

UNECE Standard S-1  
concerning the marketing and  
commercial quality control of



# Seed Potatoes

*UNECE Guide to Seed  
Potato Diseases,  
Pests and Defects*



UNITED NATIONS



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UNITED NATIONS

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# Note

Further copies of this *Guide*  
are available from:

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# Dedication and acknowledgements

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

Dr. John Kerr of Science and Advice for Scottish Agriculture (SASA) was the general editor of the *Guide*.

Our thanks go to the members of the UNECE Specialized Section on Standardization of Seed Potatoes whose work is reproduced here. Thanks also go to Dr. Stuart Carnegie for his guidance on the text.

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# 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 maximizing 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 physiology
- sizing and labelling.

It 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 with, 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).



# Use of this Guide

The *Guide* provides a pictorial reference to pests and diseases affecting potato quality as an aid to using the Standard.

The *Guide* is intended to assist seed potato inspectors and producers in assessing seed potato 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 the 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: <http://www.unece.org/trade/agr/standard/potatoes/PestPicturesE.html>. The photographs published in the *Guide* may be reproduced for the purposes of training, provided an acknowledgement of copyright is made.

If you can use this *Guide* to responsibly further an understanding of seed potato production by reproducing it, then please do so. However, an acknowledgement and a reference to the source material should be included.



# 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. measures 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.



# 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 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.

# UNECE classification scheme/ Label colours

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

Categories	Classes
Pre-Basic	PBTC
	PB
Basic	Class I
	Class II
Certified	Class I
	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 label



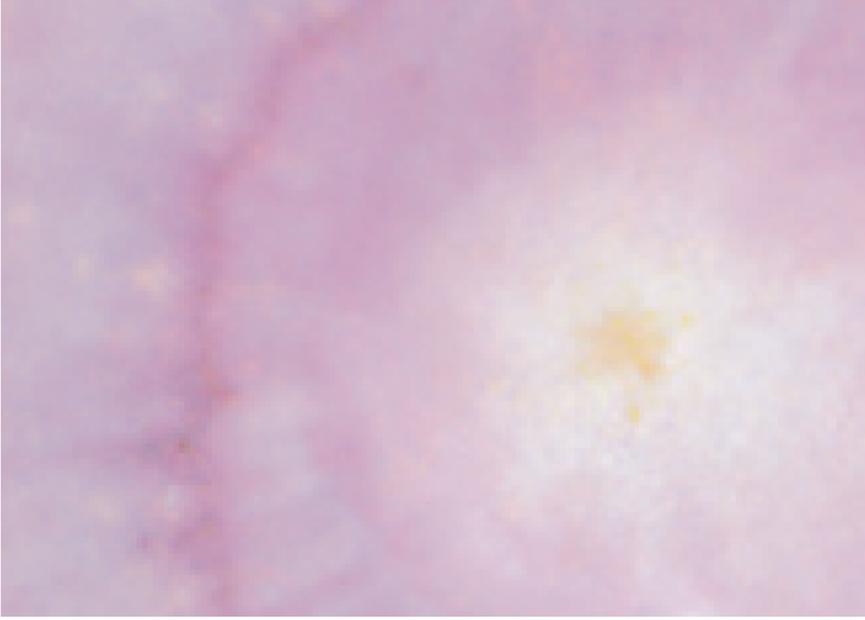
PB seed label



Basic seed label



Certified seed label



# Fungal pathogens



# *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. The two species which affect potato are *Alternaria solani* and *Alternaria alternata*. It is 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. Symptoms may be confused with tomato spotted wilt and magnesium deficiency. Early blight 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.



*Alternaria* spp. - © INRA



*Alternaria* spp. - © INRA



# *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 occurring as 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) 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.



*Colletotrichum coccodes* - © SASA



*Colletotrichum coccodes* - © SASA



*Colletotrichum coccodes* - © SASA

# *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*: 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*: 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 a grey, powdery tissue.

*F. avenaceum*: Symptoms tend to be similar to *F. solani* var. *coeruleum*, 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.



*Fusarium solani* var. *coeruleum* - © ARVALIS



*Fusarium sulphureum* - © SASA



*Fusarium avenaceum* - © SASA



# *Geotrichum 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. Storing tubers from wet patches in the field separately from rest of crop can help to manage potentially infected tubers.



*Geotrichum candidum* - © SASA



*Geotrichum candidum* - © SASA



# *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°C) conditions.

### **Control:**

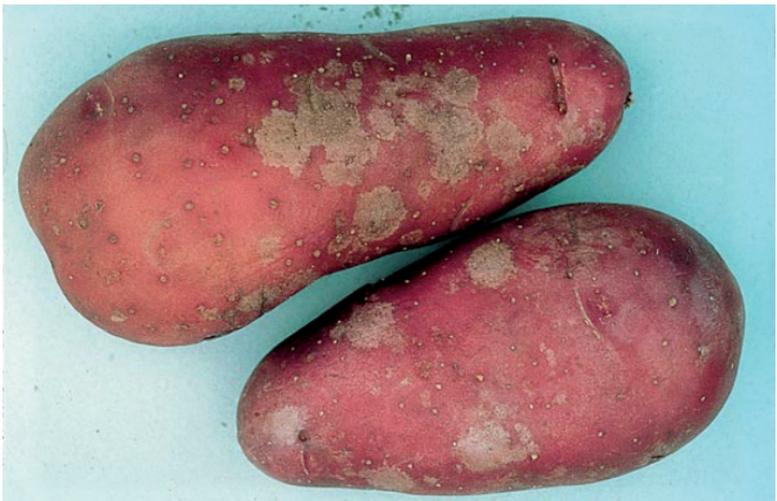
Treatment of tubers with a fungicide prior to planting or at harvest (into store) may reduce infection and limit disease development but cannot control existing infections. Cold storage helps to control the disease. Routine annual store cleaning is advisable.



*Helminthosporium solani* - © SASA



*Helminthosporium solani* - © NAK



*Helminthosporium solani* - © CNPPPT



# *Phoma foveata*

## Gangrene (a dry rot)

### **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. Initially the 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 may 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.



*Phoma foveata* - © SASA



*Phoma foveata* - © SASA



*Phoma foveata* - © NAK



# *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 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 moisture and high temperatures. Rots develop at, or soon after, harvest.

### **Control:**

Good crop rotation and drainage. Discard affected tubers.



*Phytophthora erythroseptica* - © SASA



*Phytophthora erythroseptica* - © SASA



*Phytophthora erythroseptica* - © DGAL

# *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 irregularly 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.



