Pectobacterium and *Dickeya*: Managing the risk of blackleg development and soft rot in potato plantings

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The question has been asked whether seed potatoes could be tested for soft rot causing *Enterobacteriaceae* (SRE) (*Pectobacterium* and *Dickeya* species), generally known as *Erwinia*, so that growers could assess the risk of planting seed potatoes with higher inoculum levels. In theory, the short answer is yes. Seed potatoes can be tested for SRE, but …

It is generally understood that the higher the inoculum or infection level of a specific pathogen, the higher the risk of diseases developing. However, this is mostly not the case for SRE.

Czajkowski *et al.* (2011) reported that "depending on weather conditions, heavily contaminated seed can give rise to little or no disease, and the converse is also true". Thus, one can have a high inoculum SRE load on seed potatoes and if the climate is not conducive, no disease will develop; and, one can also have seed potatoes with low levels of SRE inoculum and disease could develop given the right weather conditions.

What to make of the answer

In the Netherlands, during the period between 2015 and 2019, a post-harvest tuber test was conducted on all pre-basic seed lots (G0 to G4) in addition to the field inspections. The results were used by the growers and inspection service to improve disease management. It was not used for certification. 200-Tuber samples were randomly collected from the top of the stacks of crates in storage (Been *et al.*, 2022).

In *Figure 1* the relationship between sample size and probability of detection is graphically presented for an infection incidence of 0.05% of the tubers. It shows that analysis of 200 tubers provides a probability of only 9.5% or less that an infected tuber will be present in the sample. It further indicates that more than 4 600 out of 40 000 tubers/ha must be tested to obtain a probability of 90% that an infected tuber is present in this large sample.

With the 200-tuber sampling method, one out of 87 tubers in the field must be infected to obtain a 90% probability that at least one infected tuber will be included in the sample that is tested. Looking at a sample size of 4 600 tubers, it is the same sample size used for detecting bacterial wilt, *Ralstonia* spp.

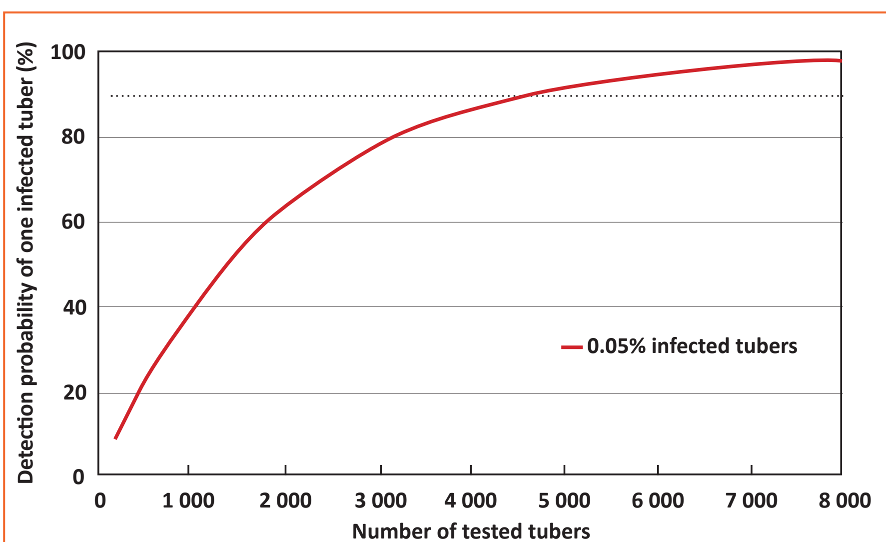
The data provided proved that the standard 200-tuber sample is not enough to detect levels of infestation at which SRE usually occurs with a high probability. Collecting more tubers to improve detection

Table 1: Pectobacterium classification.

Class	Generation
PBTC (mini tubers/micro-plants) mother plant (clonal selection)	G0
PB 1	G1
PB 2	G2
PB 3	G3
PB 4	G4
S	G5
SE	G6
E	G7
A	G8
B	G9

Category: Prebasic
Category: Basic
Category: Certified

Figure 1: Number of tested tubers and the probability of detection according to a Poisson distribution based on 0.05% of infected tubers in the lot.



probabilities will only have a marginal effect. The actual number of tubers (4 600) to be collected and tested to obtain a high detection probability of 90%, is not economically feasible. Another factor to consider is the high cost involved in testing for contamination levels.

