United Nations ECE/TRADE/C/WP.7/2013/10

# Economic and Social Council

Distr.: General
23 September 2013

Original: English

## Economic Commission for Europe

Committee on Trade

### Working Party on Agricultural Quality Standards

**Sixty-ninth session**
Geneva, 4-6 November 2013
Item 5 of the provisional agenda
**Specialized Section on Standardization of Seed Potatoes**

# UNECE Guide on seed potato diseases, pests and disorders*

### Note by the secretariat

This text is submitted by the Specialized Section on Standardization of Seed Potatoes for approval by the Working Party as a UNECE Guide on seed potato diseases, pests and disorders.

## I. Introduction

Seed potato certification is the process of assuring the quality of seed potatoes being marketed, usually done nationally according to regulated standards. Planting healthy seed potatoes is a key factor in maximising the production of usable potatoes for consumption or processing. The United Nations Economic Commission for Europe (UNECE) has drawn up an international reference quality Standard for Seed Potatoes to help producers do exactly this.

The Standard sets out a common terminology and minimum requirements for certifying high-quality seed potatoes for international trade. It covers:

- varietal identity and purity
- genealogy and traceability
- diseases and pests
- external tuber quality and size physiology
- sizing and labelling.

* This document was submitted late due to delayed inputs.

The UNECE standard is a marketing standard setting harmonized norms in quality requirements for seed potatoes. It supplements and supports other international seed-potato phytosanitary standards and should be read in conjunction, not in place of these, in particular ISPM 12 and ISPM 33.

The Standard defines minimum requirements at the export-control point and prescribes tolerances for diseases, defects and faults in crop, lot or succeeding crop (direct progeny).

## A. Use of this guide

This guide provides a pictorial reference to pests and diseases affecting potato quality as an aid to using the standard.

This guide is intended to assist seed potato inspectors and producers in assessing quality in conjunction with the use of the Standard.

The guide is not an exhaustive list of pests and pathogens of potatoes. It focuses on the most common faults relevant to seed potato production and trade.

When using the Standard, emphasis is placed on visual assessment of faults by the inspector at the point of control. Normally, inspectors should be able to pass or fail lots based only on a visual assessment.

Most of the photographs in this guide are available in high resolution format at:
www.unece.org/trade/agr/standard/potatoes/PestPicturesE.html.
Photographs marked as “SASA© Crown Copyright” may be reproduced for the purposes of training provided an acknowledgement of copyright is made.

If you can usefully use this Guide to responsibly further an understanding of seed potato production by reproducing it, then please do so. We would, however, appreciate an acknowledgement and that a reference to the source material is provided.

## B. Crop inspection procedures

### 1. Scope

All seed potato crops to be certified under the Standard must be inspected during crop growth.

Other measures to protect the quality of seed crops may be adopted (e.g. measure to control the quality of ware crops or the hosts of potato pests close to seed production).

#### 2. Level and timing

A minimum of two inspections is recommended. Wherever possible, inspections should start when, or shortly before, the plants reach the flowering stage. In general, the inspection procedures should allow an inspector to inspect, at random, a representative sample of plants in the crop.

Plants affected by diseases, those not true to type and those of another variety should be recorded separately on the inspection report and expressed as a percentage of the number of plants inspected. Inspection of the first field generation following PBTC should be conducted at a more intensive rate, focusing on the identification of off-types.

### 3. Additional support

Inspection results will normally be based on a visual assessment of the crop. The identification of faults may be supported by appropriate tests when required.

### 4. Removal of plants with faults (roguing)

Roguing may be permitted within specified limits, provided the crop meets the required tolerances at inspection. Roguing must include removal of all tubers, as well as foliage, to ensure that no affected material is harvested with the crop.

### 5. Second opinion

Growers are entitled to ask for a confirmatory inspection by another inspector in the event of a disputed inspection.

## C. Lot inspection procedures

### 1. Scope

All seed potato lots to be certified under the Standard must be inspected before marketing.

### 2. Inspection method

A randomly collected sample representative of the seed potato tubers in a lot should be taken for inspection of tuber size and quality. The tubers need to be sufficiently clean to allow for a visual inspection, tubers should not be caked with soil.

Tubers of the sample may be cut to establish the presence or absence of internal defects. If tuber samples are to be assessed for internal defects and diseases, they should be cut along the longitudinal axis, drawn through the widest part of the tuber (i.e. from the stem end to the bud end), and examined.

### 3. Calculation of results

During the inspection process, a tuber should only be counted once for a disease. Calculate total counts and percentages for each disease and, by comparison, determine if a lot complies with various lot tolerances in the Standard.

### 4. Additional measures

If a sample exceeds the tolerance for any of the faults, an inspector may proceed to either increase the sample size and/or re-classify the lot as required to make sure that it complies with a specified standard.

### 5. Second opinion inspections

Growers will be entitled to ask for a confirmatory inspection to be conducted by another inspector in the event of a disputed inspection.

## D. UNECE Classification scheme and label colours

The Standard sets requirements for three categories of seed potatoes: Pre-basic, Basic and Certified. It offers additional choice of quality by two classes within each of these categories.

| Categories | Classes |
|---|---|
| Pre-Basic | PBTC<br>PB |
| Basic | class I<br>class II |
| Certified | class I<br>class II |

Pre-basic seed for early generation seed production: White label with a diagonal purple line.

Basic seed for further multiplication: White label.

Certified seed for end use production (ware): Blue abel.

*[Insert three label pictures (one each from three countries - request scans]*

# II. Fungal Pathogens

*Alternaria spp*.: Early Blight

*Colletotrichum coccodes*: Black Dot

*Fusarium* spp.: Dry Rot

*Goetrichum candidum*: Rubbery Rot

*Helminthosporium solani*: Silver Scurf

*Phoma foveata*: Gangrene

*Phytophthora erythroseptica*: Pink Rot

*Phytophthora infestans*: Late Blight (foliage and tuber)

*Polyscytalum pustulans*: Skin Spot

*Pythium* spp.: Watery Wound Rot (Leak)

*Rhizoctonia solani*: Stem Canker/Black Scurf

*Sclerotinia sclerotiorum*: White Mould/Stalk Break

*Spongospora subterranean*: Powdery Scab

*Synchytrium endobioticum*: Wart disease

*Verticillium* spp.: Verticillium Wilt

## A. *Alternaria* spp.: Early blight

**Status in UNECE**: Tolerances for dry rot. Not regulated in the growing crop.

**Recommended diagnostics**: Visual observation of leaves and tubers. Two species affect potato: *Alternaria solani* and *Alternaria alternata*. It is almost impossible to distinguish between the symptoms caused by the two species.

