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Guide for Seed Potato Inspectors*

Submitted by the secretariat

This document is submitted by the secretariat following the decision by the Working Party on Agricultural Quality Standards taken at its 2012 session (ECE/TRADE/C/WP.7/2012/2, para. 41) to start work on a UNECE "Guide for Seed Potato Inspectors".

I. Introduction

To harvest a plentiful and healthy yield of seed potatoes for trading internationally, producers have first to plant seed potatoes of the highest quality. 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 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.

The UNECE standard is a marketing standard setting harmonized norms in quality requirements for seed potatoes. It supplements and supports other international seed-potato

* This document was submitted late due to delayed inputs.

phytosanitary standards and should be read in conjunction with, but not in place of these: in particular ISPM 12 and ISPM 33.

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

A. 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
	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.

Insert three label pictures (one each from three countries - request scans)

B. Minimum Conditions

The seed potatoes marketed under the Standard shall be free from the following:

Globodera rostochiensis (soil tolerance)
Globodera pallida (soil tolerance)
Synchytrium endobioticum
Clavibacter michiganensis
Ralstonia solanacearum
Potato spindle tuber viroid
Tomato stolbur
Meloidogyne chitwoodi and *fallax*
Ditylenchus destructor
Phthorimaea operculella

The following crop tolerances apply:

(Number of plants with faults as a percentage of the plants inspected)

	PBTC	Pre-basic	Basic Class I	Basic Class II	Certified Class I	Certified Class II
Blackleg	0	0	0.5	1.0	1.5	2.0
Severe virus	0	0.1	0.2	0.4	1.0	2.0
Total virus	0	0.1	0.4	0.8	2.0	10.0
Other varieties and off types	0	0.01	0.25	0.25	0.5	0.5

The following lot tolerances apply (1%):
(Faults found as a percentage of the inspected sample)

	PBTC	Pre-basic	Basic Class I	Basic Class II	Certified Class I	Certified Class II
Earth and extraneous matter	1	1	2	2	2	2
Dry and wet rot†	0	0.2	1	1	1	1
External defects	3	3	3	3	3	3
Shrivelled tubers	0	0.5	1	1	1	1
Chilling injury	0	0.2	1	1	1	1
Tuber moth damage	0	4 (20)*	4 (20)*	4 (20)*	4 (20)*	4 (20)*
Scab (common and netted)	0	5 (1/3)*	5 (1/3)*	5 (1/3)*	5 (1/3)*	5 (1/3)*
Powdery scab	0	1 (10)*	3 (10)*	3 (10)*	3 (10)*	3 (10)*
Rhizoctonia	0	1 (1)*	5 (10)*	5 (10)*	5 (10)*	5 (10)*
Total faults	3	5	6	6	6	6

† not caused by *S. endobioticum, C. michiganensis, R. solanacearum*

* the figure in brackets is the allowable % surface/cut area covered. Tubers are counted if they exceed this level.

Note regarding surface area tolerances:

When assessing surface diseases tubers with low levels of infection (one or two lesions of infected tissue) are not counted. A tuber is deemed to be affected by the disease only if the surface area affected **exceeds** the coverage tolerance, as indicated by the figure in brackets in the tolerance table.

The following direct progeny tolerances apply (1%):
(Number of plants with faults as a percentage of the plants inspected)

	PBTC	Pre-basic	Basic Class I	Basic Class II	Certified Class I	Certified Class II
Other varieties and off types	0	0.01	0.25	0.25	0.5	0.5
Severe virus	0	0.5	1.0	2.0	5.0	10.0
Total virus	0	0.5	2.0	4.0	10.0	10.0

Certifying authorities may use post-harvest tuber test or post-control grow-out assessment to establish compliance with the direct progeny tolerance. The standard provides information, including statistical consideration, on these measures.

C. Use of this Guide

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 the faults by the inspector at the point of control. Normally inspectors should be able to pass or fail lots based on the visual assessment only.

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 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 the provision of a reference to the source material.

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

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 alternate.* It is almost impossible to distinguish the two species.