*Phytophthora infestans* - © SASA



*Phytophthora infestans* - © LfL Bayern



*Phytophthora infestans* - © NAK



*Phytophthora infestans* - © NAK



# *Phytophthora infestans*

## Late blight (tuber)

### **Status in UNECE:**

Tuber tolerance for dry or wet rot.

### **Recommended diagnostics:**

Visual observation of plants and tubers.

### **Symptoms:**

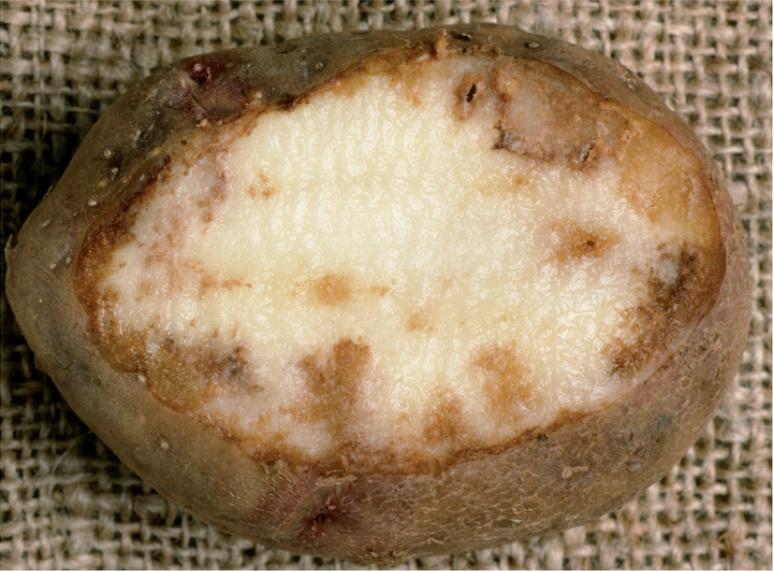
Infected tubers usually develop a dark-brown, sometimes purplish, area on the tuber surface. The internal rot is a reddish-brown, granular rot which can remain close to the surface or progress to the centre of the tuber. Development of the rot is irregular and without a distinct leading edge; it can 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.



*Phytophthora infestans* - © SASA



*Phytophthora infestans* - © FN3PT



# *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 occurring 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 only develops after 2-3 months storage. Its development is favoured by low temperatures. Planting diseased tubers can result in non- or uneven-emergence and weak plants.

**Inoculum:**

Mainly seed-borne but can be spread by spores and infested 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 benzimidazole fungicides do exist.



*Polyscytalum pustulans* - © SASA



*Polyscytalum pustulans* - © SASA



# *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:**

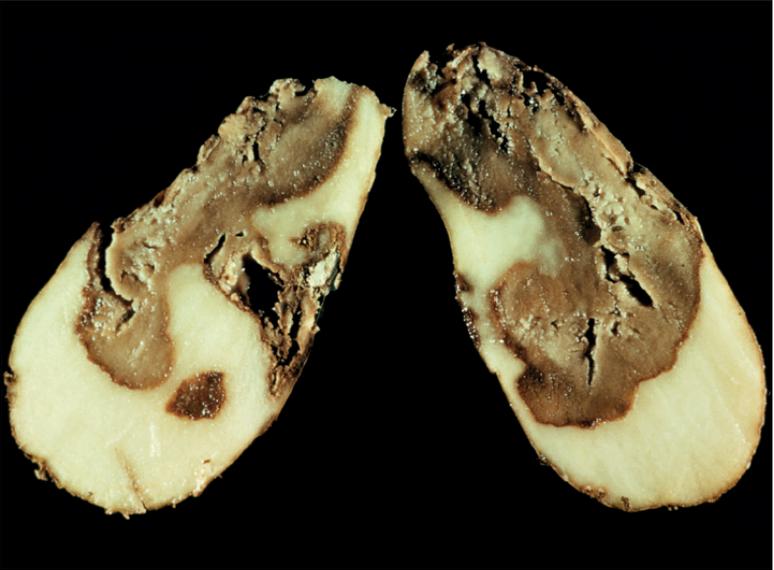
Tuber rots develop at wounds soon after harvest when growing conditions are hot. Tubers are discoloured, with a greasy feel. Rots develop in flesh of tuber, with a clear dark line separating healthy outer tissue from spongy, soft brown diseased tissue which turns dark on exposure to air. Rotten tissue 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.



*Pythium* spp.- © SASA



*Pythium* spp.- © SASA

# *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. The fungal growth results in a dry and brittle tissue.

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 by star-like elephant hide netting and trumpet-shaped holes can be a symptom of *Rhizoctonia*.

### **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.



*Rhizoctonia solani* - © SASA



*Rhizoctonia solani* - © NAK



*Rhizoctonia solani* - © NAK



*Rhizoctonia solani* - © SASA



*Rhizoctonia solani* - © CNPPPT



*Rhizoctonia solani* - © NAK



*Rhizoctonia solani* - © SRUC

# *Sclerotinia sclerotiorum*

## White mould / Stalk break

### **Status in UNECE:**

Tolerances for dry rot. Not regulated in the growing crop.

### **Recommended diagnostics:**

Visual observation of stems.

### **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 develop 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 oilseed rape (canola), which is an alternative host.

### **Control:**

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



*Sclerotinia sclerotiorum* - © SASA



*Sclerotinia sclerotiorum* - © SASA



*Sclerotinia sclerotiorum* - © NAK



*Sclerotinia sclerotiorum* - © SASA



# *Spongospora subterranea* Powdery scab

**Status in UNECE:**

Tuber tolerance for powdery scab.

**Recommended diagnostics:**

Visual observation of tubers with confirmation of spore balls using a microscope.

