Epidemiology, diagnostics and control of potato diseases

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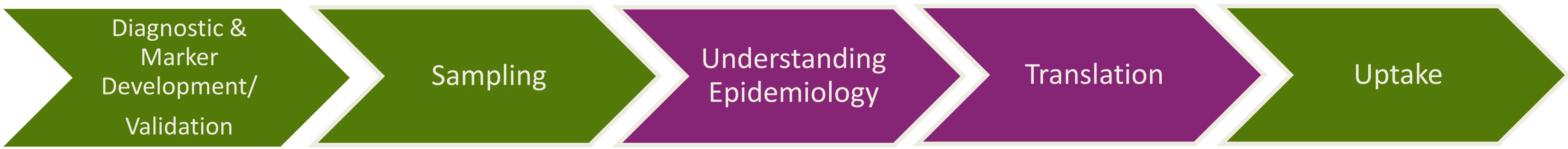
The James Hutton Institute


Diagnostic & Marker Development/ Validation
Sampling
Understanding Epidemiology
Translation
Uptake

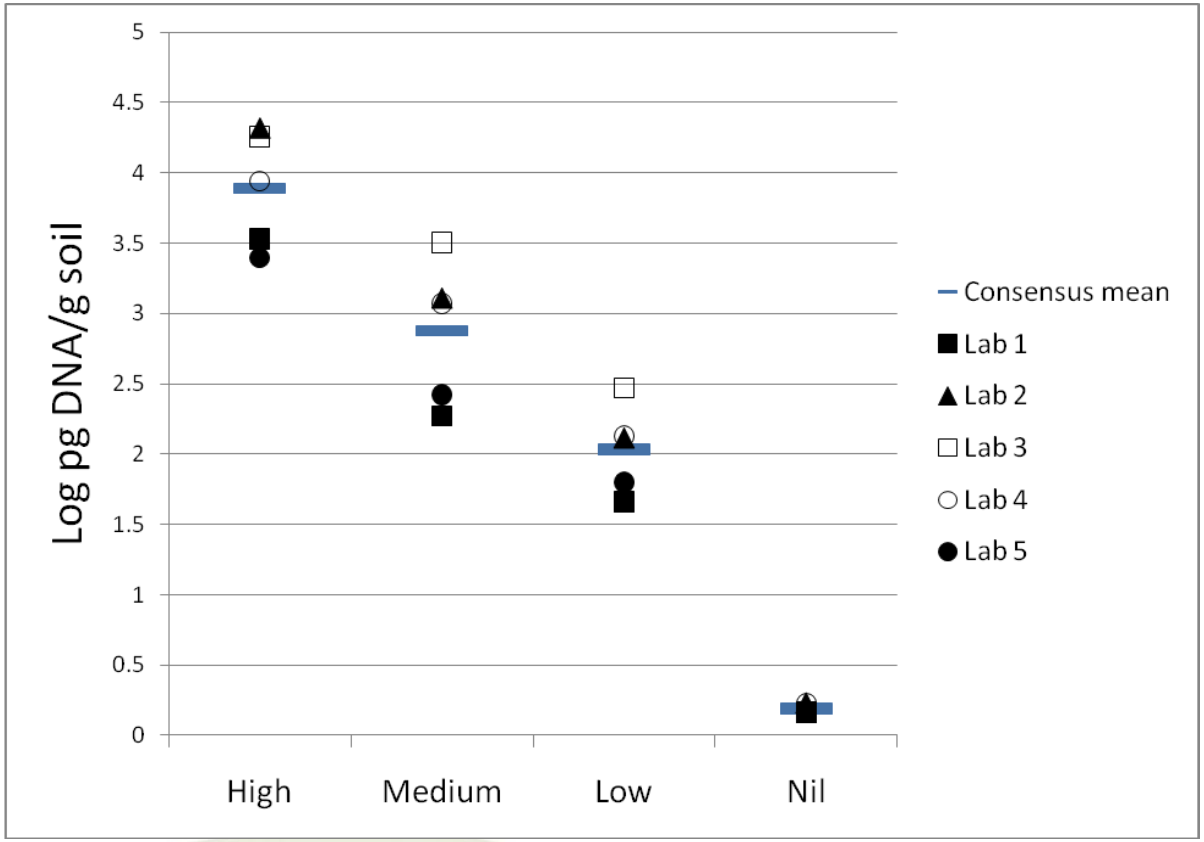
Predicting disease as a pro-active management tool

- Quantitative assay – which pathogen and how much?
  - Presence/absence tests useful but not necessarily related to risk
- Neutral and functional markers to characterise populations
- Sampling strategy – can we find the pathogen in the field ?
- What do the results mean?
  - Inoculum thresholds for risk
  - Epidemiology of individual diseases
  - Population characteristics
  - Effect of environment on disease risk
  - Available control measures
- Disease Management

Background

- Assays for the detection/quantification/characterisation of potato pathogens are available.
- Technology is not the limiting factor.
- Translation of results into practice is critical.
- Practical applications and take-up
- Focus on
  - *Colletotrichum coccodes* (black dot)
  - *Spongospora subterranea* (powdery scab)

Laboratory comparisons – powdery scab assay



Sample	CV%
High	3.5
Medium	9.8
Low	27.7
Nil	0.0

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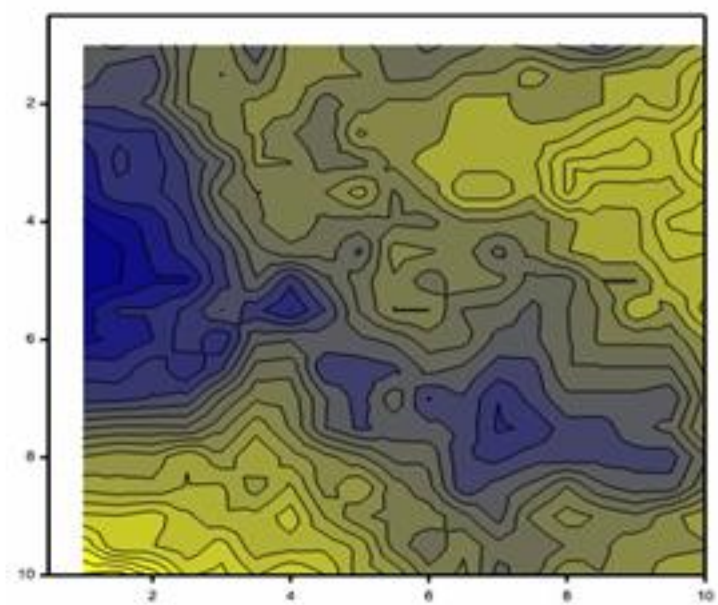
Sampling strategy: soil-borne pathogens

S. Wale

Underpins the reliability of soil testing.

- must be representative of field scale
- must be practical (sampling/processing time/cost)
- based on “old” PCN sampling strategy

- Sampling area: 4ha or less. (divide larger fields)
- Sample size: 1Kg for standard testing
- Sampling points: 100 x 10g samples (0-15 cm depth)
- Sampling pattern: W pattern.
- DNA extraction: 60g from 1kg



Jeff Peters (Fera)

Brierley *et al.,* 2009. Quantifying potato pathogen DNA in soil. *Applied Soil Ecology* 41, 234-8.