Symptoms: *Alternaria* causes lesions on the leaves, which often have a target spot appearance of concentric rings. These usually appear a few weeks after emergence and start as very small black or brown spots on lower leaves, which then coalesce. This causes the leaf tissue to die as the disease spreads. The disease is distinct from late blight as spores on the leaves cannot be seen, even with a hand lens, and there is no distinctive milky ring of sporulation around the lesion on the underside of the leaf. Tubers may have 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 controlled chemically as a by-product of late blight sprays. Specific sprays may assist for 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 on specific medium.

Symptoms: Tuber skin blemish disease with silvery, irregularly shaped lesions present at harvest quickly darken. 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 are comfortably diagnosed with a hand lens. In the growing plant, in warm climates it may contribute to early dying disease.

Inoculum: Soilborne and favoured by wet soil conditions. Symptoms may progress and become more severe in store, particularly under warm humid conditions.

Control: Long rotations.

C. *Fusarium* spp.: Dry Rot

Status in UNECE: Tolerance for dry rot.

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

Symptoms: There are several different species of *Fusarium* with slightly different symptoms: generally, dry rots develop around an initial wound dehydrating the tuber. Crop symptoms are limited to weak plants or non-emergence.

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

F. sulphureum (middle): Small lesions develop at wounds and expand producing symptoms externally similar to gangrene, i.e. slighty depressed with a wavy edge. 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 soilborne. Infection and disease progression are triggered by damage, e.g. grading.

Control: Minimize damage, fungicides, long rotations.

D. *Goetrichum candidum*: Rubbery Rot

Status in UNECE: Tolerance for wet rot.

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

Symptoms: Tuber 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: Associated with waterlogged soils in warm conditions towards harvest.

Control: Ensure adequate soil drainage. Storage of tubers separate from wet patches in the field 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 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, in the soil or from spores remaining in stores. Symptoms are normally present at harvest but the disease develops in store.

Control: Treatment of tubers prior to planting or at harvest (into store) may prevent infection, but there are no reliable chemical controls once infection has occurred. 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 on specific medium.

Symptoms:

Tuber: Storage rot. 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.

Inoculum: Mainly seedborne; can be spread in aerosols during rainfall. Tubers may be contaminated at harvest, but gangrene develops only after 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 on specific medium.

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

Tuber: 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: Soilborne. 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 field, though excessive levels may prevent crop inspection.

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, whitish spore–bearing mould develops around the lesions under moist conditions. 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. Airborne 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. Removal of potential inoculum sources.

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: A tuber infection will show as a darker 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.

Rot development is irregular without a distinct leading edge and can be threadlike.

Affected tubers often have firm flesh with brown areas, but secondary infection can lead to 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 after damage.

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: Tuber skin blemish disease with small (1-2 mm), brown-black pimples develop on the skin, usually 2-3 months after harvest. In severe cases, eyes may be killed.

Affected tubers can result in uneven plants and non-emergence.

Inoculum: Mainly soilborne, but can spread by spores and infected dust within store. The disease is favoured by wet conditions at harvest when tubers may become widely contaminated. Skin spot may appear later in store if temperatures are low and symptoms generally develop after three months in store.

Control: Early harvest followed by dry curing. Fungicides applied soon after harvest may assist control, though resistant strains do exist.

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

Status in UNECE: Tolerance for wet rot.

Recommended diagnostics: Visual observation of tubers and identification 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: Soilborne. Infection of contaminated tubers occurs through wounds. Rots develop rapidly on newly lifted tubers where 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. Not counted in the field.

Recommended diagnostics:

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 soilborne. Most frequent on light soils under dry, cold conditions

Control: Use well-sprouted seed. Avoid early planting in cold conditions and avoid deep planting. 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: Soilborne: most infection is from windborne ascospores that are produced by fungus on the soil surface. The disease is encouraged by prolonged high humidity in well-developed canopies with wet leaves (e.g. sprinkler irrigation on fertile soils). The disease is more likely where potatoes follow oil seed rape (canola), which is an alternate 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), leaving tattered fragments 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.

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 in 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. Two species cause 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 be on one side of a compound leaf, or even the leaflet, due to vascular tissue being blocked. Leaves turn yellow or pale green and affected plants become stunted. A brown discolouration may be seen in the stem vascular ring if a slanting diagonal cut is made across the stem.

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

Inoculum: Soilborne. Both species have a wide host range and can survive in soils for relatively long periods.