**Symptoms:**

Tuber: round, individual, raised scabs present on tubers at harvest; lesions erupt exposing brown powdery tissue (sporeballs) with tattered fragments of skin along edge of lesion. Infection at time of eye development can result in outgrowths (cankers) 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:**

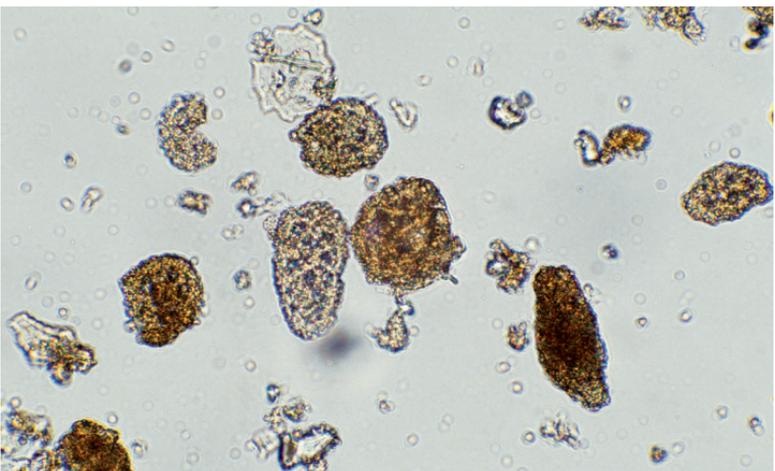
Use of resistant varieties and long rotations are the most effective ways to control disease derived from infested land. Take care with irrigation, especially during tuber initiation.



*Spongospora subterranea* - © NAK



*Spongospora subterranea* (cankers) - © SASA



*Spongospora subterranea* - © SASA



# *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 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.



*Synchytrium endobioticum*



*Synchytrium endobioticum*



*Synchytrium endobioticum* - © SASA



# *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 plants.

## **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 discolouration may also be seen in the vascular tissue of the tuber but this is rare in some regions.

## **Inoculum:**

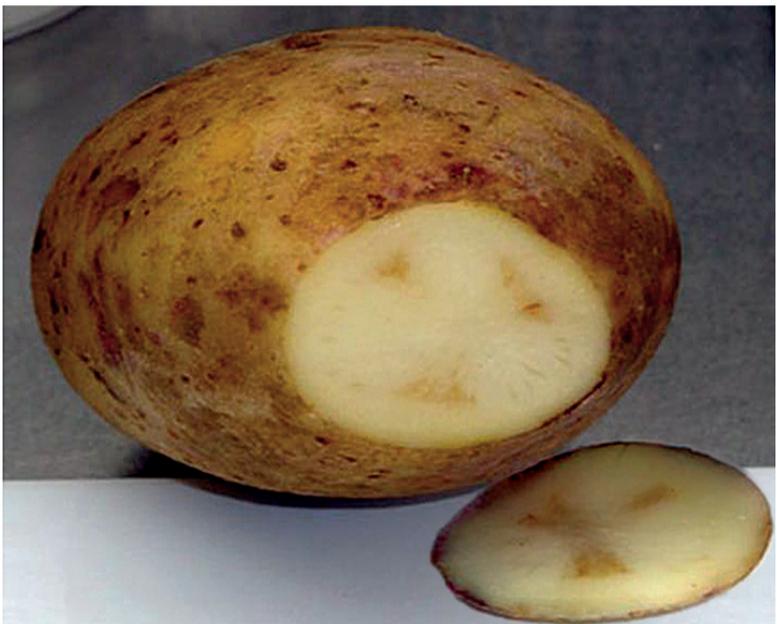
Soil-borne. Both species have a wide host range and can survive in soil for relatively long periods.

## **Control:**

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



*Verticillium* spp. - © INRA



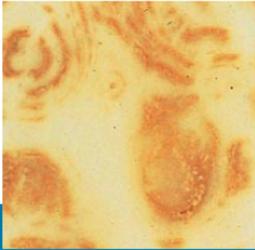
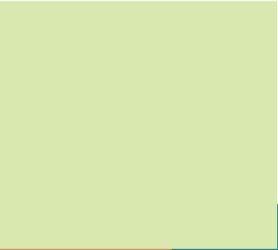
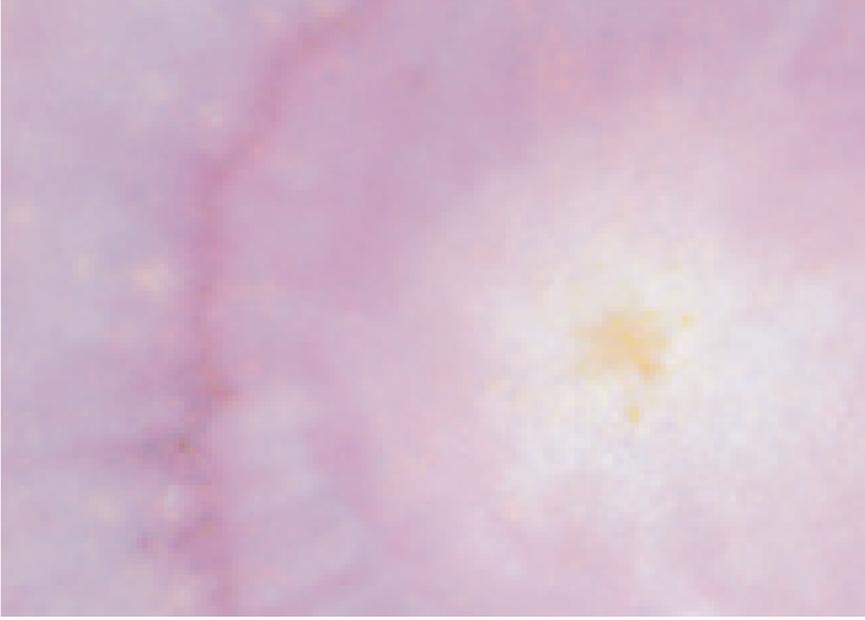
*Verticillium* spp.- © Melbourne University



Members of the Specialized Section, Cairo 2009



Members of the Specialized Section, Edinburgh 2012



# Viruses and viroids



# Mild mosaic

## **Status in UNECE:**

Crop tolerance for mild mosaic. Direct progeny tolerance for total virus.

## **Recommended diagnostics:**

Visual observation of plants 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<sup>N</sup> 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 by movement of machinery, people and 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 infected crops. Aphicide and mineral oil sprays. Early haulm destruction.



Mild mosaic - © NAK



Mild mosaic (PVX on Ostara) - © NAK



Mild mosaic (PVY on Spunta)



# Potato leafroll virus

## (PLRV)

### **Status in UNECE:**

Crop tolerance for leafroll. Direct progeny tolerance for severe virus.

### **Recommended diagnostics:**

Visual observation of plants, supported by ELISA test.

### **Symptoms:**

Primary: rolling from the leaf base of the youngest, upper leaves, sometimes with a purple discolouration; 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 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.