Epidemiology of individual diseases

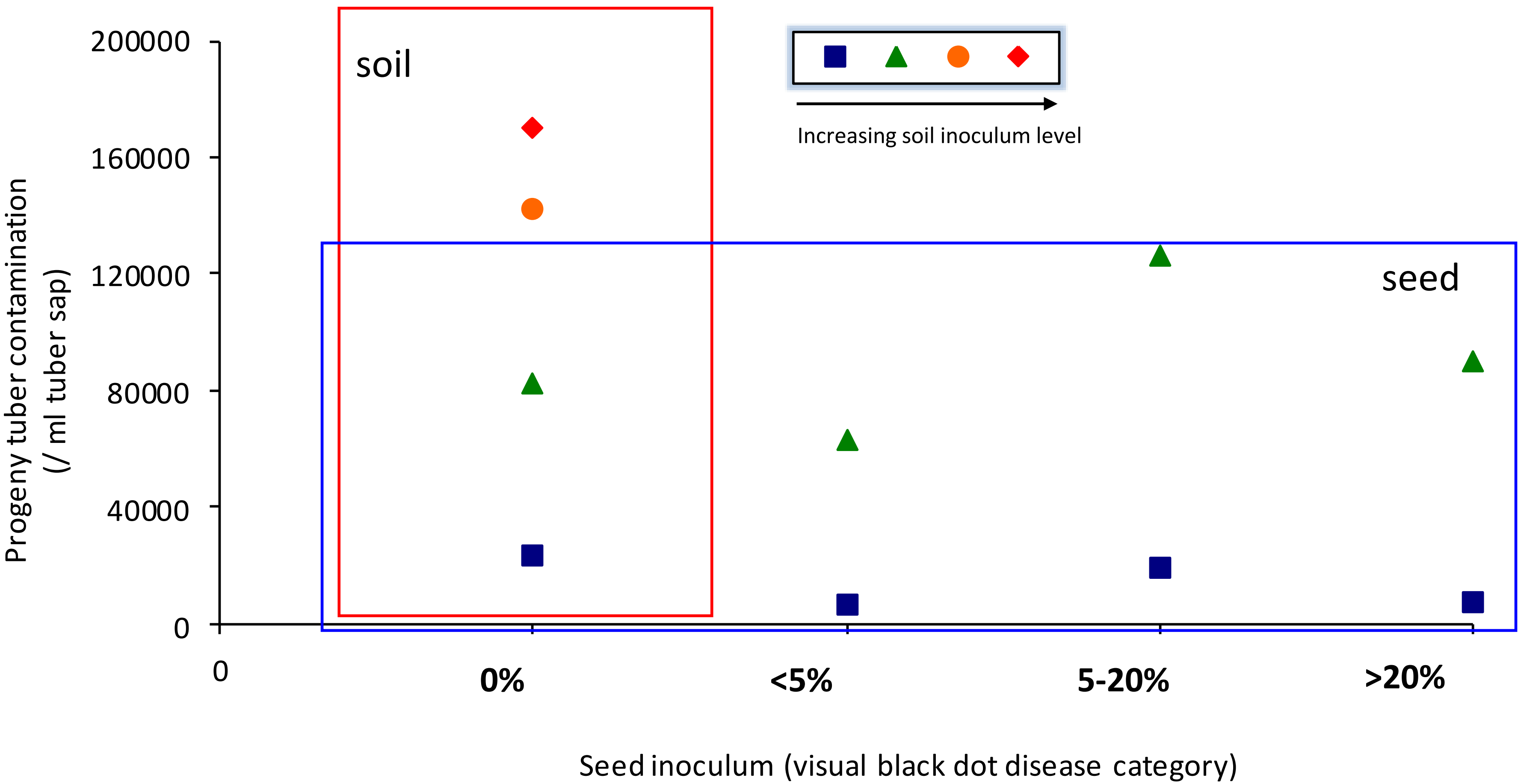
Re-visiting basic questions using quantitative tools/markers

- Sources of inoculum?
- When does infection takes place?
- What factors affect the development of symptoms?
- What are the characteristics of the pathogen population?

Sources of inoculum

- **Relationship between inoculum and disease**

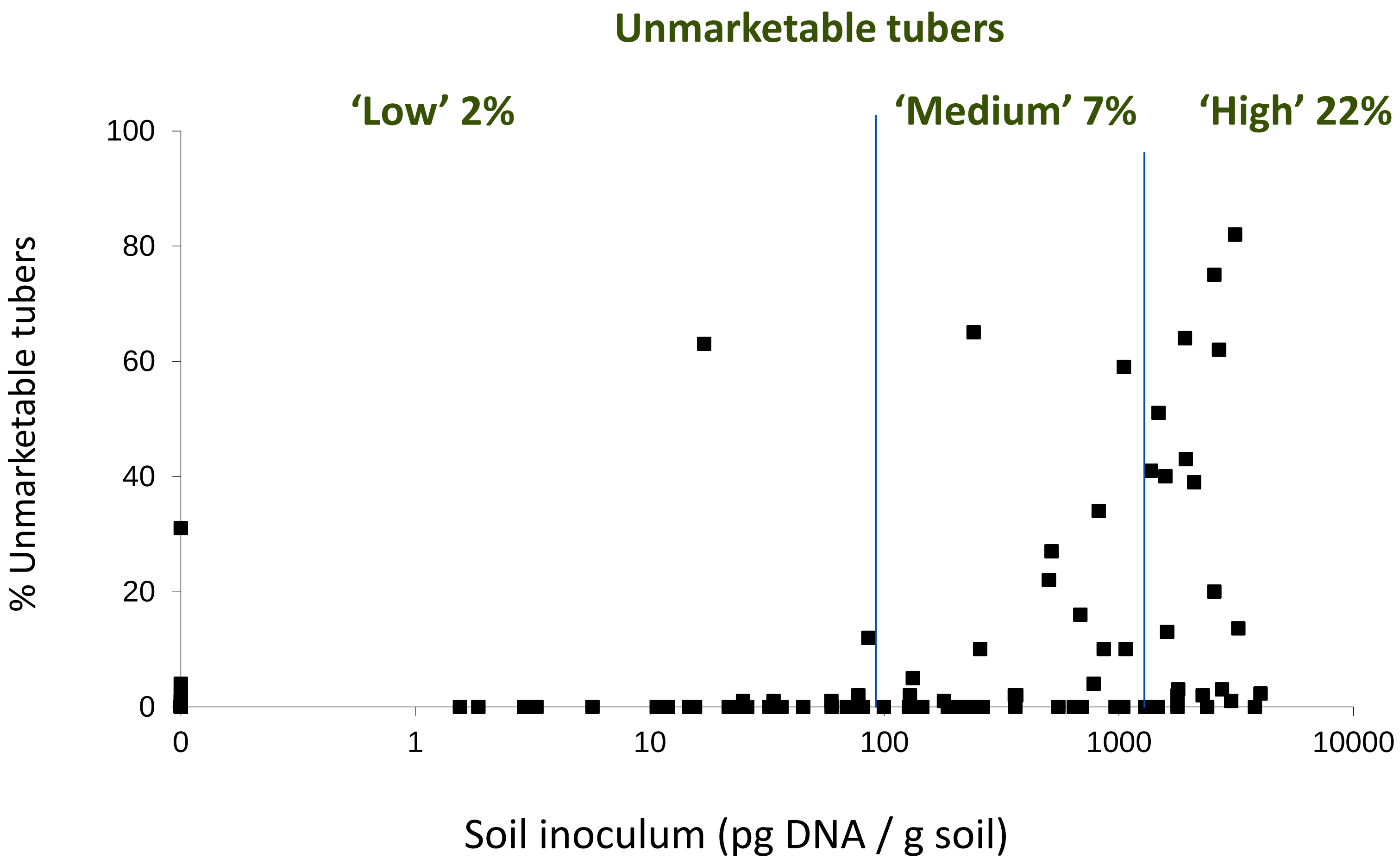
Effect of seed- and soil-borne inoculum on progeny tuber contamination by *C.coccodes*