**Symptoms**: Infection by *Alternaria* spp. causes lesions on the leaves, which often have a target spot appearance of concentric rings. These usually appear a few weeks after plant emergence and appear initially on lower leaves as very small black or brown spots, which

later coalesce. This causes the leaf tissue to die as the disease spreads. The disease differs from late blight in that there is no development of milky-white sporulation around the lesion on the underside of the leaf in humid conditions.

Infected tubers may develop a largely superficial dry rot.

**Inoculum:** The fungus survives on potato or other host debris in the field, or directly in the soil as spores.

**Control:** Normally, early blight is controlled chemically as a by-product of the application of late blight fungicides, particularly those incorporating mancozeb. Specific sprays may be necessary with susceptible varieties.

## B. *Colletotrichum coccodes*: Black dot

**Status in UNECE:** Controlled indirectly through tolerance for shrivelled tubers.

**Recommended diagnostics:** Visual observation of tubers (with a hand lens) and identification of fungus on specific medium.

**Symptoms:** Tuber skin blemish disease with silvery, irregularly shaped lesions present at harvest. Symptoms may become more severe in store, particularly under warm humid conditions but lesion expansion is very limited compared with silver scurf. Lesions are similar to but less well defined than silver scurf. The oval, pinhead black bodies (microsclerotia, bottom right) are often visible on the skin and may be readily diagnosed using a hand lens.

Infection of the growing plant may contribute to early dying disease in warm climates.

**Inoculum:** Soil-borne and favoured by wet soil conditions.

**Control:** Long rotations.

## C. *Fusarium* spp.: Dry rot

**Status in UNECE:** Tolerance for dry rot.

**Recommended diagnostics:** Visual observation of tubers and identification of fungi on specific medium.

**Symptoms:** There are several different species of *Fusarium* causing slightly different symptoms: generally, dry rots develop around a wound leading to dehydration of the tuber. In the growing crop, planting seed tubers affected by dry rot can result in weak plants or non-emergence.

*F. solani* var. *coeruleum* (top): Circular rot with concentric wrinkles on skin and white, orange or blue mycelial growth on surface. Light brown rot with a diffuse edge develops inwards from skin.

*F. sulphureum* (middle): Small lesions develop at wounds and expand producing symptoms externally similar to gangrene, i.e. slightly depressed and irregular in shape. Internally, lesions develop cavities filled with grey, powdery tissue.

*F. avenaceum* (bottom): Symptoms tend to be similar to *F. solani* var. *coeraleum* although rots are often smaller and affected tissue is dark brown.

**Inoculum**: Seed and soil-borne. Infection and disease progression are triggered by damage, e.g. at grading and favoured by warm storage conditions.

**Control:** Minimize damage, apply fungicides, use long rotations.

## D. *Goetrichum candidum*: Rubbery rot

**Status in UNECE:** Tolerance for wet rot.

**Recommended diagnostics:** Visual observation of tubers and identification of fungus on specific medium.

**Symptoms:** Rot develops at or soon after harvest in tubers from waterlogged soils.

Tuber surface is discoloured with patches of white mycelium developing on surface which feels damp. Internally, a grey, watery rot develops rapidly inwards from skin.

When cut, the tubers exude water with a sour milk or vinegary smell.

**Inoculum:** Soil-borne, associated with waterlogged soils in warm conditions towards harvest.

**Control:** Ensure adequate soil drainage. Storage of tubers from wet patches in the field separately from the rest of crop can help to manage potentially infected tubers.

## E. *Helminthosporium solani*: Silver scurf

**Status in UNECE:** Controlled indirectly through tolerance for shrivelled tubers.

**Recommended diagnostics:** Visual observation of tubers and identification of fungus on specific medium.

**Symptoms:** Tuber skin blemish disease which starts as small, round, silvery patches on the skin. In humid conditions, dark sooty conidiophores can develop around the edge of lesions. Large, silvery patches develop as individual lesions expand and merge during storage. Tubers can become dehydrated, leading to shrivelling.

**Inoculum:** Infection can originate from seed tubers, infested soil and spores surviving in dry soil in stores. Symptoms are not normally present at harvest but the disease can develop rapidly in store under humid, warm (>3$^{o}$C) conditions.

**Control:** Treatment of tubers with a fungicide prior to planting or at harvest (into store) may reduce infection and limit disease development but cannot control existing infections. Cold storage helps to control the disease. Routine annual store cleaning is advisable.

## F. *Phoma foveata*: Gangrene

**Status in UNECE:** Tolerance for dry rot.

**Recommended diagnostics:** Visual observation of tubers and identification of fungi on specific medium.

**Symptoms**: Storage rot of tubers. Initial lesions are round, dark and slightly depressed, often like a thumb mark. As lesions develop they become black and sunken with an irregular wavy edge. Black pycnidia can form on the surface. Rotted tissue is generally brown or black with a well-defined margin between healthy and diseased tissue. Cavities are usually lined with purple, yellow or white mycelia. Gangrene symptoms may also be caused by less aggressive *Phoma* spp., e.g. *P. exigua*.

**Inoculum**: Mainly seed-borne; can be spread in aerosols during rainfall. Tubers may be contaminated at harvest, but gangrene develops only after harvest following grading and/or at low storage temperatures.

**Control**: Early harvest followed by dry curing. Fungicides applied soon after harvest. Resistant varieties.

## G. *Phytophthora erythroseptica*: Pink rot

**Status in UNECE**: Tolerance for wet rot.

**Recommended diagnostics**: Visual observation of tubers and identification of fungus on specific medium.

**Symptoms**: Tubers are rubbery, usually affected at the heel end. Affected tissue turns pink on exposure to air within an hour.

Rots may develop at lenticels and eyes soon after harvest when conditions have been wet and warm just before harvest.

Tubers can have a distinctive sweet smell and ooze a colourless, clear liquid if squeezed hard.

**Inoculum**: Soil-borne. Infection is favoured by high soil moistures and high temperatures. Rots develop at, or soon after, harvest.