Potato leafroll virus - © LWK Niedersachsen



Potato leafroll virus - © NAK



# 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 plants 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 a 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:**

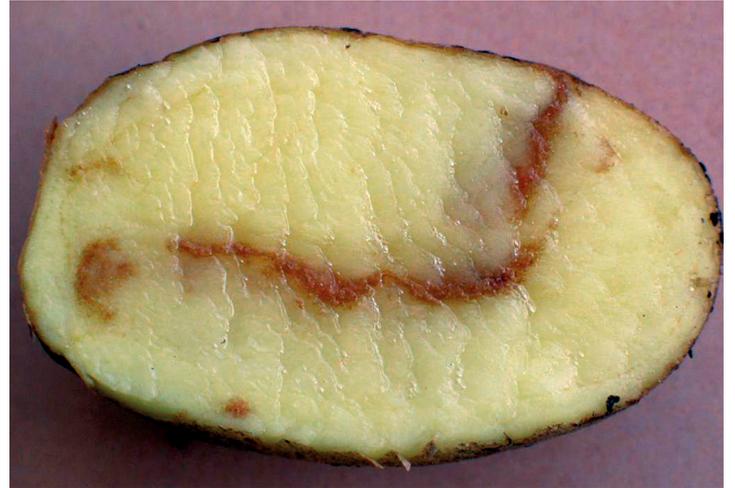
PMTV is transmitted by *Spongospora subterranea* (powdery scab). In the absence of the vector, PMTV will self-eliminate because of the relatively low rate of transmission of the virus within the plant from seed to daughter tuber.

## **Control:**

Resistant varieties and as for *S. subterranea*.



Potato mop top virus/Spraing - © FN3PT



Potato mop top virus/Spraing - © NAK



Potato mop top virus/Spraing - © SASA



Potato mop top virus/Spraing - © CNPPT



Potato mop top virus/Spraing - © SASA

# Severe mosaic

**Status in UNECE:**

Crop tolerance for severe mosaic. Direct progeny tolerance for severe virus.

**Recommended diagnostics:**

Visual observation of plants supported by ELISA test.

**Symptoms:**

Severe mosaic is associated with PVY (particularly PVY<sup>0</sup>), 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 infected crops. Aphicide and mineral oil sprays. Early haulm destruction.



Severe mosaic



Severe mosaic - © SASA



Severe mosaic - © SASA

# Tobacco rattle virus/Spraing (TRV)

**Status in UNECE:**

Not regulated.

**Recommended diagnostics:**

Visual observation of tubers and PCR (polymerase chain reaction) 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.

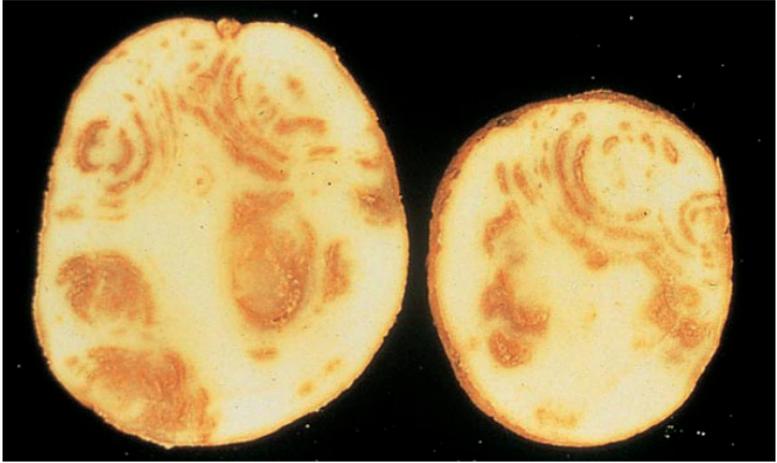
Tubers may develop spraing (see PMTV): brown, corky arcs and spots in the tuber flesh which are sometimes visible on the skin surface. These differ subtly from PMTV but differences among varieties make differentiation of visual symptoms problematic.

**Inoculum:**

TRV is transmitted by free living *Trichodorus* and *Paratrichodorus* nematodes (not PCN), which are most prevalent in light sandy soils and move in the soil-water column. TRV has a very wide host range, making rotational 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 trichodorids but not TRV) in the potato rotation in conjunction with good weed control. Avoid over irrigating at tuber initiation.



Tobacco rattle virus/Spraing - © University Clemton, USA



Tobacco rattle virus/Spraing - © SASA



Tobacco rattle virus/Spraing - © SASA



# Tomato spotted wilt virus (TSWV)

## **Status in UNECE:**

Not regulated.

## **Recommended diagnostics:**

Visual observation of plants and tubers.

## **Symptoms:**

Plant: Primary symptoms are leaves turning pale, necrotic spots then develop and can become larger 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.

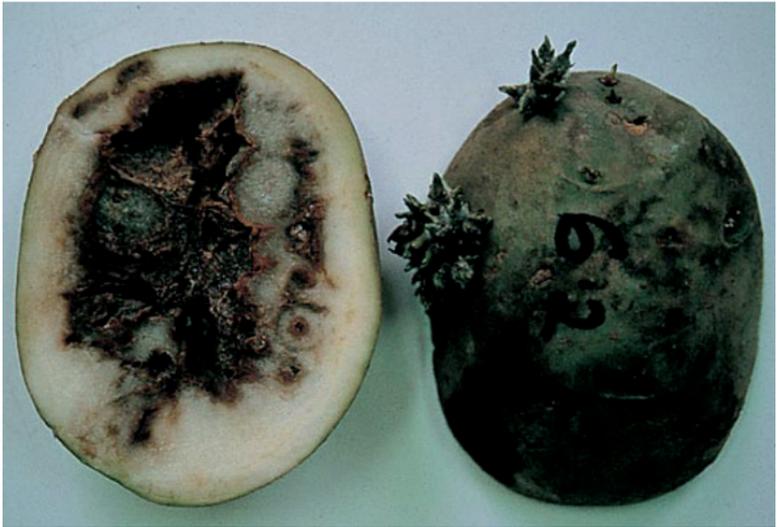
Tuber: Affected tubers are usually small and may have superficial black lesions. The tubers may also develop internal symptoms ranging from small, dark, necrotic spotting to more extensive dark internal necrosis.

## **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.



Tomato spotted wilt virus - © Wilson, Australia



Tomato spotted wilt virus - © ViCSP



# PVY<sup>NTN</sup>/Potato Tuber Necrotic Ringspot Disease (PTNRD)

## **Status in UNECE:**

Crop and progeny tolerance for mild/severe virus, and externally symptomatic tubers may be regulated as an external defect.