Lees *et al*., 2010. *Plant Pathology* 59, 693-702

Colletotrichum coccodes - black dot soil inoculum

120 commercial fields x 3 years

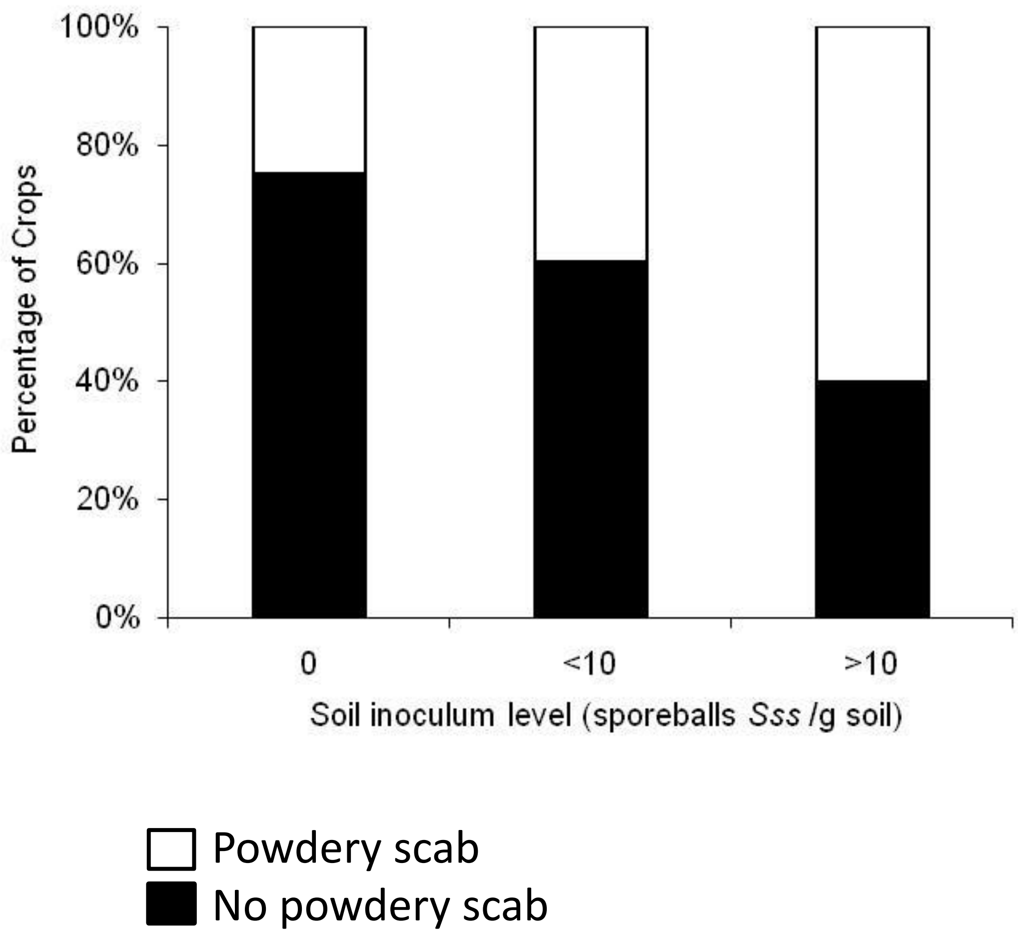


Lees *et al* (2010). *Plant Pathology* 59, 693-702.

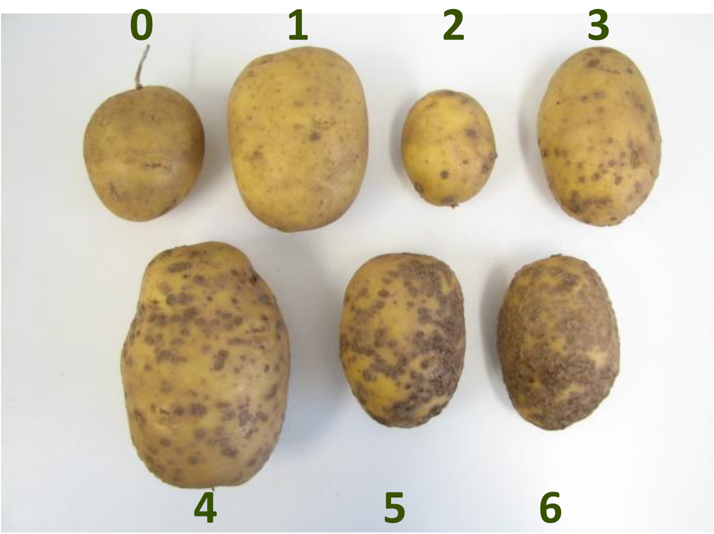
Powdery scab - monitoring of commercial potato fields

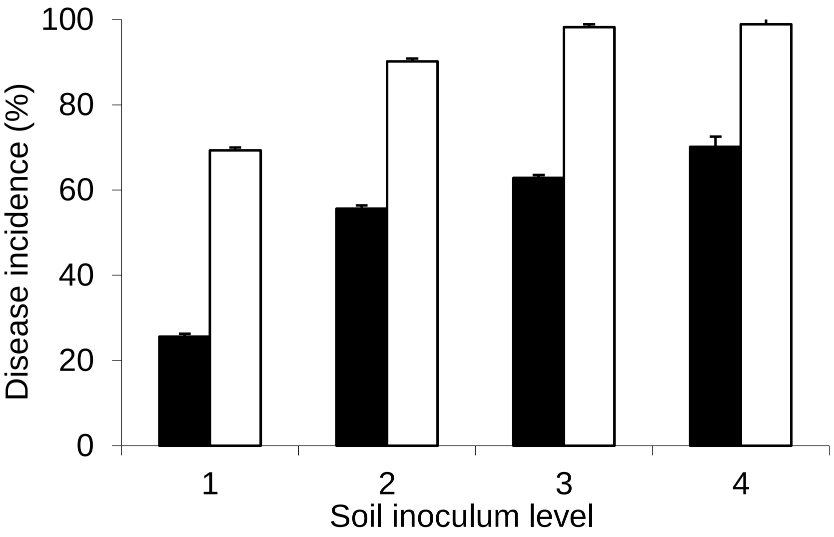
The percentage of crops with powdery scab increased from 25% to 65% according to pre-plant levels of soil inoculum.

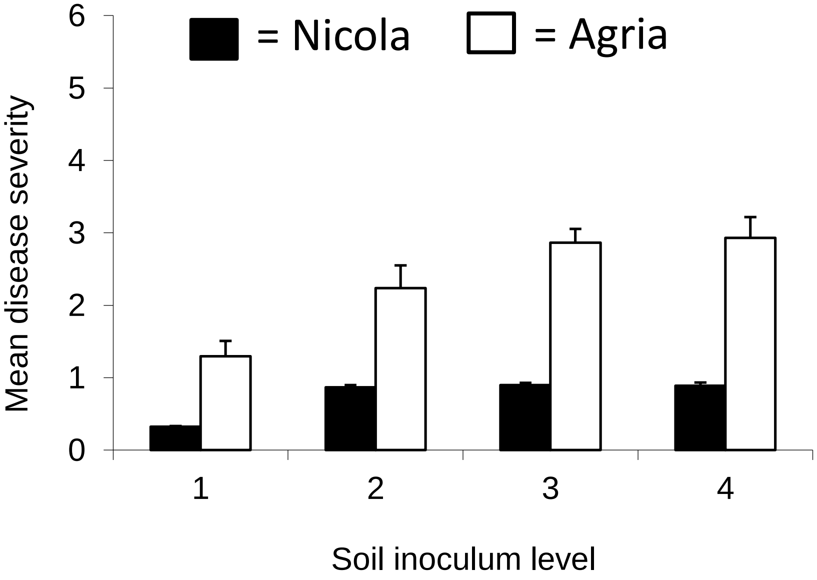
Seed-borne inoculum was responsible for disease where no soil-borne inoculum detected



Relationship between inoculum and disease in the field (x 3 years): powdery scab







Level of soil inoculum significantly affects powdery scab incidence and severity on progeny tubers.

Evidence towards use of diagnostic test for field selection

Brierley *et al* (2013). *Plant Pathology* 62, 413–420.
Merz *et al* (2012). *Plant Pathology* 61, 29–36.

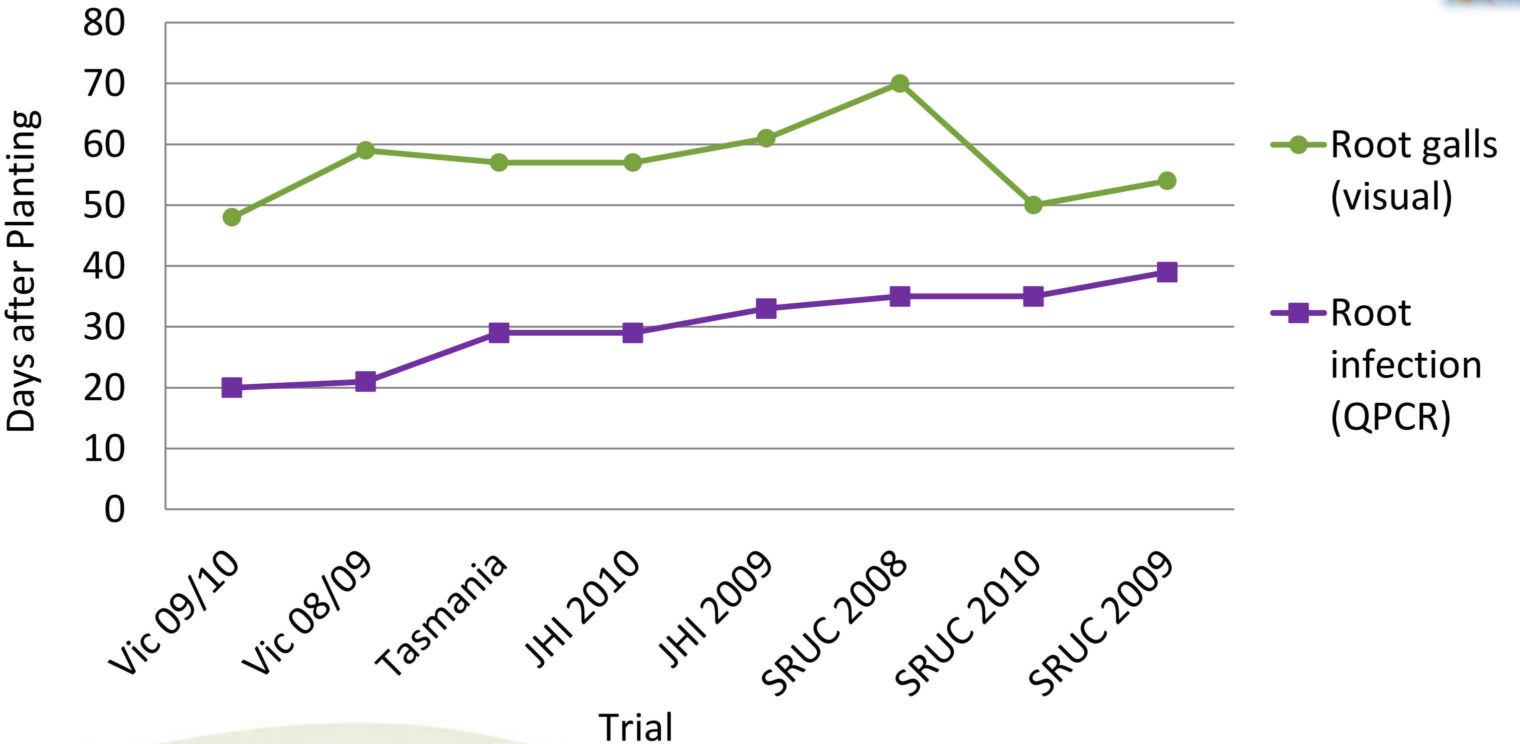
How does environment affect infection and disease?
- targeting control timing for powdery scab