**Control**: Good crop rotation and drainage. Discard affected tubers.

## H. *Phytophthora infestans*: Late blight (foliage)

**Status in UNECE**: Tuber tolerance for dry or wet rot. Not counted in the crop although excessive levels may prevent crop inspection and, hence, certification of crop.

**Recommended diagnostics**: Visual observation of plants and tubers.

**Symptoms**: Lesions on leaves generally appear first as irregular shaped dark spots which enlarge as new lesions develop.

On the upper surface, a lighter green halo often surrounds the necrotic area and, on the lower surface, a milky-white ring of sporulation develops around the lesions under moist conditions. Spores can be seen with a hand lens.

Stem lesions are elongated, grey brown to black in colour and often encircle the stem. These lesions are often found at leaf axils and the apex of stems.

**Inoculum**: Infected seed tubers and groundkeepers; dumps of discarded tubers. Air-borne spores from other infected crops or groundkeepers. Infection and disease development follows periods of warm humid weather.

**Control**: Use of foliar fungicides, resistant varieties and healthy seed potatoes. Removal of potential inoculum sources e.g. infected potato dumps.

## I. *Phytophthora infestans*: Late blight (tuber)

**Status in UNECE**: Tuber tolerance for dry or wet rot.

**Recommended diagnostics**: Visual observation of plants and tubers.

**Symptoms**: Infected tubers usually develop a dark brown, sometimes purplish, area on the tuber surface. The internal rot is a reddish brown, granular rot which can remain close to the surface or progress to the centre of the tuber.

Development of the rot is irregular without a distinct leading edge, it can also be thread-like.

Affected tubers often have firm flesh with brown areas but secondary infection can lead to a wet breakdown of the tubers.

**Inoculum**: Spores from foliage infect tubers in soil. Tuber rots may be present at harvest and continue to develop during storage, often stimulated by damage at grading.

**Control**: Prevention of tuber blight in harvested tubers by controlling the disease in the field.

## J. *Polyscytalum pustulans*: Skin spot

**Status in UNECE**: Not regulated.

**Recommended diagnostics**: Visual observation of tubers.

**Symptoms**: Skin blemish disease of small (1-2 mm), brown-black pimples develop either singly or in groups on the tuber surface, often around eyes. In severe cases, eyes may be killed. Infected tubers are symptomless at harvest and skin spot develops after 2-3 months storage. Its development is favoured by low temperatures.

Planting diseased tubers can result in no or uneven emergence and weak plants.

**Inoculum**: Mainly soil-borne but can spread by spores and infected dust within store. Infection occurs on stem bases, stolons and roots, and spores produced on these under wet conditions may contaminate tubers at harvest.

**Control**: Early harvest followed by dry curing. Fungicides applied soon after harvest may assist control, but strains resistant to benzimadazole fungicides do exist.

## K. *Pythium* spp.: Watery wound rot (leak)

**Status in UNECE**: Tolerance for wet rot.

**Recommended diagnostics**: Visual observation of tubers and identification of fungus on specific medium.

**Symptoms**: Tuber rots develop at wounds soon after harvest when growing conditions are hot. Tubers are discoloured with greasy feel.

Rots develop in flesh of tuber with a clear dark line separating healthy outer tissue from spongy, soft brown diseased tissue which turns dark on exposure to air.

Rotten tissue initially smells alcoholic but, once advanced smells fishy.

**Inoculum**: Soil-borne. Infection of contaminated tubers occurs through wounds. Rots develop rapidly on newly lifted tubers whose skin has not set properly. Favoured by warm weather at harvest.

**Control**: Avoid fields with a history of the disease. Ensure firm skin set. Minimize damage at lifting and loading in stores. Dry curing with positive ventilation.

## L. *Rhizoctonia solani*: Stem canker/Black scurf

**Status in UNECE**: Tuber tolerance for black scurf and external defects. Not regulated in the growing crop.

**Recommended diagnostics**: Visual observation of tubers.

**Symptoms**:
*Plant:* Uneven emergence, wilting and stunting.

*Stem and stolons:* Brown, slightly sunken, sharp-edged lesions develop on stem bases. A superficial white powdery collar of fungal growth may be seen on stems just above soil level.

*Tuber:* Blemish caused by dark brown or black sclerotia forming on tuber surface; coverage may be difficult to assess accurately on unwashed dirty tubers.

Growth cracking accompanied with star-like elephant hide netting and trumpet shaped holes can be a symptom of *Rhizoctonia* (*inset image bottom right*).

**Inoculum**: Seed- and soil-borne. Most frequent on light soils under dry, cold conditions.

**Control**: Use well-sprouted seed tubers. Avoid early and deep planting in cold conditions. Use long rotations. Fungicides applied before planting.

## M. *Sclerotinia sclerotiorum*: White mould/Stalk break

**Status in UNECE**: Tolerances for dry rot. Not regulated in the growing crop.

**Recommended diagnostics**: Visual observation of stem.

**Symptoms**: White mould mainly infects the growing plant. Stems are infected at leaf axils and wounds, producing almost white lesions with a distinct edge. Woolly mycelium develops on lesions under moist conditions. The stem lesions frequently encircle the stem, leading to a wilting of the leaflets, which turn papery-white around the edges. Affected stems turn yellow/brown.

Tubers may have a heel end rot but this is rare. Internally, the rot is pale brown with fluffy white mycelia and black sclerotia developing in cavities.

**Inoculum**: Soil-borne: most infection occurs from wind-borne ascospores that are produced by the fungus on the soil surface. The disease is encouraged by prolonged high humidity in well-developed foliar canopies with wet leaves (e.g. sprinkler irrigation on fertile soils). The disease is more likely when potatoes follow oil seed rape (canola) which is an alternative host.

**Control**: Avoid high risk fields, plant following cereal crops, use varieties with an open canopy.

## N. *Spongospora subterranea*: Powdery scab

**Status in UNECE**: Tuber tolerance for powdery scab.

**Recommended diagnostics**: Visual observation of tubers with confirmation of spore balls under a microscope.

**Symptoms**:

*Tuber:* Round individual, raised scabs present on tubers at harvest, lesions erupt exposing brown powdery tissue (sporeballs) with tattered fragment of skin along edge of lesion. Infection at time of eye development can result in outgrowths (cankers: lower picture) of varying sizes developing at rose end of tubers. Root galls can also form on stolons and roots

Infection at time of eye development can result in outgrowths (cankers: lower picture) of varying sizes developing at rose end of tubers. Root galls can also form on stolons and roots.