## **Recommended diagnostics:**

Visual 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.



PVY<sup>NTN</sup> - © FN3PT



PVY<sup>NTN</sup> - © SASA



PVY<sup>NTN</sup> - © NAK



# Potato spindle tuber viroid (PSTV)

## **Status in UNECE:**

Zero tolerance.

## **Recommended diagnostics:**

Visual observation of plants and tubers. Test by molecular hybridization and PCR.

## **Symptoms:**

Plant and tuber symptoms vary with 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 to prominently swollen and looks like heavy "eyebrows". In serious cases, the tubers may be deformed with deep growth cracks.

## **Inoculum:**

Unlike most 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 potatoes.

## **Control:**

Use clean seed potatoes. Avoid cutting infected seed potatoes. Outbreaks of PSTV should normally be reported to the plant health authority.



Potato spindle tuber viroid - © SASA



Potato spindle tuber viroid



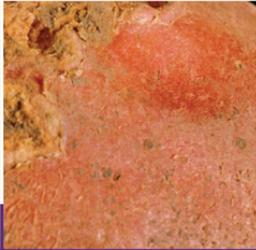
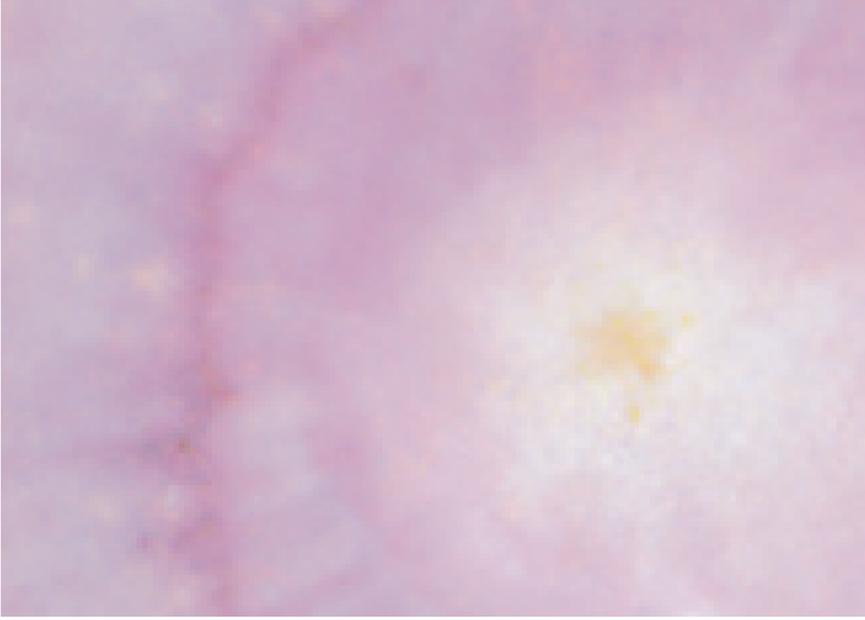
Potato spindle tuber viroid



Potato inspection in Alaska© - NDSSD



Potato production in the desert in Egypt - © NDSSD



# Bacterial pathogens



# *Clavibacter michiganensis* subsp. *sepedonicus*

## Ring rot

### **Status in UNECE:**

Zero tolerance.

### **Recommended diagnostics:**

Visual observation of plants and tubers, test by IF (immunofluorescence) and PCR.

### **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:** Tubers of some varieties can be symptomlessly infected. 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.



*Clavibacter michiganensis* subsp. *sepedonicus* - Nina Zidack



*Clavibacter michiganensis* subsp. *sepedonicus* - © NDSSD



*Clavibacter michiganensis* subsp. *sepedonicus* - © NDSSD



*Clavibacter michiganensis* subsp. *sepedonicus* - © DGAL



*Clavibacter michiganensis* subsp. *sepedonicus* - © NDSSD

# *Dickeya/* *Pectobacterium* spp. Blackleg

**Status in UNECE:**

Crop tolerance for blackleg. Tuber tolerance for wet rot.

**Recommended diagnostics:**

Visual observation of plants and tubers.

**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.

Both pathogens can produce 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 and 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.



*Dickeya/Pectobacterium* spp. - © SASA



*Dickeya/Pectobacterium* spp. - © SASA



*Dickeya/Pectobacterium* spp. - © NAK



*Dickeya/Pectobacterium* spp. - © NAK



*Dickeya/Pectobacterium* spp. - © NAK



*Dickeya/Pectobacterium* spp. - © SASA



*Dickeya/Pectobacterium* spp. - © FN3PT



*Dickeya/Pectobacterium* spp. - © NAK

# *Ralstonia solanacearum*

## Brown rot

### Status in UNECE:

Zero tolerance.

### Recommended diagnostics:

Visual observation of plants and tubers, 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 eyes, lenticels and/or stolon-end of the tuber, resulting in soil adherence in 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.



*Ralstonia solanacearum* - © FN3PT



*Ralstonia solanacearum* - © SASA



*Ralstonia solanacearum* - © SASA



*Ralstonia solanacearum* - © SASA

# *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:**

Visual observation of tubers.

## **Symptoms:**

Range from superficial corky lesions to extensive raised scabs or pits occurring either singly or in groups. Sometimes symptoms can appear similar to powdery scab. Netted scab symptoms are a superficial corky russetting 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.



*Streptomyces* spp. - © SASA



*Streptomyces* spp. - © NDSSD



*Streptomyces* spp. - © NAK



*Streptomyces* spp. - © NAK

# 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.



Potato stolbur - © ILVO/Rachid TAHZIMA



Potato stolbur - © ILVO/Rachid TAHZIMA



Potato stolbur - © ILVO/Rachid TAHZIMA



Potato stolbur - © ILVO/Rachid TAHZIMA



# Witch's 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 witch's 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 to emerge or to produce viable plants.

**Inoculum:**

Caused by a phytoplasma and vectored by leafhoppers. The disease is spread from inoculum reservoirs in the wider environment, particularly weeds and leguminous crops. Other phytoplasmas include aster yellows, purple top and haywire.

**Control:**

The disease is self-eliminating as the progeny tubers from infected plants either produce weak plants or do not sprout.



Witch's broom - © SASA



Witch's broom - © SASA

# Zebra chip

**Status in UNECE:**

Not regulated.

**Recommended diagnostics:**

Visual observation of leaves and tubers.

**Symptoms:**

Foliage symptoms include an initial wilting of affected plants, followed by chlorosis and curling of the leaves and can progress to plant death.