- 9 trials internationally (Scotland, Australia, Tasmania)
- One susceptible (Agria, Estima, Kennebec) and one intermediate cultivar (Desiree, Nicola, Saturna)
- No seed treatment. Irrigation applied for up to 4 weeks after tuber initiation. Herbicide, Late Blight and aphid control as per standard practice.
- Infection and disease assessments
- Environmental monitoring

Real-time PCR assessment of samples

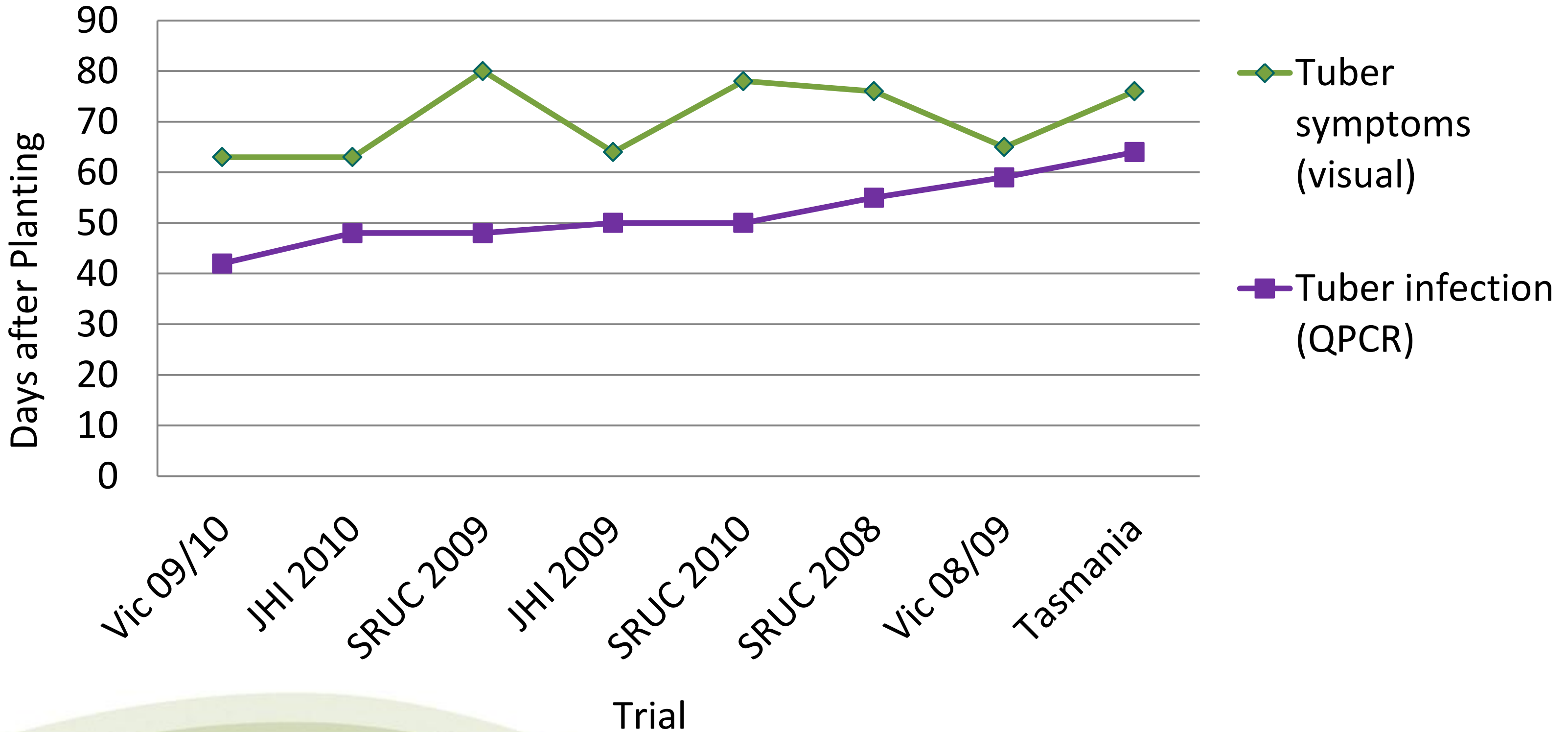
- Assessed root and tuber samples weekly for disease and for presence of *S. subterranea* DNA using real-time PCR
- Soil inoculum level was measured
- Timing of infection and disease development are given as days after planting (DAP).

Determining time of root infection and symptom development (*S. subterranea*)



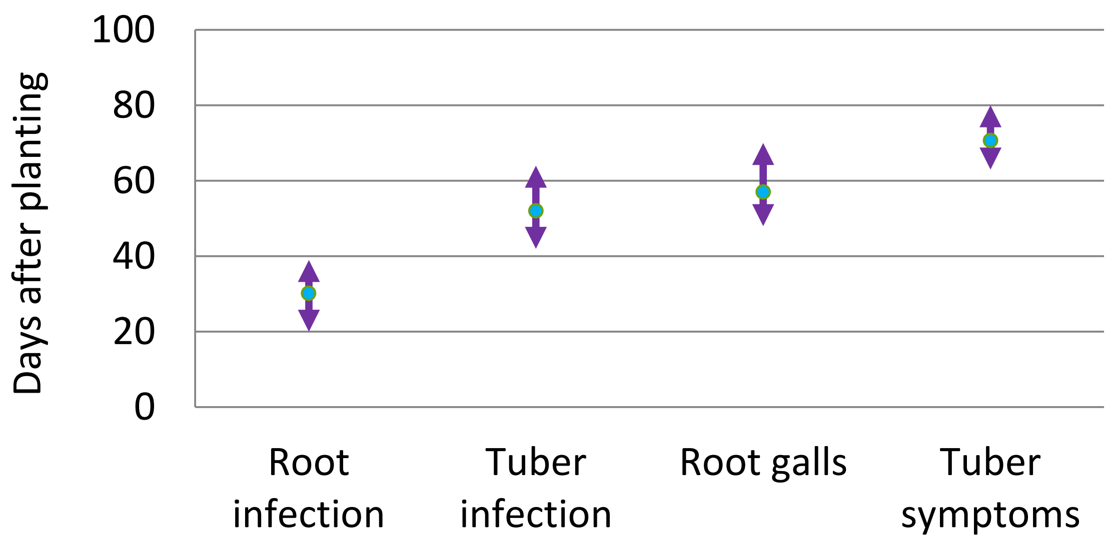
- Root infection occurred earlier in Victoria = earlier emergence (warmer soil)
- Root galling occurred over a three week time span at all sites (48 to 70 DAP)
- Root galling was not observed until ~ 3 weeks after root infection