**Inoculum**: Soil- and seed-borne. Most prevalent on heavy soils. Infection is favoured by wet, cool conditions at tuber initiation.

**Control**: Use of resistant varieties and long rotations are the most effective ways to control the disease derived from infected land. Take care with irrigation, especially during tuber initiation.

## O. *Synchytrium endobioticum*: Wart disease

**Status in UNECE**: Zero tolerance.

**Recommended diagnostics**: Visual observation of tubers and stem base. Supported by microscopy (spores).

**Symptoms**: Cauliflower-like growths develop at or below soil level on stems, stolons and tubers. These warts are green when above ground and cream below. As the crop dies down, the “warts” decay, becoming black.

**Inoculum**: Thick-walled spores are released into the soil from decayed warts and can remain infective for at least 30 years. Plants may become infected from soil inoculum. Spread is mainly by means of human activity, including machinery and planting infected tubers.

**Control**: Many cultivars are resistant. Outbreaks of this disease should usually be notified to the plant health authority. Cultivation of potatoes may be prohibited on land infested with Wart disease.

## P. *Verticillium* spp.: Verticillium wilt

**Status in UNECE**: Not regulated.

Verticillium wilt (sometimes called Potato Early Dying) is a disease of the vascular tissue of potato. There are two species causing the disease: *V. albo-atrum* and *V. dahliae*. The disease causes plants to mature and senesce early.

**Recommended diagnostics**: Visual observation of leaves and plant.

**Symptoms**: Plants wilt especially on hot sunny days. Wilting symptoms can often develop on only one side of a compound leaf or even a leaflet, due to vascular tissue being blocked. Leaves turn yellow or pale green and affected plants are stunted. A brown discolouration may be seen in the vascular ring of the stem if a slanting diagonal cut is made across the stem.

A discoloration may also be seen in the vascular tissue of the tuber but this is rare in some regions.

**Inoculum**: Soil-borne. Both species have a wide host range and can survive in soil for relatively long periods.

**Control**: Use an integrated approach of clean seed potatoes, long rotations with non-host crops and good control of host weeds and groundkeepers.

*[Pictures:*
*Members of the section Cairo 2009*
*Members of the section Edinburgh 2012]*

# III. Viruses and Viroids

**Viruses:**

Mild mosaic

Potato Leafroll Virus (PLRV)

Potato Mop Top Virus (PMTV)

Severe mosaic

Tobacco Rattle Virus (TRV)

Tomato Spotted Wilt Virus (TSWV)

$PVY^{NTN}$/Potato Tuber Necrotic Ringspot Diseases (PTNRD)

**Viroids:** Potato Spindle Tuber Viroid (PSTV).

## A. Mild mosaic

**Status in UNECE**: Crop tolerance for mild mosaic. Direct progeny tolerance for total virus.

**Recommended diagnostics**: Visual observation of plant supported by ELISA test. Test kits are available for use in the field.

**Symptoms**: Mild mosaic is associated with PVX and PVS but mild symptoms can also result from infection by other viruses e.g. PVA and $PVY^{N}$ strains. Plants with mild mosaic display varying degrees of mottling (a mosaic pattern of light and dark green on leaflets). There is no leaf distortion. In some varieties, the expression is only pale plants (no mosaic), making diagnosis difficult. Some varieties can be infected by virus but develop no symptoms. Symptoms are dependent on the interaction of variety with virus/virus strain.

**Inoculum**: Seed potatoes, groundkeepers and adjacent crops (especially ware) are all significant sources. PVX and PVS are contact transmitted, i.e. plant-to-plant or movement of machinery, people or animals through a crop. For the other viruses see **severe mosaic**.

**Control**: Use healthy seed potatoes, rogue early in growing season, minimize inoculum sources i.e. control groundkeepers, maintain separation from infested crops. Aphicide and mineral oil sprays. Early haulm destruction.

## B. Potato leafroll virus (PLRV)

**Status in UNECE**: Crop tolerance for leafroll. Direct progeny tolerance for total virus.

**Recommended diagnostics**: Visual observation of plant supported by ELISA test.

**Symptoms**:

*Primary:* Rolling from the leaf base of the youngest, upper leaves, sometimes with a purple discoloration; these symptoms are only seen if infection occurs in early stages of plant growth or in hot climates.

*Secondary* (from infected tubers): Leaves roll inwards and become dry, brittle and sometimes brown. Rolling develops initially on the lower leaves and moves up the plant. Plants are stunted and may be hidden below the canopy of adjacent healthy plants.

*Tubers* may develop a net necrosis: brown flecks of necrotic tissue in the vascular tissue. In susceptible varieties, this can occur after primary or secondary infection.

**Inoculum**: Principally seed-borne but groundkeepers and adjacent crops (especially ware) can be significant sources. Unlike mosaic viruses, PLRV is transmitted persistently by aphids, especially *Myzus persicae*, i.e. aphids acquiring PLRV remain infectious for life.

**Control**: As for mosaics, but aphicides are more effective. Take care to avoid build-up of aphicide resistance.

## C. Potato mop top virus/Spraing (PMTV)

**Status in UNECE**: Not regulated, except that deformed tubers are regulated as an external defect.

**Recommended diagnostics**: Visual observation of plant supported by ELISA test. Virus is erratically distributed within the plant; so test results from affected plants may be negative. ELISA testing of symptomatic and asymptomatic tubers is normally reliable.

**Symptoms**: Symptoms occur the year following transmission and vary by variety. The severest effect is shortening of the internodes at the top of the stem producing a stunted bunched top (mop head); a milder symptom is yellow chevrons or splashes on the leaves with no effect on plant growth. Usually only 1-2 stems show symptoms.

Tubers may develop spraing (see also TRV): reddish-brown rings or lines on the tuber surface which extend as arcs of red-brown, necrotic tissue through the tuber flesh. Only a proportion of tubers from an infected plant are affected. Other tuber symptoms include growth cracking and elephant hide.

**Inoculum**: PMTV is transmitted by *Spongospora subterranea* (powdery scab). In the absence of the vector, PMTV will self-eliminate because of the relatively low rate of transmission of the virus within the plant from seed to daughter tuber.