Tuber symptoms include discolouration of the medullary rays and necrotic flecking. The affected tuber tissue turns dark-brown on frying, giving the characteristic zebra-like stripes. Tuber symptoms may not be seen until after frying.

**Inoculum:**

Caused by the bacteria-like organism *Candidatus Liberibacter solanacearum* and is vectored by the tomato/potato psyllid. The disease is introduced into potatoes by psyllids carrying the organism. The relationship with the non-potato host plants and the epidemiology of the disease is not well understood.

**Control:**

Control the vector using insecticides.



Tomato/potato psyllid - © NDSU/Gudmestad



Zebra chip - © NDSU&UM/Robinson



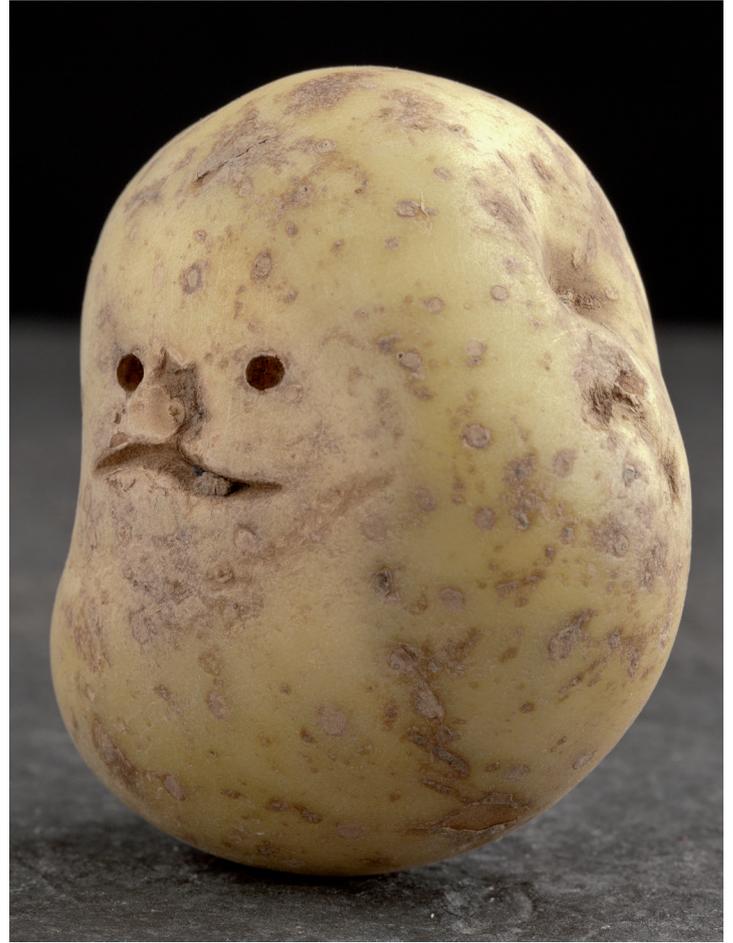
Zebra chip - © NDSU&UM/Robinson



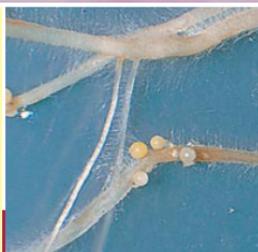
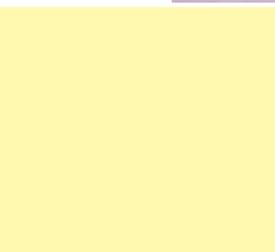
Zebra chip - © NDSU&UM/Robinson



Zebra chip - © NDSSD



Wireworm damage - © SASA



# Pests



# *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). These 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.



*Ditylenchus destructor* - © DGAL

# *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.



*Globodera* spp. - © DGAL



*Globodera* spp. - © INRA



*Globodera* spp. - © SASA



*Globodera* spp. - © SASA



# *Meloidogyne* spp. Root knot nematode

**Status in UNECE:**

Zero tolerance.

**Recommended diagnostics:**

Visual observation of tubers, microscopic examination of cut tubers, 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 or galls develop on the roots. The galls are abnormal plant growths formed around 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 seed 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.



*Meloidogyne* spp. - © NAK



*Meloidogyne* spp. - © NAK



# Agriotes/Tandonia/ Arion spp. Wireworms

**Status in UNECE:**

Not regulated. There are more than 30 species of wireworms that 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:**

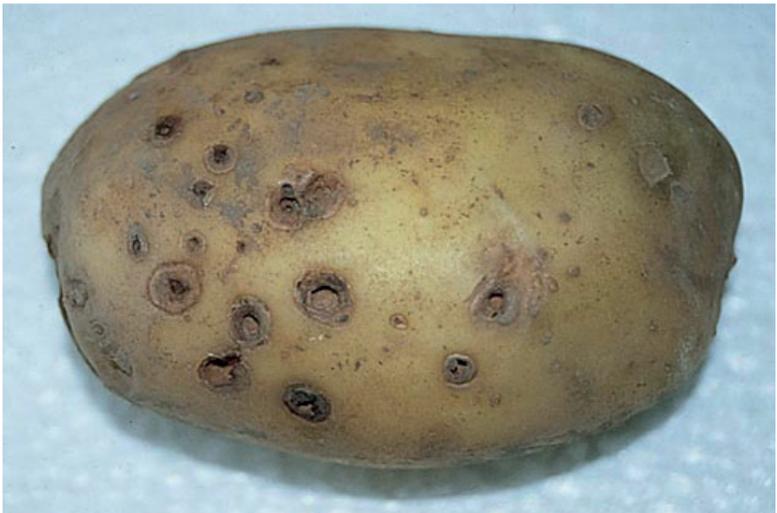
Click beetles prefer to lay their eggs in pasture, particularly permanent pasture.

**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.



Wireworms - © FN3PT



Wireworm holes - © FN3PT



# *Epitrix* spp. Potato flea beetle

**Status in UNECE:**

Not regulated. Externally symptomatic tubers are regulated as an external defect.

**Recommended diagnostics:**

Visual observation 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 localized 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:**

Apply insecticides.



"Shot-holes" left by the beetle - © GERMICOPA



Surface furrows left by the larvae - © Anses-LSVI



Surface furrows left by the larvae - © Anses-LSVI



Surface furrows left by the larvae - © GERMICOPA



Potato flea beetle - © GERMICOPA

# *Leptinotarsa decemlineata*

## Colorado beetle

**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 on the 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.



Colorado beetle eggs - © NAK



Adult Colorado beetle - © SASA



Colorado beetle larvae - © FN3PT



# *Phthorimaea operculella* 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 in the tuber. Affected tubers may lose excessive moisture through the wounds, resulting in shrivelling. Secondary infection by fungal 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.