Determining time of tuber infection and symptom development (*S. subterranea*)

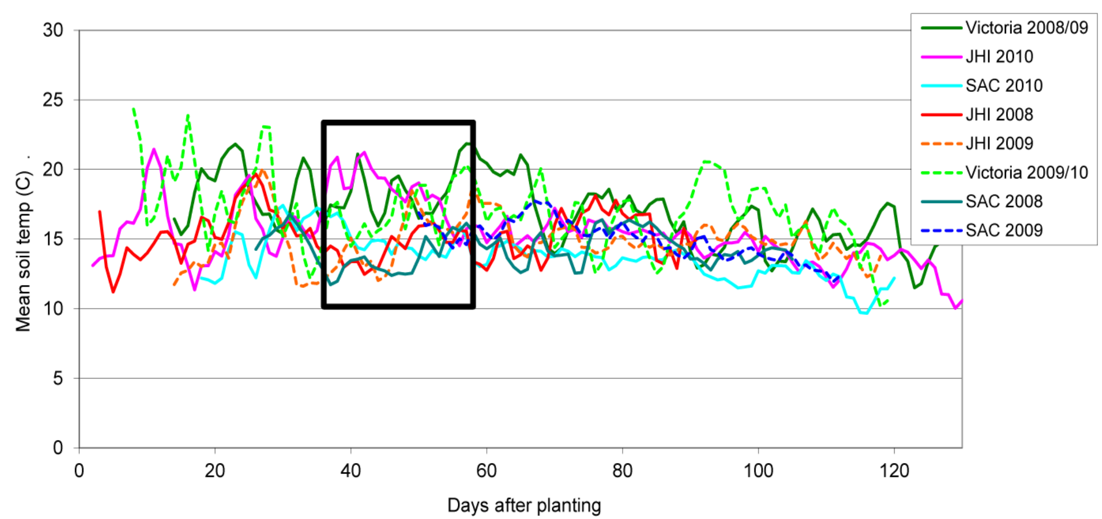


- At all sites, tuber infection was observed at the first sampling time after tuber initiation
- Until 64 DAP symptom development was negligible.

Timeline – infection and symptom development across all trials (*S. subterranea*)



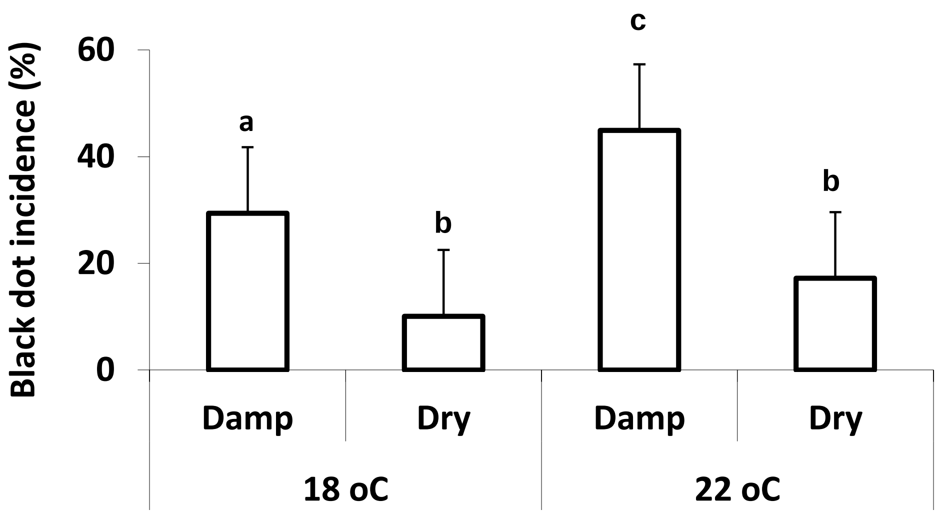
- **Associated environmental variables known**
- **Can study relationship between environment and infection/disease**

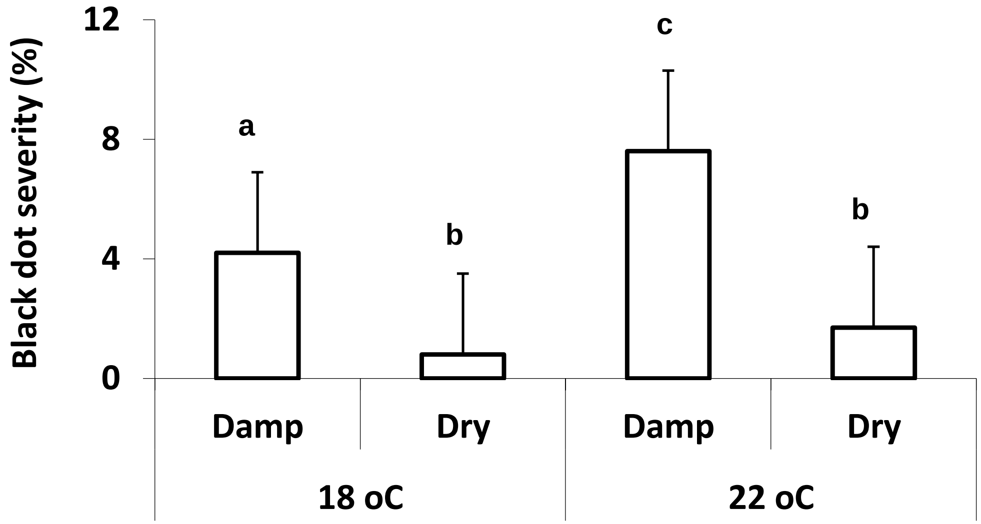


Interpreting results

- Epidemiological knowledge of individual diseases is critical for interpreting results and making control recommendations.
- Environmental and agronomic parameters must be factored into practical management advice.
- Successful adoption of predictive diagnostic tools to inform management decisions relies on a truly integrated approach.