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

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: Field 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 other viruses e.g. PVA and recently in 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 expression is only pale plants (no mosaic), making diagnosis difficult. Some varieties can harbour the virus with no symptoms. Symptoms are dependent on the variety and/or virus/virus strain.

Inoculum: Seed, 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 the crop. For the other viruses see **severe mosaic**.

Control: Use healthy seed, rogue early, 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: Field 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 leaves sometimes with a purple discoloration – only seen if infection is early or in hot climates.

Secondary (from infected tubers): Leaves roll inwards and become dry, brittle and sometimes brown. The 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 show 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 seedborne but groundkeepers and adjacent crops (especially ware) can be significant sources. Unlike mosaic viruses, PLRV is transmitted persistently by aphids, especially *Myzus persicae*. 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.

Recommended diagnostics: Visual observation of plant supported by ELISA test. As the virus is erratically distributed within the plant, test results from affected plants may be negative. ELISA testing of symptomatic 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 have 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 low rate of transmission of the virus within the plant.

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

D. Severe Mosaic

Status in UNECE: Field 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, these can exhibit mild mosaic and sometimes be present without symptoms. 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 infection within seconds but lose it within hours. Spread vectored by migratory (e.g. cereal) aphids is difficult to control. Other insect pests may vector the virus in some regions.

Control: Use healthy seed, 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. ELISA misses some isolates.

Symptoms:

Plant: Mottling and distortion of leaves and stunting of some or all stems. Leaf symptoms can have distinctive pinching towards the leaflet point, 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 cultivar variation makes differentiation on visual symptoms problematic.

Inoculum: TRV is transmitted by free living *Trichodorus* and *Para-trichodorus* 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 potatoes, the virus is self-eliminating in the absence of vectors.

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

F. Tomato spotted wilt virus (TSWV)

Recommended diagnostics: Visual observation of plants and tubers.

Symptoms:

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

Tubers: Affected tubers are usually small and may have superficial black lesions. The tubers may also have internal symptoms 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: Field and progeny tolerance for mild/severe virus.

Recommended diagnostics: Observation of tubers. As symptom expression is determined by variety - PVY strain - environment interaction, laboratory tests alone cannot identify PTNRD.

Symptoms: This tuber symptom is seen in some varieties caused by some strains of PVY. Symptoms are favoured by high temperatures. PVY strains associated with PTNRD tend to have mild mosaic symptoms in the field and some varieties have symptomless foliage infection.

The tuber symptoms progress in store from a smooth pink to reddish-brown necrotic ring or arc on the tuber surface to become raised and finally 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.

Growing plants may appear atypically upright in habit and stunted with rugose leaflets. Tubers may be more elongated than normal or they may be typically spindle shaped and covered with 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, showing deep growth cracks.

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

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

IV. Bacterial Pathogens

Bacteria:

Clavibacter michiganensis subsp. *sepedonicus*: Ring rot

Dickeya / Pectobacterium spp.: Blackleg

Ralstonia solanacearum: Brown rot

Streptomyces spp.: Common and netted scab

Phytoplasmas:

Potato Stolbur

A. *Clavibacter michiganensis subsp. sepedonicus*: Ring rot

Status in UNECE: Zero tolerance.

Recommended diagnostics: Observation of plant and tuber, test by immunofluorescence (IF) and PCR.

Symptoms:

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

Tubers: The vascular ring and surrounding tissue are pale yellow or glassy, becoming darker. 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: Seedborne: Some varieties can be symptomlessly affected. Latently infected seed tubers; contaminated machinery; particularly cutting equipment.

Control: Normally treated as a quarantine pest, 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: Field 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 may appear 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 which can recover. As the disease develops, a stem rot may sometimes be seen developing from the leaf axils. Both pathogens can have very similar symptoms.
Tubers: Soft brownish white rot extends from the heel end or lenticels. Affected area is bound by a dark margin. Produces a distinctive fishy smell.

Inoculum: Seedborne, but spread can occur in the field from diseased to healthy plants carried in water droplets (rain splash/aerosols). Contact with contaminated machinery/boxes is an important method of spread. *Pectobacterium*: cool and wet. *Dickeya*: warm and wet.

Control: Healthy seed. 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 immunofluorescence (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: Initially 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 to which soil may adhere.

