FUSARIUM DISEASES

potatoes aartappels SA

Compiled and published by Potatoes South Africa (Department: Research and Development)
September 2018

Copyright. You may use the information in this publication only for your own information, research or study. You may not copy, reproduce, transmit, adapt or otherwise exercise the copyright (in whole or in part) of this publication for any commercial or other purpose without the express written consent of Potatoes South Africa, and may only do so subject to the conditions to which such consent is given.

Proposed reference: Potatoes South Africa. 2018. Fact Sheet: Fusarium diseases. Available online at: http://www.potatoes.co.za/research/factsheets.aspx

Indemnity with regard to publications: http://www.potatoes.co.za/contact/disclaimer.aspx

FUSARIUM DISEASES

Infection of potatoes by pathogenic *Fusarium* species manifests as different symptoms.

- **Fusarium wilt** becomes visible from the middle to the latter part of the season. Symptoms of Fusarium wilt and Verticillium wilt are similar, and to correctly identify the cause of vascular wilts specimens need to be analysed by a diagnostic laboratory.
- **Stem-end rot** is visible at the end of the growing season and is the result of infected stolons. *Fusarium* spp. is transported in the vascular tissue to tubers.
- **Dry rot** of tubers is not a major problem for ware potatoes in general, as most ware potatoes are marketed within a few days after harvesting. When potatoes are left in the soil for weeks or months, however, dry rot can cause considerable damage, especially during dry, hot conditions. Fusarium dry rot is considered to be mainly a problem in the seed industry because some seed tubers are stored for prolonged periods.
- **Seed piece decay** caused by *Fusarium* spp. poses a high risk if the seed was grown and/or stored under conditions favourable for Fusarium and/or if the seed pieces are planted in warm soil.

In an extensive survey in the 1980s, researchers at ARC Roodeplaat found that a total of nine *Fusarium* species are pathogenic on potatoes in South Africa. *Fusarium oxysporum* and *F. solani* were found to be the most common.

THE DISEASE TRIANGLE

Pathogens

- *Fusarium oxysporum* and *F. solani* are the predominant species causing Fusarium diseases in South Africa.
- Tubers can be infected by more than one *Fusarium* species.
- Fusarium is common in soils where ever potatoes are grown.
- Local isolates of pathogenic *Fusaria* are possibly adapted to the high temperatures which prevail in the production regions.

Host plant

- Plants are most commonly entered by fusaria through wounds in the periderm.
- Cultivars vary in terms of susceptibility to *Fusarium* species.
- Fusarium wilt often occurs in waterlogged soils as a result of nematode infestation.

Environment

- Maximum decay of stored potato tubers occurs on tubers incubated at high humidity and high temperature.
- Warm soil temperatures are conducive to dry rot.

MANAGE THE RISK OF FUSARIUM DISEASES

	RISK	MANAGEMENT
FIELD CHOICE	Field with a history of Fusarium diseases	- If Fusarium diseases are known to occur on a specific field, avoid planting there. - A long rotation cycle (more than five years) will lower the risk of Fusarium.
	Volunteer potatoes were not controlled	- Control volunteers for the whole rotation cycle as volunteer potatoes maintain the infestation level of the soil.
	Warm, sandy soils	- Make sure that the rotation cycle is sufficiently long on these fields to lower the risk of Fusarium diseases. - Manage nematodes.
	Fields with a history of nematode damage	- Manage conditions to limit nematodes. - If possible, avoid planting potatoes in these fields for a period of five years.
CULTIVAR CHOICE	Susceptible cultivars are planted	- Cultivars vary in susceptibility to Fusarium diseases. The relative susceptibility of the most popular cultivars in South Africa has not been determined. - The susceptibility rating of cultivars as determined in other countries is of limited value as the most common *Fusarium* species in South Africa are not the same as in Europe, the United Kingdom or the United States of America.
PLANT-ING TIME	Planting in warm soil	- Make sure seed potatoes with a low incidence of dry rot is planted. - Manage nematodes. - Do not over-irrigate.
SEED POTATOES	Infected seed potatoes are planted	- Request an inspection report from your seed potato supplier before the order is confirmed. - Plant only certified seed with a low incidence of dry rot symptoms. - Inspect seed before planting, particularly if the seed was stored for a few months. - Consult Potatoes South Africa's Guide for the Handling of Seed Potatoes.
	Seed tubers are cut	- Plant seed tubers of the required size to avoid the risks of seed cutting. - Do not cut seed tubers for planting in warm soil. - Use only seed lots of the best quality for cutting. - Maintain good standards of sanitation during cutting. - See: The Cutting of Seed Potatoes. CHIPS March/April 2016
CROP MAINTENANCE	Waterlogged conditions	- Manage irrigation scheduling to avoid waterlogged conditions in order to lower the risk of nematodes and secondary infection by soft rot pathogens.