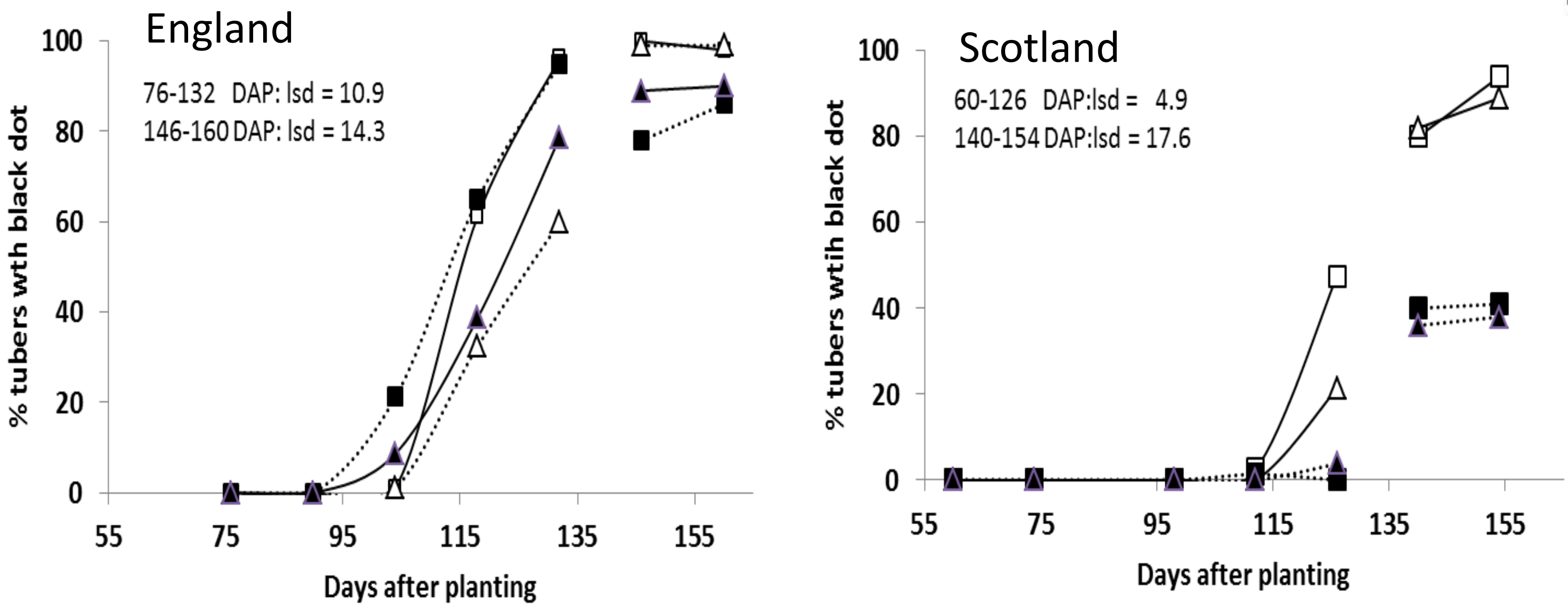
Black dot- controlled environment





Lees et al 2010. Plant Pathology

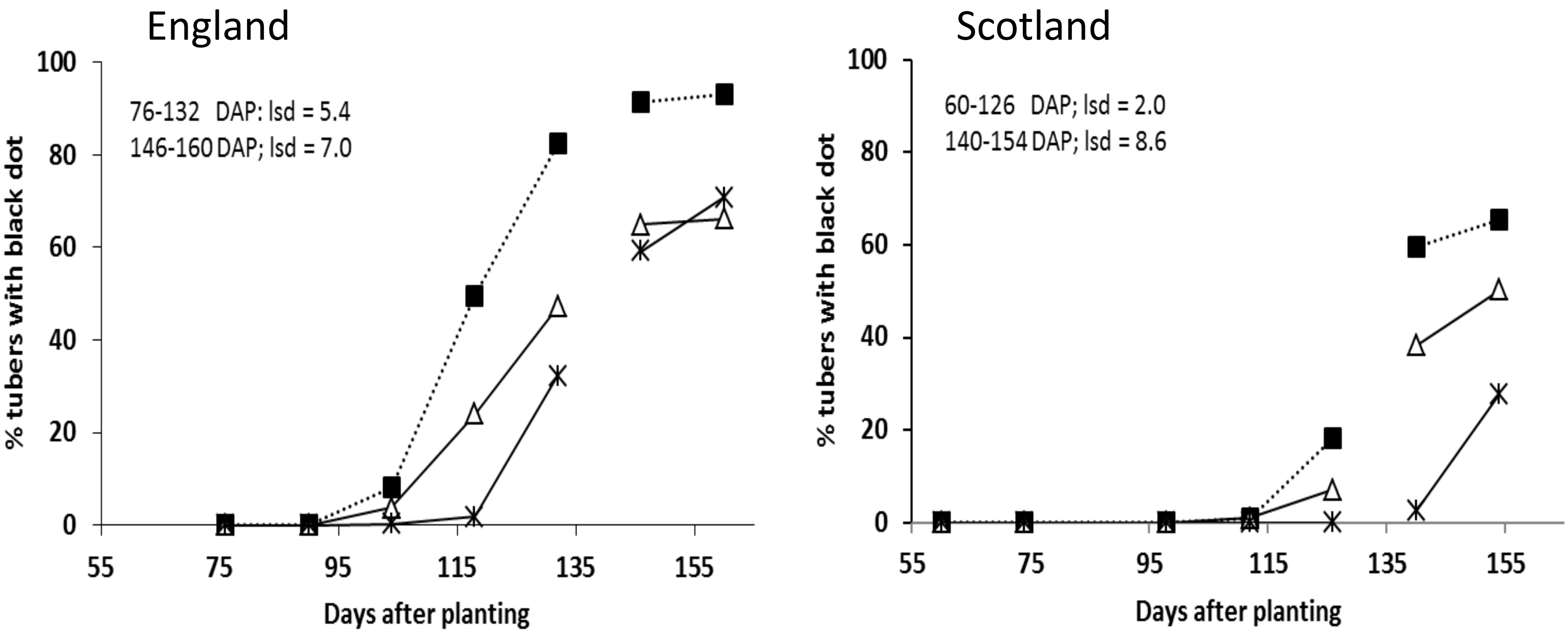
Effect of Irrigation and Azoxystrobin on black dot (Maris Piper)



- Irrigation/- Azoxystrobin □
- Irrigation/+ Azoxystrobin ■
+ Irrigation/- Azoxystrobin Δ
+ Irrigation/+ Azoxystrobin ▲

Brierley et al. Plant Pathology (submitted)

Effect of cultivar on black dot



Recorded at 2 weekly intervals and at early and late harvests

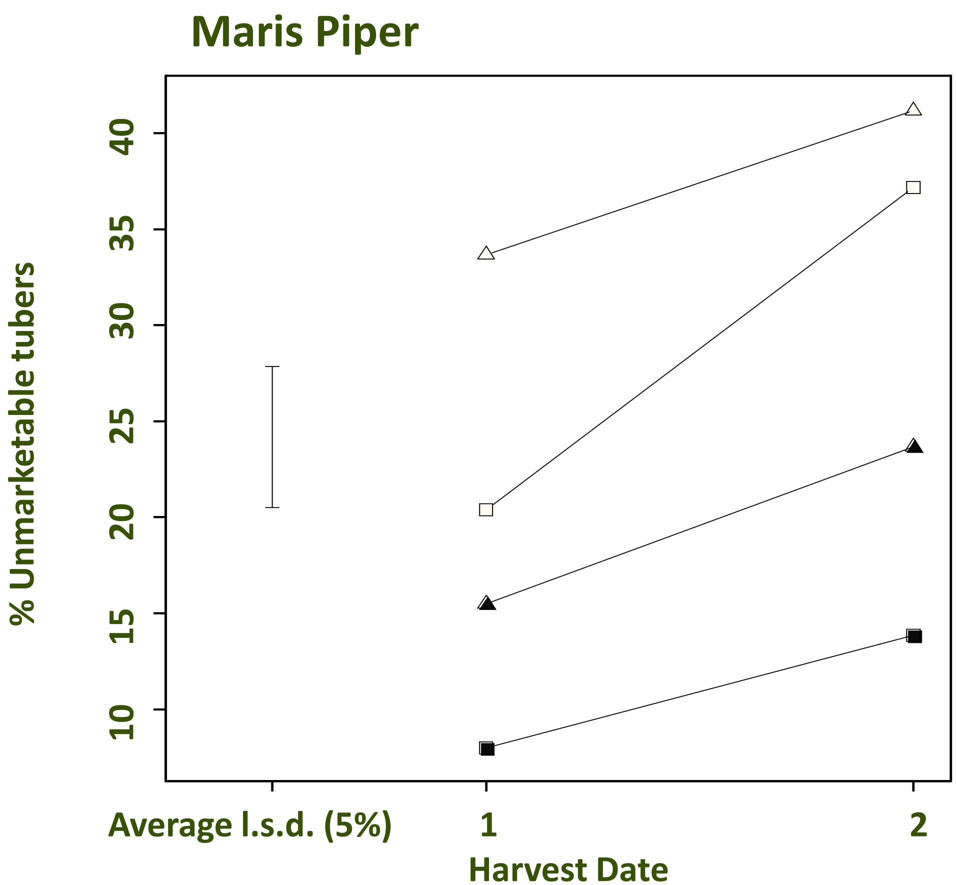
■ Maris Piper (4)

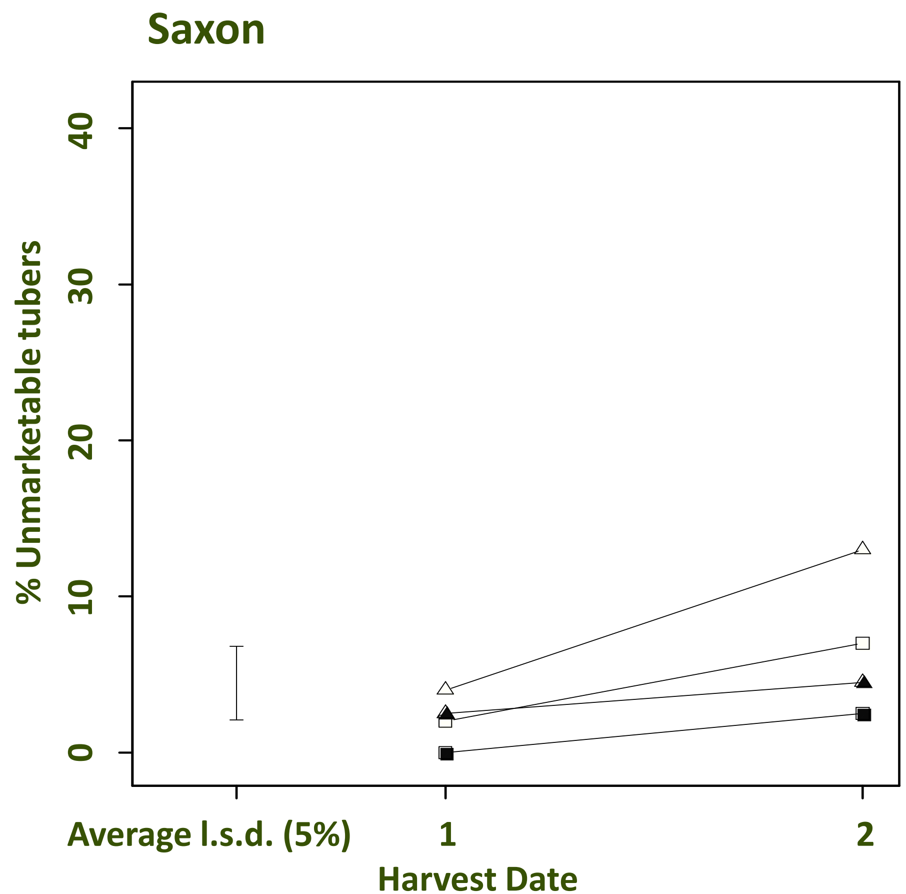
Δ Sante (5)