Inoculum: Brown rot is mainly tuberborne, as latently infected tubers can cause disease when planted in the next season. The bacterium can spread on machinery and in irrigation water. The disease can also persist in fields in infected groundkeepers.

Control: Normally treated as a quarantine pest, i.e. exclusion from and eradicated 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. In netted form as a superficial corky russeting of the skin.

Inoculum: Soilborne. 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, over-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. Plants may have aerial tubers and many axillary buds. Disease will usually result in premature death. 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 natural hosts, notably *Solanaceae* including some crop plants (e.g. eggplant, tomato and pepper). The disease is transmitted by leafhoppers.

Control: Use healthy seed and control weeds.

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

Leptinotarsa decemlineata: Colorado Beetle

Phthorimea opercullella: Tuber Moth

Epitrix?

A. *Ditylenchus destructor*: Root Rot Nematode

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

Recommended diagnostics: Visual observation of tubers.

Symptoms: As nematodes enter the tuber through the lenticels or eyes, symptoms are not normally seen until after harvest. Initially symptoms are grey to white mealy spots beneath the tuber surface (visible if cut or peeled). The symptoms progress towards the vascular tissue, the affected spots coalesce and darken, and 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 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 is possible.

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

Status in UNECE: Zero tolerance. Land used for seed potato production should be free from PCN.

Recommended diagnostics: Testing of soil (flotation followed by microscopy or PCR). Visual observation of the field.

Symptoms: Two species of *Globodera* affect potato: G. *rostochiensis* and G. *pallida*. In the field, PCN infestation is characterized by patches of weaker or stunted plants with a tendency to wilt, or plants with 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, particularly from farm-saved seed from untested land. Infestation can be caused by movement of soil on machinery or through flooding, and even carried 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 recognised in the standard: M. *chitwoodi* and M. *fallax.*

In growing plants the roots form knots or galls. The galls are abnormal growth formed around a feeding juvenile nematode. Galls may be produced on the tuber surface, depending on the cultivar. 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.

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 significant.
Tuber damage: 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. *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 stems of the plants. This produces irregular holes in the leaflets and sometimes extensive to total defoliation of the plants. All mobile stages feed on the foliage of the potato plant.

Inoculum: The adult is about 10mm 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 2mm 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.

F. *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 potatoes.

Plant: The larvae mine into the leaves and eat the inner tissue, particularly of the main veins, though this damage is not normally economically significant.
Tuber: At harvest, affected tubers may show little visible evidence of infestation but be harbouring eggs or young larvae. As the larvae feed on the tubers, damage becomes extensive with galleries just under the skin or deep into the tuber. Affected tubers may lose excessive moisture through the wounds becoming shrivelled. 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 and an integrated control strategy.

VI. Other Disorders

Chilling Injury/Frost Damage

External Defects/Damage

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. Symptoms on the tuber surface as a dark brown, sometimes sunken, patch. Symptoms may be internal. Frosted (right and lower pictures) tuber tissue exudes water, and the edges of the lesions 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 in store.

B. External Defects/Damage

Status in UNECE: Tolerance for external defects.

Recommended diagnostics: Visual observation of tubers.

Symptoms: Deformed, bruised or cracked tubers or tubers with missing pieces. Cracks or holes in tubers can lead to secondary infection with pathogens leading to rots.

Causes: Damage can be caused mechanically by poor handling or due to pests (e.g. wireworms, slugs, rodents). Growth cracks caused by a period of rapid tuber expansion in the field are sometimes counted as damage.

Control: Good crop husbandry and careful handling.

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.

We greatly appreciate the photographic contributions which make this guide possible, in particular those from 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 and Nigel Cattlin. ISBN 978-1-84076021-7

Potato Diseases: Diseases, Pests and Defects. Editors E. van der Zaag et al.
ISBN 90-802036-2-9

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

VIII. Items for consideration for inclusion in the pest list

The following items are considered important by the potato industry in the United Kingdom:

Violet Root Rot

Tobacco necrosis virus (TNV)

Free Living Nematodes (FLN)

Slugs in Potatoes

Blackheart

Defoliation

Fertilizer Damage to Potatoes

Heat Injury and Stress

Herbicide Damage to Potatoes

Hollow Heart and Internal Browning

Internal Sprouting

Nutrient Deficiencies in Potatoes

Pit Rot

Secondary Growth