**Control**: Resistant varieties and as for *S. subterranea*.

## D. Severe Mosaic

**Status in UNECE**: Crop tolerance for severe mosaic. Direct progeny tolerance for severe virus.

**Recommended diagnostics**: Visual observation of plant supported by ELISA test.

**Symptoms**: Severe mosaic is associated with PVY (particularly $PVY^O$), PVA, PVV and PVM, and with PVX and PVS in combination with other viruses. However, in some varieties, these viruses can cause only mild mosaic and, sometimes, even be symptomless. Symptoms are similar to mild mosaic but are accompanied by leaf distortion and/or stunting of the plant. In very severe cases, leaf necrosis and leaf drop can occur.

**Inoculum**: PVA, PVM, PVV, PVY and some strains of PVS are spread by aphids non-persistently, i.e. they acquire the virus within seconds but lose it within hours. Viruses are transmitted by migratory (e.g. cereal) aphids which are difficult to control. Other insect pests may transmit these viruses in some regions.

**Control**: Use healthy seed potatoes, rogue early, minimize inoculum sources, i.e. control groundkeepers, maintain separation from infested crops. Aphicide and mineral oil sprays. Early haulm destruction.

## E. Tobacco rattle virus/Spraing (TRV)

**Status in UNECE**: Not regulated.

**Recommended diagnostics**: Observation of tubers and PCR test. ELISA does not detect some isolates.

**Symptoms**:

*Plant:* Mottling and distortion of leaves, and stunting of some or all stems. Leaf symptoms are a distinctive pinching towards the tip of the leaflet, accompanied by purplish-red or yellow margins.

*Tubers* may have spraing (see PMTV): brown, corky arcs and spots in the tuber flesh which are sometimes visible on the skin surface. These differ subtly from PMTV but the differences amongst varieties makes differentiation on visual symptoms problematic.

**Inoculum**: TRV is transmitted by free living *Trichodorus* and *Paratrichodorus* nematodes (not PCN) which are most prevalent in light sandy soils and move in soil water column. TRV has a very wide host range, making rotation intervals between potato crops almost irrelevant for control. In potato multiplication, the virus is self-eliminating in the absence of vectors.

**Control**: Use wheat, barley and oat (hosts of trichodorid but not TRV) in the potato rotation in conjunction with good weed control. Avoid over-irrigating at tuber initiation.

## F. Tomato spotted wilt virus (TSWV)

**Status in UNECE**: Not regulated.

**Recommended diagnostics**: Visual observation of plants and tuber.

**Symptoms**:

*Plant:* Primary symptoms are leaves turning pale, necrotic spots then develop and can become large with concentric rings. These may be confused with symptoms of *Alternaria* infection. Secondary symptoms (from infected mother tubers): plants are stunted with bunched growth and may develop brown desiccated leaves. Affected plants may die early.

*Tuber:* Affected tubers are usually small and may have superficial black lesions. The tubers may also develop internal symptoms ranging from small, dark, necrotic spotting to more extensive dark internal necrosis.

**Inoculum**: TSWV has a wide host range and is spread by thrips.

**Control**: Avoid fields where vector pressure is likely to be high. Use resistant varieties and insecticides.

## G. PVY$^{NTN}$/Potato tuber necrotic ringspot diseases (PTNRD)

**Status in UNECE**: Crop and progeny tolerance for mild/severe virus, and externally symptomatic tubers are regulated as an external defect.

**Recommended diagnostics**: Observation of tubers. Symptom expression is determined by variety - PVY strain - environment interaction, so laboratory tests alone cannot identify PTNRD but can confirm the presence of virus.

**Symptoms**:

PTNRD is caused by some strains of PVY but the extent of the expression varies with variety. PVY strains associated with PTNRD tend to produce mild mosaic symptoms on infected plants in the field, but, in some varieties, foliar infection may be symptomless.

The development of tuber symptoms is favoured by high temperatures late in the growing season and after harvest. PTNRD symptoms progress in the store from a smooth pink to reddish-brown necrotic ring or arc on the tuber surface to become raised before finally resulting in an unsightly sunken crater which may turn a darker brown.

The lesions remain superficial and there are no necrotic arcs within the tuber flesh which distinguishes this disease from spraing caused by PMTV or TRV.

**Inoculum and control**: As for PVY: see mild/severe mosaic virus. Affected tubers can be removed at grading.

## H. Potato spindle tuber viroid (PSTV)

**Status in UNECE**: Zero tolerance.

**Recommended diagnostics**: Observation of plant and tuber. Test by molecular hybridization and PCR.

**Symptoms**: Plant and tuber symptoms vary with the variety, viroid strain and environmental conditions.

Plants may appear atypically upright in habit and stunted with rugose leaflets. Tubers may be more elongated than normal or may be typically spindle shaped and have a remarkably large number of eyes. The tissue around the eyes is slightly too prominently swollen and looks like heavy “eyebrows”. In serious cases, the tubers may be deformed with deep growth cracks.

**Inoculum:** Unlike most many other potato pathogens, PSTV can be transmitted in true potato seed (and seed of other hosts). The disease can also be spread mechanically, particularly by cutting infected seed.

**Control:** Use clean seed potatoes. Avoid cutting infected seed potatoes. Outbreaks of PSTV should normally be reported to the Plant Health Authority.

*[Pictures of potato production, two countries?]*

# IV. Bacterial pathogens

**Bacteria:**

*Clavibacter michiganensis* ssp. *sepedonicus*: Ring rot

*Dickeya / Pectobacterium* spp.: Blackleg

*Ralstonia solanacearum*: Brown rot

*Streptomyces* spp.: Common and netted scab

**Phytoplasmas:**

Potato Stolbur

Witches' Broom

## A. *Clavibacter michiganensis* ssp. sepedonicus: Ring rot

**Status in UNECE**: Zero tolerance.

**Recommended diagnostics**: Observation of plant and tuber, test by IF (Immunofluorescence) and PCR (polymerase chain reaction).

**Symptoms**:

*Plant:* Symptoms which generally occur late in the season are fairly typical of a vascular wilt, usually affecting the lower leaves and, sometimes, accompanied by leaf rolling. Areas between the leaf veins become chlorotic and the leaf margins become necrotic. Symptoms can be difficult to distinguish from those of other diseases and crop damage.