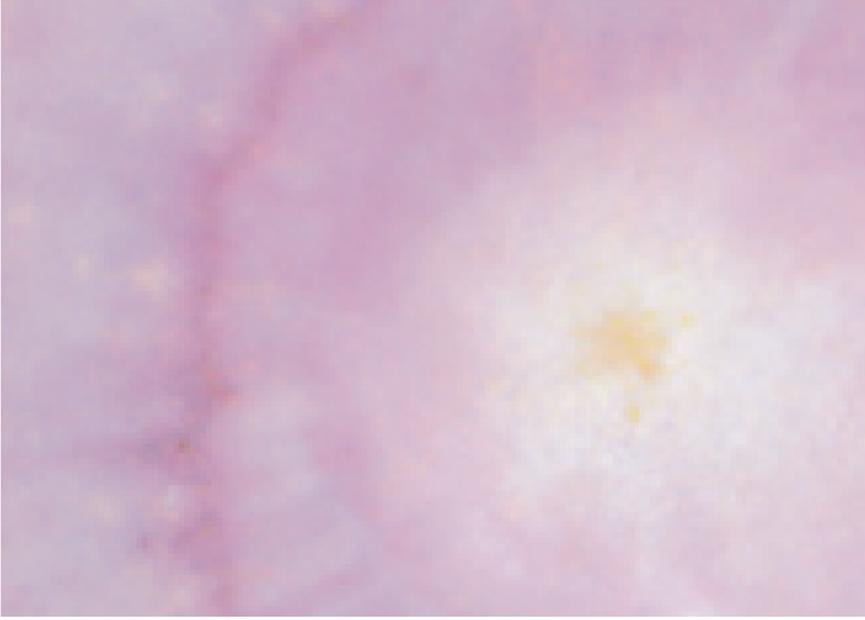
Damage by tuber moth larvae



Damage by tuber moth larvae



Slug causing damage - © SASA



# Other disorders



# Chemical damage

**Status in UNECE:**

Not regulated.

**Recommended diagnostics:**

Visual observation of plants and tubers.

**Symptoms:**

Foliage symptoms vary by the chemical involved and include sulphury yellowing of the leaflet margins, distortion of the foliage including rolling of the leaflets or a fiddlehead-like growth habit. Crops may also have poor emergence with numerous tubers failing to emerge and uneven plant growth of emerged plants.

Tuber symptoms include growth cracking or elephant hide and multiple weak stems at emergence.

**Causes:**

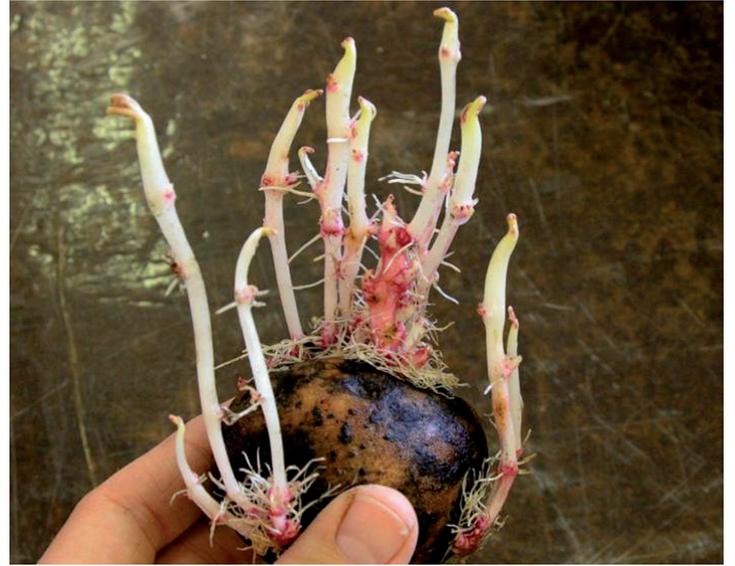
Accidental spraying, contaminated spray tanks or spray drift of non-target plant protection products. Normally problems are associated with herbicides including glyphosate, aminopyralid/clopyralid, dicamba, and acetolactate synthase inhibitors.

**Control:**

Careful application of herbicides. Awareness-raising of spray operators, particularly those involved in the protection of crops other than potatoes grown in the vicinity of seed potatoes.



Chemical damage - © NDSU&UM/Robinson



Chemical damage - © NDSU&UM/Robinson



Chemical damage - © SASA



Chemical damage - © NDSU&UM/Robinson



Chemical damage - © NDSU&UM/Robinson



Chemical damage - © SASA

# Chilling injury/ Frost damage

**Status in UNECE:**

Tuber tolerance for Chilling injury/Frost damage is counted as wet rot.

**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 tissue exudes water, and the edges of affected areas are blackened. There is often a clear demarcation line between healthy and affected tissue.

**Causes:**

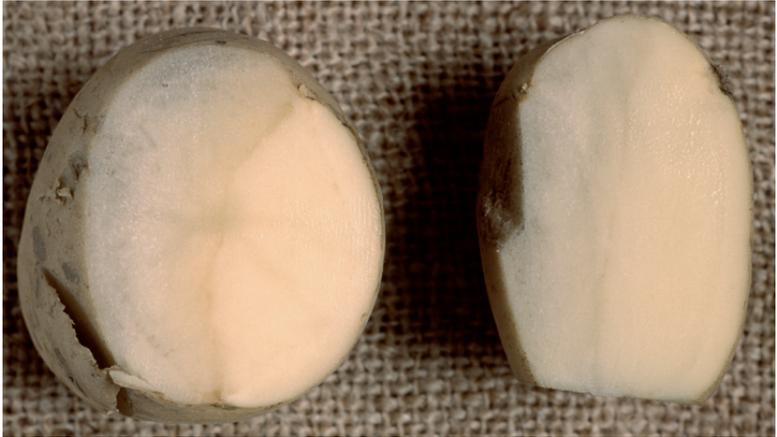
Cold temperatures (below 1°C) prior to harvest and in store. Tuber damage may also result from heat shock where tubers are exposed to rapid temperature changes (not necessarily below freezing point).