X Saxon (7)

Brierley et al. Plant Pathology (submitted)

Effect of harvest date (crop duration) on black dot



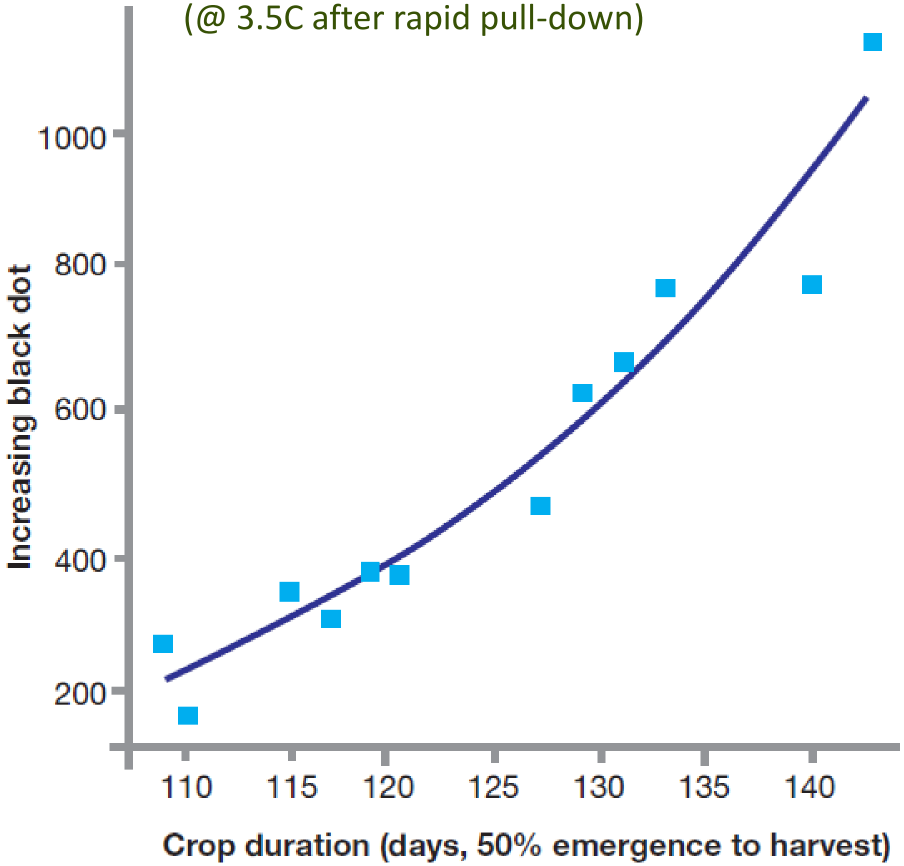


+ irrigation/- azoxystrobin (Δ)
- irrigation/- azoxystrobin (□)
+ irrigation/+ azoxystrobin (▲)
- irrigation/+ azoxystrobin (■)

Brierley et al. Plant Pathology (submitted)

Storage

Disease accumulated after 20 weeks storage
(@ 3.5C after rapid pull-down)



Peters et al (submitted). Factors that influence the post-harvest development of black dot on potatoes. Plant Pathology.

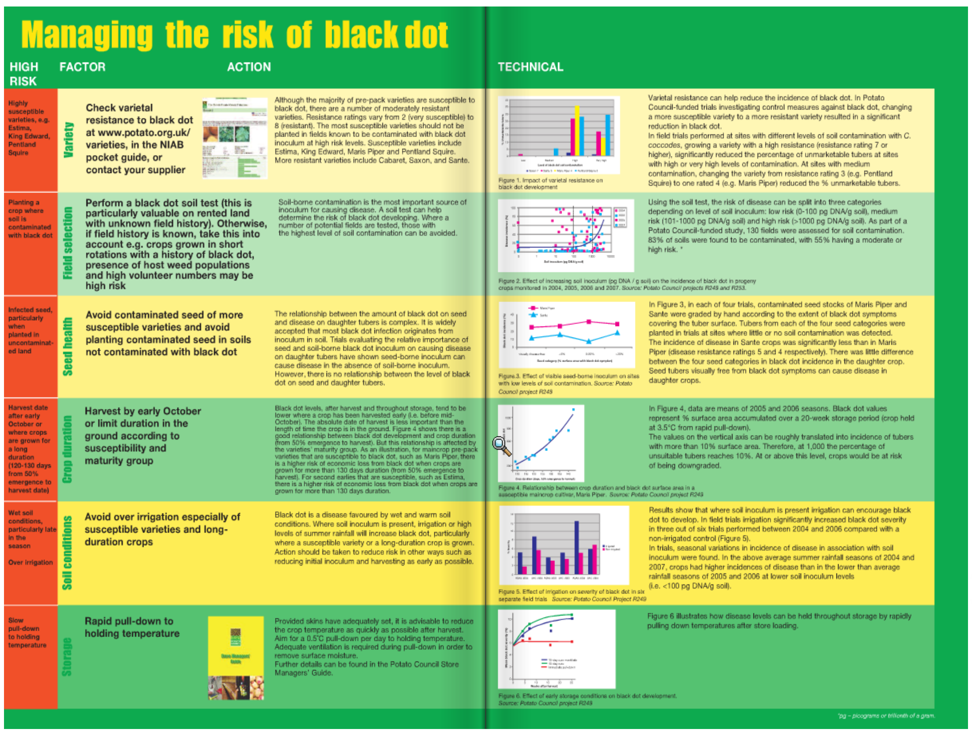
Black Dot

- Main Effects:
  - Soil inoculum levels relate to disease risk
  - Seed inoculum is relatively unimportant
  - Cultivar resistance significantly reduces black dot
  - Irrigation increases black dot incidence and severity
  - Azoxystrobin significantly reduced disease even with later harvests (26.7% to 14.6 % unmarketable tubers of Maris Piper over all trials).
  - Delayed harvest significantly increases disease particularly at high soil inoculum levels

Disease Management – bringing the information together

Quantify inoculum → Select Field → Select Cultivar

Understanding individual and combined effects of inoculum, environment and control measures