*Tubers:* The vascular ring and surrounding tissue are pale yellow or glassy, becoming darker as the disease progresses. The rot is odourless and cheesy or crumbly. Rotting may later extend into the central pith. As the rot develops in the vascular ring, the skin becomes discoloured and deep cracks develop.

**Inoculum:** Seed-borne: Some varieties can be symptomlessly affected. The bacteria can also be spread on contaminated machinery, particularly cutting equipment.

**Control**: Treated as a quarantine pest in most countries i.e. exclusion from potato production with the pathogen being eradicated in the event of an outbreak.

## B. *Dickeya / Pectobacterium* spp.: Blackleg

**Status in UNECE**: Crop tolerance for blackleg. Tuber tolerance for wet rot.

**Recommended diagnostics**: Observation of plant and tuber.

**Symptoms**:

*Pectobacterium* spp.: Plants are stunted and have a "hard" appearance. Leaves are stiff and erect, often rolling inwards at the top. A black slimy rot usually appears at the stem base as the disease proceeds. Affected stems are easily pulled out.

*Dickeya* spp.: Initially, plant symptoms are a soft, sometimes asymmetrical, wilt from which the plant recovers. As the disease develops, a stem rot may be seen, sometimes developing from the leaf axils.

However, both pathogens can have very similar symptoms making diagnosis of the causal bacteria very difficult.

*Tubers:* Soft brownish-white rot extends from the heel end or lenticels. Affected area is bounded by a dark margin. A distinctive fishy smell is produced.

**Inoculum**: Seed-borne but spread can occur in the crop from diseased to healthy plants with the bacteria being carried in water droplets (rain splash/aerosols) and by insects. Contact with contaminated machinery/boxes is an important method of spread.

Infection by both pathogens and disease development is favoured by wet growing conditions, but cool weather is more favourable for *Pectobacterium* and warm for *Dickeya*.

**Control**: Healthy seed potatoes. Attention to hygiene at all stages.

## C. *Ralstonia solanacearum*: Brown rot

**Status in UNECE**: Zero tolerance.

**Recommended diagnostics**: Observation of plant and tuber, test by IF and PCR.

**Symptoms**:

*Plant:* Symptoms include wilting of the youngest leaflets during the hottest part of the day; plants may appear to recover at night. In cool climates, wilting does not always occur. Development leads to stunting of plants, general wilting, yellowing of foliage and plant death. Bacterial slime may exude from the vascular tissue of cut stems.

*Tubers:* The initial symptoms are a brown staining of the vascular ring starting at the stolon end. As the disease progresses, the vascular tissue rots away completely and a pale-coloured sticky ooze may appear at the eye, lenticels and/or stolon end of the tuber, resulting in soil adherence at these areas.

**Inoculum**: Brown rot is mainly tuber-borne, often symptomless. Latently infected tubers can cause disease when planted in the next season. The bacterium can be spread on contaminated machinery and in irrigation water, and can also persist in fields in infected groundkeepers.

**Control**: Treated as a quarantine pest in most countries, i.e. exclusion from potato production and eradication in the event of an outbreak.

## D. *Streptomyces* spp.: Common and netted scab

**Status in UNECE**: Tuber tolerance for common and netted scab.

Common scab is caused by *Streptomyces scabiei* and other *Streptomyces* spp. e.g. *S. europaeiscabiei* and *S. stelliscabiei*. Netted scab can be caused by *S. europaeiscabiei* and *S. reticuliscabiei*.

**Recommended diagnostics**: Observation of tuber.

**Symptoms**: Range from superficial, corky lesions to extensive, raised scabs occurring either singly or in groups. Netted scab symptoms are a superficial, corky, russeting of the skin.

**Inoculum**: Soil-borne. Disease development is favoured by warm dry soils, particularly at and following tuber initiation. Most prevalent on light, free draining soils. Symptoms do not develop during storage.

**Control**: Use resistant varieties. Irrigation at, or soon after, tuber initiation; however, too much irrigation may increase the risk of powdery scab. Avoid alkaline soils or soils which have been limed.

## E. Potato stolbur

**Status in UNECE**: Zero tolerance.

**Recommended diagnostics**: Visual observation of leaves and tubers.

**Symptoms**: Stunting of the plants with a rolling of the leaf accompanied by a yellow or purple discolouration. Affected plants may produce aerial tubers and many axillary buds. Disease will usually result in premature death of plant.

Affected tubers may be flaccid and these may produce abnormal sprouts, including spindly sprouts (sometimes called “hair sprouting”).

**Inoculum**: There are a wide range of naturally growing hosts, notably *Solanaceae* including some crop plants (e.g. eggplant, tomato and pepper). The disease is transmitted by leafhoppers.

**Control**: Use healthy seed potatoes and control weeds.

## F. Witches’ broom

**Status in UNECE**: Not regulated.

**Recommended Diagnostics**: Visual observation of leaves and tubers

**Symptoms**: As the name suggests the symptomatic plants have an erect growth habit so that the top of the plant has the appearance of the bristles of a witches’ broom. Plants grown from infected tubers are also stunted and appear bushy due to the number of weak stems. Most infected tubers will produce many weak stems which fail emerge to produce viable plants.

**Inoculum**: Caused by a phytoplasma and is vectored by leafhoppers. The disease is spread from inoculum reservoirs in the wider environment particularly weeds and leguminous crops.

**Control**: The disease is self eliminating as the progeny tubers form infected plants either do not sprout or produce weak plants.

*[Wire worm damage]*

# V. Pests

**Nematodes:**

*Ditylenchus destructor*: Root rot nematode

*Globodera* spp.: Potato Cyst Nematode (PCN)

*Meloidogyne* spp.: Root knot nematodes

**Insects:**

*Agriotes / Tandonia / Arion* spp.: Wireworm

*Epitrix* spp.: Potato flea beetle

*Leptinotarsa decemlineata*: Colorado beetle

*Phthorimea opercullella*: Tuber moth.

## A. *Ditylenchus destructor*: Root rot nematode

**Status in UNECE:** Zero tolerance. Sometimes called Potato Tuber Nematode

**Recommended diagnostics:** Visual observation of tubers.

**Symptoms**: Nematodes enter the tuber through lenticels or eyes and symptoms are not normally seen until after harvest. Initially, grey to white mealy spots develop beneath the tuber surface (visible if cut or peeled). This progress towards the vascular tissue and the affected spots coalesce and darken. The skin becomes papery and cracked. Affected tubers are susceptible to secondary infection by opportunistic fungal or bacterial pathogens.