**Control:**

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



Chilling injury - © SASA



Frost damage - © SASA



Frost damage - © SASA

# Growth 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 during handling are covered under Damage.

## Causes:

Growth 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 by star-like netting.

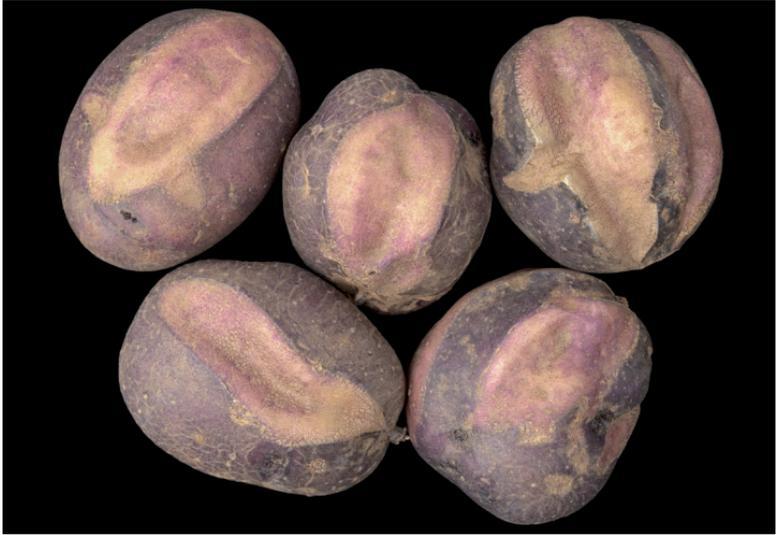
Herbicide cracks: certain herbicides can cause deformation and severe cracks in daughter tubers of plants contaminated by accidental spraying or spray drift.

## Control:

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



Growth cracks - © FN3PT



Virus cracks - © SASA



Herbicide cracks - © CNPPPT



Rhizoctonia cracks - © SASA

# 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:**

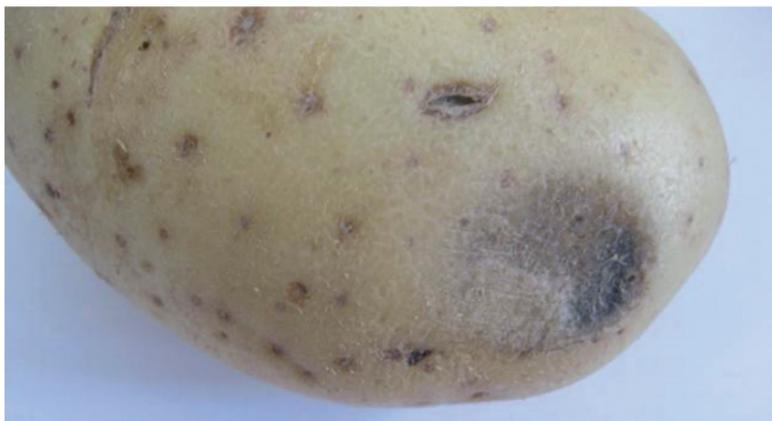
Mechanical damage is caused when handling the tubers and can occur from harvest to delivery. Impacts during handling can lead to small thumbnail cracks or more severe, deeper superficial cracks and even shatter cracks that extend into the tuber flesh. Many factors can affect damage levels but, overall,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

Bruising can be caused by shocks or pressure.

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

## **Control:**

Use appropriate well-maintained machinery running at the correct speed. Apply careful handling and good storage management. Take care when harvesting in dry conditions and avoid handling cold tubers. Good pest control during crop growth and storage.



Pressure bruise - © FN3PT



Mechanical/handling damage - © NAK



Mechanical/handling damage - © SASA



Pressure bruise - © Bretagne Plants



# 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 knobby 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 conditions, 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 metabolize 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 minimize the time between haulm destruction and harvest to reduce glassiness.



Misshapen tuber - © NAK



Secondary growth



Glassiness - © NAK



# 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 forced air ventilation; 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. Minimize skin blemish diseases and market at-risk stocks early.



Shrivelled tubers - © NAK



Shrivelled tubers - © NAK

## Further reading:

*Diseases, Pests and Disorders of Potatoes, a colour handbook.*

Stuart Wale, HW (Bud) Platt and Nigel Cattlin (2008).  
ISBN 978-1-84076021-7

*Potato Diseases: Diseases, Pests and Defects.*

Editors 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, UK.  
ISBN 0-632-01222-6

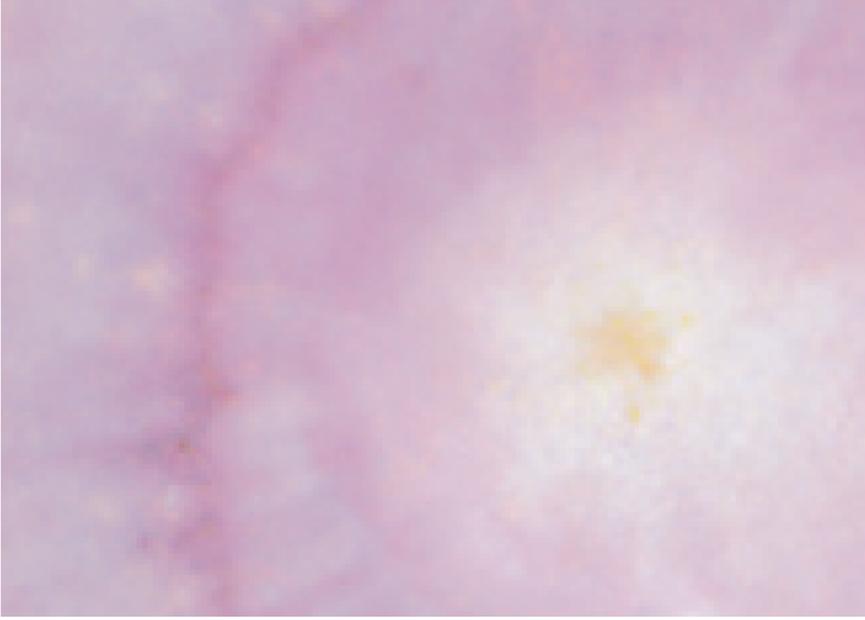
*FAO/IPGRI Technical Guidelines for the Safe Movement of  
Germplasm. No. 19 Potato, Colin J Jeffries.*

ISBN 92-9043-390-6

*A practical guide to diseases, pests and disorders of the  
potato: Identification guide and data sheets. FN3PT *et al.*  
(2012).*

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