The success of the Nederlandse Algemene Keuringsdienst field inspections (NAK), with more than 50% of the infected fields having been detected even after producers rogued the diseased plants they found during their inspections, and considering that the inspectors surveyed only a small part of the field visually (5 to 10%), is far better than the success rate of the 200-tuber sampling. An increase, e.g., doubling of the currently inspected area per seed potato lot to between 10 and 20% will have a significantly greater positive effect on the detection of infested seed potato lots than an equivalent increase in the number of tested tubers.

Scheme assessment of SRE

In the South African Seed Potato Certification Scheme (Scheme), all initial potato micro-propagative material must test negative for the presence of SRE for uptake in the Scheme. All subsequent potato micro-propagative material sent to other tissue culture facilities and mini tuber production facilities, also have a zero tolerance for SRE infections.

Four mini tubers per 100 tissue culture plants planted in mini tuber production facilities are tested for the presence of SRE. The detection of SRE in such samples leads to the rejection of the mini tuber lot sampled as there is a zero tolerance for SRE in G0 seed potatoes (mini tubers). The same zero tolerance applies to imported potato micro-propagative material and imported mini tubers.

No further testing of later-generation seed potatoes for SRE is done in the Scheme for reasons already stated. When comparing the Scheme tolerances for SRE in field inspections to that of the United Nations' Economic Commission

Table 2: South African Scheme tolerances.

Generation	Field inspection	Soft rot *Enterobacteriaceae* (SRE)*
		*Blackleg
G0	First	0
	Second	0
G1 – 3	First	**0.5**
	Second	0.1
G4 – 6	First	**1.5**
	Second	0.5
G7 – Certified commercial	First	**5**
	Second	**2**

for Europe (UNECE) during field inspections, the South African Scheme compares similarly.

UNECE tolerances determine that the proportion of growing plants affected by blackleg may not exceed:

- In crop for the production of the pre-basic category, 0%.
- In crop for the production of Basic I class seed, 0.5% and of Basic II class seed, 1%.
- In crop for the production of Certified I class seed, 1.5% and of Certified II class seed, 2%.

The Scheme also compares well with the UNECE standard tolerances for wet rot, namely 0% for mini tubers, then 0.1% for G1 to G7, with 0.2% maximum for Certified Commercial seed potatoes, whereas the UNECE standard cites a 0.2% tolerance for pre-basic seed potatoes and 0.5% maximum for the rest including up to Certified II.

The following sets out the position of the Specialised Section on blackleg of seed potatoes as agreed upon at the 44th session in March 2017:

- Blackleg occurrence in seed potato crops is an important indicator of quality. In the UNECE Standard for Seed Potatoes, strict tolerances for blackleg in the growing crop and during lot inspection underpin, as part of the rot tolerance, the control of this disease in certified seed.
- *Disease expression in the progeny crop is not always directly related to either inspection findings or bacterial load in mother tubers. It has been demonstrated that the contamination levels of the individual mother seed lots, estimated by performing molecular testing, do not allow reliable prediction of the development of the disease in the individual succeeding crop* (own emphasis). This is due to the

An example of blackleg.

An example of soft rot.

important influence of multiple environmental and agronomic factors. Nevertheless, regular inspections and enforcing strict tolerances within the certification system continue to be the best regulatory mechanism to control the disease for all crops. In line with the *UNECE Guide to Operating a Seed Potato Certification Service*, departments of agriculture may wish to adopt more stringent tolerances when this is appropriate to their production conditions.

- Conditions which favour blackleg, particularly excessive moisture, anaerobic conditions and in the case of *Dickeya*, high temperatures, can lead to the development of the disease.
- Good agronomic practices combined with preventive measures such as avoiding excessive nitrogen supply and over-irrigation, removal of diseased tubers before planting, allowing mother tubers to fully deteriorate before harvest, forced ventilation immediately after harvest, maintaining a high degree of farm hygiene, are very important in blackleg control.