MANAGE THE RISK OF FUSARIUM DISEASES

	RISK	MANAGEMENT
HARVESTING AND GRADING	Skin has not set	- After plants have died- off, allow enough time for proper skin set to reduce damage to tubers during harvest. Irrigation must be suspended approximately ten days prior to harvesting in order to promote skin set. - Avoid application of too much nitrogen, especially in the latter half of the season.
	Mechanical damage to tubers	Harvest once the soil water content reaches 65% of available groundwater. This limits clod formation. Do not harvest when the soil and tuber temperature is <10°C. At low temperatures, tubers are more prone to cracking. Ensure that the harvester is set correctly so that the blade is deep enough to sever the roots below the tubers. The land speed of the harvester should match the chain speed to allow the tubers to move across a cushion of soil over the chain bars. Use brushes suitable for potato tubers. Identify and correct places on the sorting line where tubers are damaged to limit the wounding of tubers.
STORAGE	Dry rot develops during storage	- Make sure that damaged skin and wounded tissue of seed potatoes are properly cured before storage or transport. - Do not store seed lots for long periods if dry rot is a risk. - If ware potatoes have to be left in the soil for weeks or months, harvest fields with the highest risk of Fusarium dry rot first.

THE PATHOGENS

The genus *Fusarium* is regarded as one of the most adaptive and versatile genera in the fungal kingdom and species occur commonly in soils wherever potatoes are grown. The genus consists of many pathogenic and non-pathogenic species and a large number of crop plants serve as hosts for different pathogenic *Fusarium* species.

A total of nine *Fusarium* spp. have been identified as dry rot pathogens in South Africa, based on an extensive survey conducted on 51 farms in the 1980s. A more diverse *Fusarium* population was isolated from tubers with dry rot lesions than from those with stem-end rot lesions. This could be ascribed to Fusarium dry rot infection occurring mainly through wounds, while stem-end rot infection is more complex. *Fusarium* spp. occur either singly or in combination in diseased tubers. *Fusarium solani* and *F. oxysporum* are the predominant species isolated from the diseased tubers, with the latter in much higher densities, especially from dry rot lesions.

In the survey of the 1980s, *Fusarium oxysporum* and *F. solani* were the predominant species isolated. Eight species *(F. oxysporum, F. crookwellense, F. solani, F. sambucinum, F. acuminatum, F. graminearum, F. scirpi and F. equiseti)* caused typical dry rot lesions on inoculated potato tubers. *Fusarium oxysporum* was the most pathogenic, followed by *F. crookwellense, F. solani* and *F. sambucinum*.

DISEASE DEVELOPMENT

Infection during the growing season

Pathogenic and non-pathogenic *Fusarium* species occur commonly in most soils where potatoes are grown, and mycelia adheres to the root surface of plants. Hyphae can enter plants directly, but mostly gain entrance to plants through wounds. Where *Fusarium* enters plants directly, it is at the root tips where cell walls are thin or through natural openings, through non-suberized and enlarged lenticels and micro-cracks on tubers and stolons. Wounds are caused by insects and commonly by lesion nematodes.

After penetration into the plant, non-pathogenic Fusaria are

not able to grow inside the plant. Pathogenic *Fusarium* species, however, grow through and between plant cells towards the xylem vessels. Inside xylem vessels, micro-spores form and these spread from one xylem cell to the next. To defend itself against the pathogen, the plant produces vascular gels to localise the pathogens. This gel, together with fungal growth inside the xylem vessels, leads to reduced water uptake and wilting of an infected stolon **(Fusarium wilt)**.