**Inoculum**: The nematodes are mainly spread by the movement of infested tubers.

**Control**: Use healthy seed potatoes and avoid fields where there have been previous outbreaks. Suppression of the nematodes is difficult due to the wide host range, but cultivation of cereals in conjunction with effective weed control can assist in their reduction.

## B. *Globodera* spp.: Potato cyst nematode (PCN)

**Status in UNECE**: Zero tolerance. Land used for seed potato production should be tested and found free of PCN.

**Recommended diagnostics**: Test soil prior to planting (flotation followed by microscopy or PCR). Visual observation of the crop.

**Symptoms**: Two species of *Globodera* affect potato: *G. rostochiensis* and *G. pallida*. In the crop, PCN infestation is characterized by patches of weaker or stunted plants which tend to wilt, or plants develop a darker- or dull-coloured foliage. It may be possible to see (with the naked eye or with the aid of a hand lens) pinhead-sized white or golden yellow cysts developing on the roots.

**Inoculum**: PCN is mainly spread by the movement of infested tubers, in particular farm-saved seed potatoes from untested land. Infestation can be caused by transfer of infested soil on machinery, in flood waters and even by wind.

**Control**: Keep land free from infestation by sourcing clean seed potatoes. Use resistant varieties, long rotations and nematicides. In some regions, trap crops assist in reducing PCN populations.

## C. *Meloidogyne* spp.: Root knot nematodes

**Status in UNECE**: Zero tolerance.

**Recommended diagnostics**: Observation of tuber, microscopic examination of cut tuber, and PCR test.

**Symptoms**: Several species of *Meloidogyne* cause symptoms on potatoes. Two of these are recognized in the Standard: *M. chitwoodi* and *M. fallax*.

In growing plants, knots and galls develop on the roots. The galls are abnormal plant growths formed around a feeding juvenile nematodes. Galls may be produced on the tuber surface, depending on the variety. Tuber galls appear as small, raised lumps above the developing nematodes, giving the skin a rough appearance. Galls may be grouped in a single area or scattered near the eyes. When infested tubers are cut, small brown spots may

be seen within the tuber cortex, each spot represents a mature female surrounded by a mass of brown eggs.

**Inoculum**: Mainly spread by planting infested potatoes. Once established in an area, movement by machinery, irrigation and animals can distribute the pest. The pest can also be introduced by movement of infested soil.

**Control**: Keep land free from infestation by sourcing clean seed potatoes.

## D. *Agriotes / Tandonia / Arion* spp.: Wireworm

**Status in UNECE**: Not regulated.
More than 30 species of wireworms are known to cause damage to potatoes. These include: *Agriotes* spp.: *A obscurus*, *A. sputator*, *A. lineatus/Tandonia budapestensis* and *Arion hortensis*. Adults are known as Click beetles.

**Recommended diagnostics**: Visual observation of tubers.

**Symptoms**: Adult beetles may feed on crop foliage but the damage is not usually economically important.
*Tuber*: The larvae bore small shallow holes or deeper tunnels into the tuber. Tunnels are always narrow (unlike slug damage) but can be extensive. Wireworm damage provides an entry point for other pathogens which may lead to tuber rots.

**Inoculum**: Click beetles prefer to lay their eggs in pasture, particularly permanent pasture.

**Control**: Avoid fields with large populations of wireworms (pheromone traps and soil bait testing can be used to assess populations). Use early varieties in high-risk fields. Use insecticides at planting and appropriate insecticide seed treatments for other crops in the rotation.

## E. *Epitrix* spp.: Potato flea beetle

**Status in UNECE**: Not regulated, externally symptomatic tubers are regulated as an external defect.

**Recommended Diagnostics**: Visual examination of plants and tubers.

**Symptoms**: Four species of *Epitrix* are associated with damage to potatoes: *E. tuberis*, *E. cucumeris*, *E. similaris* and *E. subcrinata*. The adults feed on the potato foliage leaving tiny characteristic shot-holes in the leaflets. The larvae feed on the root system and tubers. It is the tuber damage that has the potential to impact on the quality of the crop. The larvae can burrow furrows in the surface of the tubers leaving unsightly damage. The damage can usually be removed by peeling.

**Inoculum**: Potato flea beetles are widespread in some regions and localised infestations have been recorded or are absent in others. The adult beetles are very mobile in the environment and can feed on a variety of hosts including several weed species. Adults present the greatest risk as larvae have not been found in harvested tubers. Eggs and larvae are very unlikely to survive on tubers that are cleaned after harvest.

**Control**: Avoid introducing the pest into regions where it is absent. In regions where the pest is endemic it is normally controlled by an insecticide programme.

## F. *Leptinotarsa decemlineata*: Colorado beetle

*[Picture eggs]*

**Status in UNECE**: Not regulated.

**Recommended diagnostics**: Visual observation of the eggs, larvae and adults.

**Symptoms**: Colorado beetles and their larvae feed on the leaves and, sometimes, stems of the plants. This produces irregular holes in the leaflets. Extensive or total defoliation of the plants can occur with severe crop infestations. All mobile stages feed on the foliage of the potato plant.

**Inoculum**: The adult is about 10 mm long with alternate black and yellow stripes running from front to back along each wing case; the head and thorax are brown with variable black markings. The larvae, which move about freely, are at first orange-brown, but later become carrot-red, with 2 rows of black dots on each side. The pupae are similar in shape and colour to the larvae, but are immobile. The eggs are yellow or orange, cylindrical and about 2 mm long. These are laid on the underside of leaves (take care not to confuse these with ladybird/ladybug (*Coccinellidae*) eggs).

**Control**: Use insecticides and long rotations.

## G. *Phthorimea opercullella*: Tuber moth

**Status in UNECE**: Zero tolerance for the live pest and cut surface tolerance for tuber damage caused by the larvae.

**Recommended diagnostics**: Visual observation of leaves and tubers.

**Symptoms**: The larvae of the tuber moth feed on both the growing plants and tubers of potato.

*Plant:* The larvae mine into the leaves and eat the inner tissue, particularly the main veins, although this damage is not normally economically important.

