore soil needs to be mixed with large quantities of organic material. This significantly limits the quantity of soil that can be treated by this method. It should be noted that composting will not effectively inactivate all pests present in the soil but will reduce the amount of viable pest propagules depending on pest species (see example 5). Efficacy depends on the performance of the system as described in EPPO Standard PM 3/66 *Guidelines for the management of plant health risks of biowaste of plant origin* (EPPO, 2008).

Example 5: Composting: Examples of data available for specific pests

Globodera rostochiensis: cysts were killed by composting for 7 days at 50-55°C (Steinmöller et al., 2012).

EPPO Standard PM 3/66: 55°C for 2 weeks or at least 65°C for one week. The time/temperature combinations for composting mentioned above will eliminate most plant pests. However, there are reports in the scientific literature, based on various experimental methods, which have shown that some heat tolerant organisms have survived these time/ temperature combinations.

- *Clavibacter sepedonicus* (Steinmöller et al., 2007) is not killed by composting (3 months at less than 50°C or 21 days at above 65°C).
- *Synchytrium endobioticum* is not killed by composting (3 months at less than 50°C or 21 days at above 65°C or 70 days at 30-45°C, 21 days at 50-55°C, or 12 days at 60-65°C (Steinmöller et al., 2007; Steinmöller et al., 2012).

Anaerobic digestion

Anaerobic soil disinfestation, also known as biological soil disinfestation or anaerobically mediated biological soil disinfestation, relies on organic amendments to supply labile carbon to soil microbes to create anaerobic conditions in moist and plastic-covered soil that reduce nematode, pathogen and weed populations in soil. Anaerobic digestion is not primarily for the treatment of soil material, therefore soil needs to be mixed with large quantities of organic material. This significantly limits the quantity of soil that can be treated by this method. However, the efficacy of sanitation via anaerobic digestion for specific pests relates strongly to the technical conditions of the treatment (e.g. temperature and effective retention time) and these conditions should be demonstrated (see example 6).

Example 6: Anaerobic digestion: examples of data available for specific pests

van Overbeek et al. (2014) showed strong (> 99.4 %) declines in both *Ralstonia solanacearum* and *Globodera pallida* in soil attached to harvested products.

Shrestha et al. (2016) reviewed numerous previous studies on anaerobic soil disinfestation in a meta-analysis and showed that this technique suppresses bacterial, oomycete and fungal pathogens and has some effect on nematodes and weeds.