Tubers can be infected by spores that enter tubers through the vascular tissue of infected stolons. Typical symptoms are browning of the vascular tissue of the tuber and dry rot that start at the stolon end of tubers to culminate in **stolon-end rot**.

If, however, infected tubers (whether through vascular tissue or through wounds in the periderm) are stored in the soil for a number of months before harvesting, **dry rot** develops. Dry rot can be particularly severe during hot and dry periods.

Infection of tubers during and after harvesting

Fusarium is not able to enter tubers through the suberized periderm (skin). However, wounding of the periderm during lifting, harvesting, sorting and packing as well as micro-wounds caused by nematodes and enlarged lenticels or tuber cracks, offer a multitude of entrance points into tuber tissue. Pathogenic *Fusaria* then colonise the tuber tissue and cause dry rot. Unless tubers are stored, *Fusarium* poses no risk of rot to ware potatoes. Colonisation of tissue takes place at a low rate when tubers are stored at low temperature. When tubers are removed from cold storage to allow for sprouting, dry rot can develop in a short period of time.

Secondary infection

Hot, humid conditions in the soil during the growing season and during storage are favourable for soft rot bacteria *(Pectobacterium)* to invade dry rot lesions. It is thus possible that both dry rot and soft rot occur in a single tuber.

Seed pieces

Fusarium dry rot and soft rot caused by *Pectobacterium*, are the most important causes of seed-piece decay. The cut surfaces expose tuber tissue to desiccation and are major infection sites for bacterial and/or fungal pathogens, causing seed-piece decay. Often, single sprouts emerge from partly decayed seed pieces, giving rise to small, slow-growing plants that are more susceptible to other diseases and which produce low yields.

SYMPTOMS

Affected tissue is usually fawn or light brown in colour, and stain to a darker brown when exposed to air. The advancing margin of the rot integrates into the healthy tissue. Due to the loss of moisture from the tissue, cavities are often lined with white, yellow or pink mycelium that forms below the site of infection. In storage, blue, black, purple, grey, white, yellow or pink spore masses may form in these cavities. Older dead tissue assumes a variety of colours and is dry and spongy at low temperatures. Internally infected tissue often becomes firm and dry or even powdery.

Tuber lesions at wounds or enlarged lenticels are visible as small brown areas about one month after infection. Infection spreads slowly and the periderm covering lesions sinks and wrinkles, sometimes in concentric rings round the site of infection as the dead tissue becomes dry and powdery. When rotting proceeds, dark spore-forming structures are frequently formed on the dead periderm, possibly pink, white or blue in colour. Rotten tubers shrivel and become mummified. In the field, shrivelling of infected seed tubers and pitting of infected seed pieces may not be evident. The surface covering the lesions is brown, and the underlying necrotic tissue has fewer cavities. Necrotic tissue may attract soil insects and larvae, which serve as vectors of *Pectobacterium* spp. in wet soils and often enter as secondary pathogens. Symptoms caused by *Fusarium* spp. alone, or in combination with *Pectobacterium* spp., include total or partial decay of seed pieces, reduction of plant vigour and poor stand.

Although stem-end rot symptoms are very similar to those of storage rot, these symptoms are usually visible at harvest, localised on the stem end of the tuber. Some of the infected tubers may show a sunken, wrinkled, dry stem-end rot of varying diameters, while others may only show a slight sign of rot around the point of the stolon attachment. When the latter tubers are cut across near the base, vascular browning extending to various depths in the tuber, is visible. Vascular browning may affect the whole vascular ring, but more often involves only separate portions thereof.

The first symptoms of Fusarium wilt usually occur in the middle of the growing season when infected plants turn a lighter colour, followed by yellowing, curling of the lower leaves, and wilting.