*Tuber:* At harvest, affected tubers may show little visible evidence of infestation but may be harbouring eggs or young larvae. As the larvae feed on the tubers, damage becomes extensive with galleries developing just under the skin or deep into the tuber. Affected tubers may lose excessive moisture through the wounds, resulting in shrivelling. Secondary infection by fugal pathogens can also lead to tuber rotting.

**Inoculum**: Tuber moths are present in conjunction with potato production in most tropical and subtropical regions. Infestation can be carried by infested tubers into store or adults can enter stores to lay eggs.

**Control**: Use clean seed potatoes and an integrated control strategy.

*[Slug causing damage]*

# VI. Other Disorders

Chilling injury/Frost damage

Cracks (present prior to harvest)

Damage

Misshapes / Secondary growth / Glassiness

Shrivelled tubers.

## A. Chilling injury / Frost damage

**Status in UNECE**: Tuber tolerance for chilling injury.

**Recommended diagnostics**: Visual observation of tubers.

**Symptoms**: Chilling injury causes the tuber flesh to become reddish brown to black. The symptom on the tuber surface is a dark brown, sometimes sunken, patch. Symptoms may also occur internally. Frosted (right and lower pictures) tissue exudes water, and the edges of affected areas are blackened. There is often a clear demarcation line between healthy and affected tissue.

**Cause**: Cold temperatures (below 1ºC) prior to harvest and in store. Tuber damage may also result from heat shock where tubers are exposed to rapid temperature changes (not necessarily below freezing point).

**Control**: Harvest tubers prior to frost and avoid excessive cooling or cold areas in store.

## B. Cracks (present prior to harvest)

**Status in UNECE**: Tolerance for external defects.

**Recommended Diagnostics**: Visual observation of tubers.

**Symptoms**: Growth cracks are deformation of the tuber present prior to harvest and range in severity. Cracks which form early in the growth period will become less severe as the tubers reach their full size. Cracks associated with disease or herbicide damage may be more severe.

Cracks caused by during handling are covered under Damage.

**Cause**: Cracks can be caused by a number of factors or combinations of these.

*Physiological* cracks are caused by rapid tuber expansion often triggered by an increase in soil moisture following a dry period.

*Virus* cracks: growth cracking can be associated with virus infection (mosaic viruses and PMTV) with tuber symptoms usually indistinguishable from physiological cracking.

*Rhizoctonia* cracks: infection by *R. solani* can cause tuber misshapes and cracking accompanied with star-like netting.

*Herbicide* cracks: certain herbicides can cause deformation and severe cracks in daughter tubers of plants contaminated by accidental spraying or spray drift.

**Control**: Good crop husbandry including control of soil moisture levels and diseases. Good training of spray operators.

## C. Damage

**Status in UNECE**: Tolerance for external defects.

**Recommended Diagnostics**: Visual observation of tubers.

**Symptoms**: Bruised or cracked tubers, or tubers with missing pieces or holes and galleries on the tuber flesh. Cracks or holes in tubers can lead to secondary infection by rot pathogens.

**Causes**:

*Mechanical damage* is caused when handling the tubers and can occur from harvest to delivery. Impacts during handling can lead to small thumbnail cracks or more severe, deeper superficial cracks and even shatter cracks that extend into the tuber flesh. Many factors can affect damage levels but, overall, damage is minimised by appropriate care at each handling step.

*Pest damage* can be caused by a variety of organisms including slugs, wireworms, tuber moth, flea beetles and rodents.

**Control**: Use appropriate well maintained machinery running at the correct speed. Take care when harvesting in dry conditions and avoid handling cold tubers. Good pest control during crop growth and storage.

## D. Misshapes / Secondary growth / Glassiness

**Status in UNECE**: Tolerance for external defects.

**Recommended Diagnostics**: Visual observation of tubers.

**Symptoms**: Misshapes are any tubers which deviate from the normal shape for the variety. These include bottle or dolly/dumbbell shaped or knobbly tubers. Glassy tubers (sometimes known as jelly end rot) are those where starch grains are absent from the tuber flesh leading to a transparent glassy appearance.

**Causes**: These symptoms are generally caused by uneven growth condition, especially a warm period followed by rainfall. The uneven conditions cause an irregular second phase of tuber formation, following normal initiation and elongation. In this second elongation phase, the misshapes form. Glassiness is caused in the earliest formed tubers when the foliage dies back and tubers further along the stolon draw energy from the tubers closer to the mother plant causing them to metabolise their starch.

**Control**: Provide a good seed bed for susceptible varieties and manage the crop to prevent uneven growth. In crops where secondary tubers have formed, destroy the haulm early or minimise the time between haulm destruction and harvest to reduce glassiness.

## E. Shrivelled tubers

**Status in UNECE**: Tolerance for shrivelled tubers.

**Recommended Diagnostics**: Visual observation of tubers.

**Symptoms**: Tubers which have lost their turgidity and have become wrinkled and pliable.

**Causes**: Tubers become shrivelled when they are dehydrated. This can have a number of causes including: excessive drying (too much air flow in forced air ventilation (letterbox) systems; tuber moisture loss due to skin blemish diseases like silver scurf; long term storage and sprouting.

**Control**: Monitor tubers carefully during/curing. Store tubers in appropriate conditions for the variety and duration of storage. Minimise skin blemish diseases and market at risk stocks early.

# VII. Dedication and acknowledgements

This guide is dedicated to the memory of our friend and colleague Günter Erbe.

Our thanks go to members of the Specialized Section whose work is reproduced here. Thanks to Dr Carnegie for his guidance on the text.

We greatly appreciate the photographic contributions which make this guide possible, in particular Sylvia Breslin and Stuart Greig at SASA (Scottish and Advice for Scottish Agriculture).

**Further reading:**

Diseases, Pests and Disorders of Potatoes, a colour handbook. Stuart Wale, H.W. (Bud) Platt (2008). ISBN 978-1-84076021-7
Potato Diseases: Diseases, Pests and Defects. Editors E. Dr D.E. van der Zaag et al. (1994). ISBN 90-802036-2-9

European Handbook of Plant Diseases. Edited by I.M. Smith, J. Dunez, D.H. Phillips, R.A. Lelliott and S.A. Archer (1988). Blackwell Scientific Publications, United Kingdom. ISBN 0-632-01222-6

FAO/IPGRI Technical Guidelines for the Safe Movement of Germplasm No. 19 Potato, Colin J Jeffries. ISBN 92-9043-390-6