Controlling blackleg and soft rot

- De Boer *et al.* (2012) reported that rogueing in the control of blackleg is only effective if the entire plant is physically removed, including the mother tuber as well as the progeny tubers. All measures must also be taken to prevent contact of diseased tissue with other plants in the field.
- The main environmental factor for a shift from latency to disease development is the presence of water on tubers, which triggers a cascade of events leading to the onset of rotting (Pérombelon and Lowe, 1975).
- There are no available potato cultivars which are resistant to SRE, and no control agents are registered for the treatment of plant material (Van der Wolf *et al.*, 2021b).
- In contrast to tuber rot, stem diseases generally develop under aerobic conditions. Blackleg develops when large numbers of the pathogen invade the stems after multiplication in the rotting mother tubers.
- The more important factor is soil water level (rainfall/irrigation) which, if prolonged, induces development of the anaerobic conditions in mother tubers, favouring bacterial multiplication and initiation of rotting (Pérombelon *et al.*, 1989).
- The soft rot bacteria do not overwinter in the soil. Survival in soil is restricted to one week to six months, depending on environmental conditions such as soil temperature, moisture and pH. Survival can be extended in association with plant material, including volunteers (Czajkowski *et al.*, 2011).
- It is now generally accepted that the major source of blackleg infection is the latently infected seed (mother) tubers (Pérombelon, 1974).
- Crop contamination can also occur from airborne sources. Soft rot bacteria can be carried from diseased plants by airborne insects over long distances to contaminate other potato crops. Also, they can be present in aerosols produced by rain impaction on blackleg plants and by haulm pulverisation before harvest.
- Contamination of crops can also occur during mechanical flailing (Pérombelon *et al.*, 1979).
- Most importantly, contamination of tubers can occur during harvesting and handling (grading) in-store via the disintegration of rotting tubers and the spread of rotting tissue on machinery into wounds inflicted during handling (Elphinstone and Pérombelon, 1986; Pérombelon and Van der Wolf, 2002).
- Another critical condition in disease development is the level of seed contamination, as shown in the case of *Pectobacterium atrosepticum*. The higher the bacterial density, the more likely the pathogen will predominate in the incipient lesion and the sooner rotting is initiated (Bain *et al.*, 1990).
- Progeny tuber contamination is related to seed tuber contamination as well as blackleg disease (Toth *et al.*, 2003).
- The importance of calcium (Ca) in the resistance of plants against bacterial pathogens cannot be emphasised enough as Ca improves the structure and integrity of plant cell wall components, resulting in higher resistance to diseases involving tissue maceration. (Bateman and Miller, 1966; Berry *et al.*, 1988) and (Platero and Tejerina, 1976; McGuire and Kelman, 1984; Berry *et al.*, 1988).
- Washing and disinfection of machines used when planting, spraying, haulm flailing, harvesting and grading in store no doubt helps to reduce

risks of introducing soft rot bacteria in a pathogen-free crop (Pérombelon and Kelman, 1980; Pérombelon, 2002).

When there is no oxygen in the soil, combined with high temperatures, rotting will occur and the pathogen comes in as a secondary infection.

Minimising risk development

- Plant seed potatoes in well-drained soils.
- Rogue infected plants with the mother and daughter tubers without coming into contact with healthy plants.
- Wash and disinfect all machinery used for planting, spraying, haulm killing, harvesting, grading and sorting.
- Plant mature tubers to reduce the risk of wounding.
- Dry tubers with forced ventilation to favour wound healing.
- Store in well-ventilated areas at low temperatures to avoid condensation on tubers.
- Harvest early.
- Amend soils low in Ca to strengthen cell walls which in turn will lead to increased resistance to bacterial diseases.
- An integrated control strategy should be followed.

Seed certification schemes are widely relied upon and used, and has only been partially successful. Seed potato growers and seed houses are requested to submit inspection reports with the seed lots, as it contributes to the value proposition of seed potatoes.

"Although many different control strategies against *Pectobacterium* spp. and *Dickeya* spp. have been employed, effective control of blackleg and soft rot diseases has not yet been achieved. Until highly resistant cultivars become available, disease control measures will continue to rely primarily on avoidance of contamination in the production of healthy certified seed. This is primarily based on seed derived from bacteria-free mini tubers, the use of rigorous seed certification schemes and strict hygienic practices" (Czajkowski *et al*., 2011).

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