The disease then proceeds up the stem over time. Sometimes the growing tips of infected plants show a purple discolouration. Another common sign of infection is the appearance of aerial tubers in the leaf axils. Infected plants eventually die prematurely. Fusarium wilt differs from bacterial wilt in the sense that wilting caused by the latter is more severe and without yellowing of the leaves. In infected plants, both the root cortices and the plant stems may exhibit a corky decay, and when the plant stems are bisected, typical browning of the vascular bundles is observed. The tissues surrounding the affected cells in the vascular ring usually appear brown, yellowish or water-soaked.

ASPECTS OF INTEGRATED MANAGEMENT

Spread

Fusarium species are soil and seed borne and form thick-walled spores (chlamydospores) that protect them from unfavourable climatic conditions and soil micro-organisms. Spores can be spread by soil adhering to implements, shoes and livestock, or by wind and water.

Soil management

The ideal is to prevent infection of the soil. However, this may not be possible as seed may carry the risk of *Fusarium* spp. In addition, resistant chlamydospores can survive in the soil for many years. As most soils in potato production regions have been used for potato production for many years, one must assume that the soil is infected and the only management strategy is an integrated approach.

Rotation with non-host plants with potatoes every 5 – 7 years is recommended to lower the infection level, and therefore the risk of Fusarium diseases.

A potato tuber disc baiting technique was developed to provide a rapid, effective, quantitative and qualitative means of assessing the absolute inoculum potential of *Fusarium* spp. dry rot pathogens in the soil adhering to tubers after lifting. This inexpensive and simple technique can be used to predict the risk of storage rot.

Nematodes in the soil cause micro-wounds on roots and stolons, which offer *Fusarium* spp. easy access into the plant. It is therefore important to manage nematodes. Make sure the soil moisture level during harvesting is around 65% to limit damage of tubers by clods during harvest.

Seed tuber treatment

Treat all seed tubers with a registered fungicide before planting, or apply the treatment to soil during planting. Overseas researchers have found that some *Fusarium* spp. or strains had become resistant to some fungicides. Unfortunately, similar research has not been conducted in South Africa for many years.

Planting

If seed lots carry a high risk of *Fusarium* and/or if the field has a history of Fusarium diseases, do not plant in cold or hot soil in order to reduce the stress and susceptibility of plants as much as possible.

Harvest and post-harvest handling

The objective of all practices during harvest and post-harvest handling must be to reduce mechanical damage as much as possible to limit the infection of seed tubers.

Seed potatoes

Seed potatoes are certified in different generations and classes after tubers are sorted based on visual symptoms of Fusarium dry rot and stem-end rot (see table below).

If the soil is infected with *Fusarium* spp., spores can adhere to the surface of seed tubers in the soil. If the periderm of such tubers is damaged during handling, spores can enter the tuber. If the periderm is not damaged, the spores serve to infect soil after planting of the seed. Seed treatment with a registered fungicide before planting is therefore recommended.

Disease	Maximum % Fusarium infected seed potatoes permissible									
	G0	G1-3			G4-6			G7-8		
		Elite	Class 1	Std	Elite	Class 1	Std	Elite	Class 1	Std
Dry rot	0	0.2	0.5	5.0	0.5	1.0	5.0	1.0	3.0	5.0
Stem-end rot	0	0.2	0.5	3.0	0.5	1.0	3.0	1.0	2.0	3.0
Maximum joint %	0	0.2	0.5	5.0	0.5	1.0	5.0	1.0	3.0	5.0

***Fusarium* species are monocyclic pathogens on potatoes**

- The size of the initial inoculation level in soil does not increase during a single season of planting potatoes, unless additional inoculum is carried into the field from an external source.
- Fusarium diseases may not be evident in the first season after introduction of inoculum into a field.
- The level of inoculum increases by repeated planting of host plants, and with that the disease becomes more serious.

FUSARIUM DRY ROT CAN BE CONFUSED WITH GANGRENE

Symptoms of gangrene are commonly characterised by small dark depressions that develop in the tuber skin. Lesions may enlarge to form a 'thumbprint'-like lesion due to decay beneath the skin. When the tubers are cut open, deep-seated lesions with a sharp edge can be seen, although symptoms can vary.

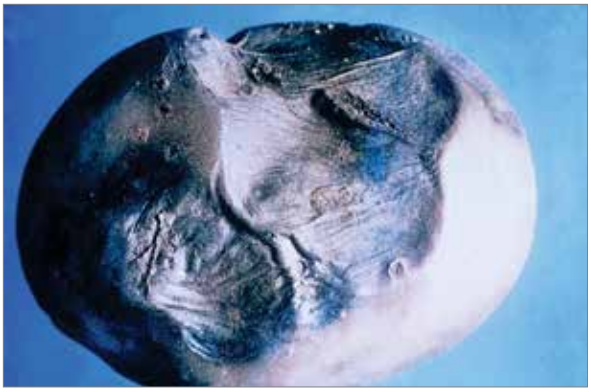


Photo: ARC-VOP

DO NOT CONFUSE FUSARIUM WILT WITH BACTERIAL WILT DISEASES

Fusarium wilt differs from bacterial wilt diseases in the sense that the latter is caused by *Ralstonia solanacearum* and soft rot pathogens such as *Pectobacterium* ssp, and which is a more severe green wilt without yellowing of the leaves.

Read more:

Potatoes South Africa, 2015. Best practices for the handling of seed potatoes. www.potatoes.co.za/research/best-practices

Potatoes South Africa, 2016. Final report: Fusarium dry rot in South Africa. www.potatoes.co.za/research/final-reports

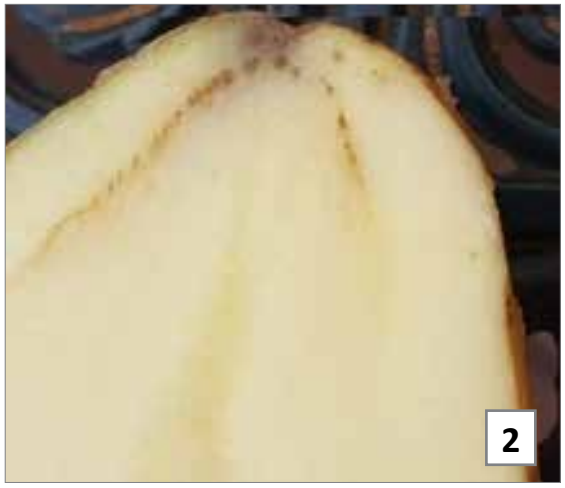
CHIPS articles already available on-line at www.potatoes.co.za/research/Chips-articles/disease -control

- Fusarium dry rot of potato in South Africa I: Fungicide treatment of seed pieces (2016)
- Fusarium dry rot of potato in South Africa II: Species associated with dry rot (2016)
- Fusarium dry rot of potato in South Africa III: Effect of temperature on dry rot development of tubers inoculated with different fusarium species (2016)
- Fusarium dry rot on potatoes: Bioassay to predict the risk (2017)

SYMPTOMS OF DRY ROT

When stems infected with Fusarium are bisected, typical browning of the vascular bundles are observed (Figure 1). In tubers, vascular bundles have a tan-brown colour (Figure 2). The start of stem-end rot (Figure 3) and a more advanced stage (Figure 6). Fusarium rot lesions on tubers where the pathogen gained entry into the tuber through enlarged lenticels (Figure 4). Figures 5 and 6 show Fusarium dry rot at an advanced stage. Seed tubers with severe dry rot (Figure 7).

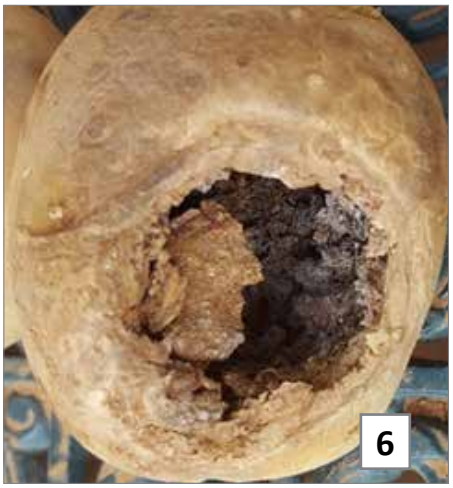

1


2


3


4


5


6


7

ACKNOWLEDGEMENT: Dr Freddie Denner (Rolfes Agri) for technical input.