Managing the risk of black dot

HIGH RISK	FACTOR	ACTION	TECHNICAL
Highly susceptible varieties, e.g. Estima, King Edward, Pentland Squire	Variety	**Check varietal resistance to black dot at www.potato.org.uk/ varieties, in the NIAB pocket guide, or contact your supplier** Although the majority of pre-pack varieties are susceptible to black dot, there are a number of moderately resistant varieties. Resistance ratings vary from 2 (very susceptible) to 8 (resistant). The most susceptible varieties should not be planted in fields known to be contaminated with black dot inoculum at high risk levels. Susceptible varieties include Estima, King Edward, Maris Piper and Pentland Squire. More resistant varieties include Cabaret, Saxon, and Sante.	Figure 1. Impact of varietal resistance on black dot development. Varietal resistance can help reduce the incidence of black dot. In Potato Council-funded trials investigating control measures against black dot, changing a more susceptible variety to a more resistant variety resulted in a significant reduction in black dot. In field trials performed at sites with different levels of soil contamination with *C. coccodes*, growing a variety with a high resistance (resistance rating 7 or higher), significantly reduced the percentage of unmarketable tubers at sites with high or very high levels of contamination. At sites with medium contamination, changing the variety from resistance rating 3 (e.g. Pentland Squire) to one rated 4 (e.g. Maris Piper) reduced the % unmarketable tubers.
Planting a crop where soil is contaminated with black dot	Field selection	**Perform a black dot soil test (this is particularly valuable on rented land with unknown field history). Otherwise, if field history is known, take this into account e.g. crops grown in short rotations with a history of black dot, presence of host weed populations and high volunteer numbers may be high risk** Soil-borne contamination is the most important source of inoculum for causing disease. A soil test can help determine the risk of black dot developing. Where a number of potential fields are tested, those with the highest level of soil contamination can be avoided.	Figure 2. Effect of increasing soil inoculum (pg DNA / g soil) on the incidence of black dot in progeny crops monitored in 2004, 2005, 2006 and 2007. *Source: Potato Council projects R249 and R253.* Using the soil test, the risk of disease can be split into three categories depending on level of soil inoculum: low risk (0-100 pg DNA/g soil), medium risk (101-1000 pg DNA/g soil) and high risk (>1000 pg DNA/g soil). As part of a Potato Council-funded study, 130 fields were assessed for soil contamination. 83% of soils were found to be contaminated, with 55% having a moderate or high risk. *
Infected seed, particularly when planted in uncontaminated land	Seed health	**Avoid contaminated seed of more susceptible varieties and avoid planting contaminated seed in soils not contaminated with black dot** The relationship between the amount of black dot on seed and disease on daughter tubers is complex. It is widely accepted that most black dot infection originates from inoculum in soil. Trials evaluating the relative importance of seed and soil-borne black dot inoculum on causing disease on daughter tubers have shown seed-borne inoculum can cause disease in the absence of soil-borne inoculum. However, there is no relationship between the level of black dot on seed and daughter tubers.	Figure.3. Effect of visible seed-borne inoculum on sites with low levels of soil contamination. *Source: Potato Council project R249* In Figure 3, in each of four trials, contaminated seed stocks of Maris Piper and Sante were graded by hand according to the extent of black dot symptoms covering the tuber surface. Tubers from each of the four seed categories were planted in trials at sites where little or no soil contamination was detected. The incidence of disease in Sante crops was significantly less than in Maris Piper (disease resistance ratings 5 and 4 respectively). There was little difference between the four seed categories in black dot incidence in the daughter crop. Seed tubers visually free from black dot symptoms can cause disease in daughter crops.
Harvest date after early October or where crops are grown for a long duration (120-130 days from 50% emergence to harvest date)	Crop duration	**Harvest by early October or limit duration in the ground according to susceptibility and maturity group** Black dot levels, after harvest and throughout storage, tend to be lower where a crop has been harvested early (i.e. before mid-October). The absolute date of harvest is less important than the length of time the crop is in the ground. Figure 4 shows there is a good relationship between black dot development and crop duration (from 50% emergence to harvest). But this relationship is affected by the varieties' maturity group. As an illustration, for maincrop pre-pack varieties that are susceptible to black dot, such as Maris Piper, there is a higher risk of economic loss from black dot when crops are grown for more than 130 days duration (from 50% emergence to harvest). For second earlies that are susceptible, such as Estima, there is a higher risk of economic loss from black dot when crops are grown for more than 130 days duration.	Figure 4. Relationship between crop duration and black dot surface area in a susceptible maincrop cultivar, Maris Piper. *Source: Potato Council project R249* In Figure 4, data are means of 2005 and 2006 seasons. Black dot values represent % surface area accumulated over a 20-week storage period (crop held at 3.5°C from rapid pull-down). The values on the vertical axis can be roughly translated into incidence of tubers with more than 10% surface area. Therefore, at 1,000 the percentage of unsuitable tubers reaches 10%. At or above this level, crops would be at risk of being downgraded.
Wet soil conditions, particularly late in the season. Over irrigation	Soil conditions	**Avoid over irrigation especially of susceptible varieties and long-duration crops** Black dot is a disease favoured by wet and warm soil conditions. Where soil inoculum is present, irrigation or high levels of summer rainfall will increase black dot, particularly where a susceptible variety or a long-duration crop is grown. Action should be taken to reduce risk in other ways such as reducing initial inoculum and harvesting as early as possible.	Figure 5. Effect of irrigation on severity of black dot in six separate field trials. *Source: Potato Council Project R249* Results show that where soil inoculum is present irrigation can encourage black dot to develop. In field trials irrigation significantly increased black dot severity in three out of six trials performed between 2004 and 2006 compared with a non-irrigated control (Figure 5). In trials, seasonal variations in incidence of disease in association with soil inoculum were found. In the above average summer rainfall seasons of 2004 and 2007, crops had higher incidences of disease than in the lower than average rainfall seasons of 2005 and 2006 at lower soil inoculum levels (i.e. <100 pg DNA/g soil).
Slow pull-down to holding temperature	Storage	**Rapid pull-down to holding temperature** Provided skins have adequately set, it is advisable to reduce the crop temperature as quickly as possible after harvest. Aim for a 0.5°C pull-down per day to holding temperature. Adequate ventilation is required during pull-down in order to remove surface moisture. Further details can be found in the Potato Council Store Managers' Guide.	Figure 6. Effect of early storage conditions on black dot development. *Source: Potato Council project R249* Figure 6 illustrates how disease levels can be held throughout storage by rapidly pulling down temperatures after store loading.

*pg – picograms or trillionth of a gram.

Chemical Control

↓

Agronomy

↓

Less Disease

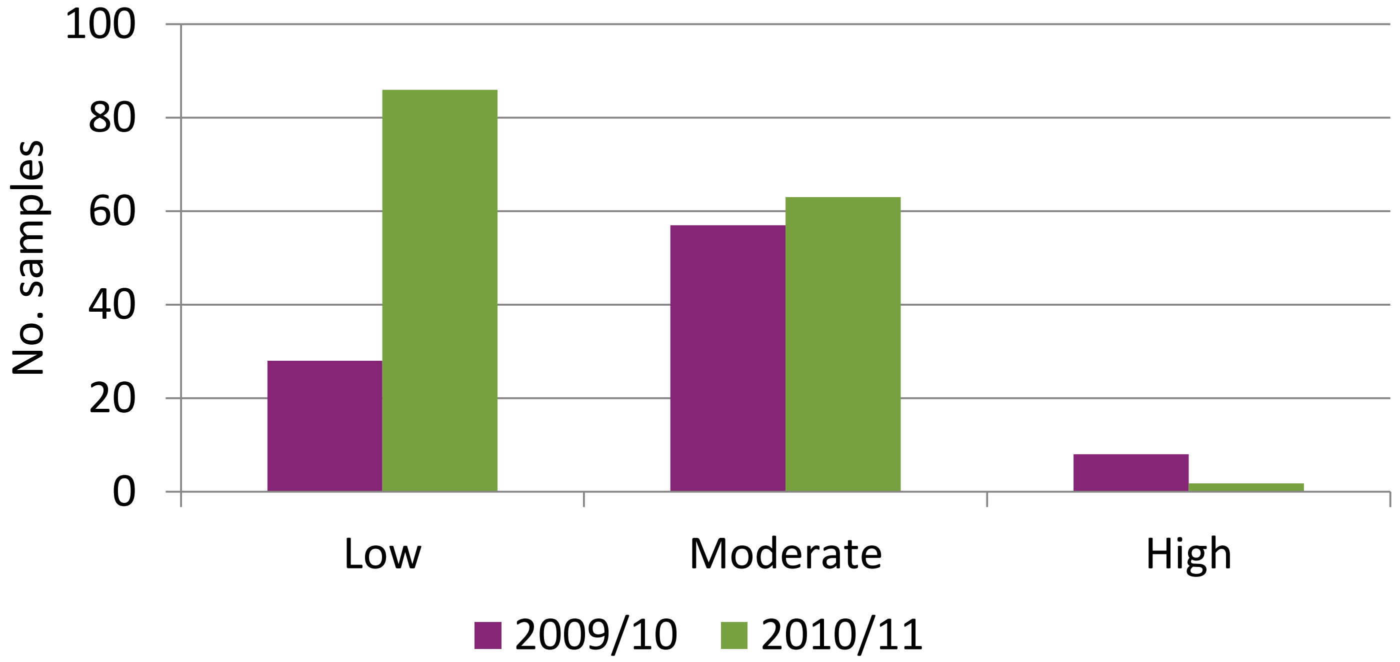
↓

Economic & Environmental benefits

Potential Benefits

- Knowledge of potential disease risk
- Facilitates decision making
  - Choice of field/crop/cultivar/rotations/control options
- Part of an integrated disease management programme
- Legislation for reduced pesticide use or evidence for need for application
- Research tool

Commercial soil diagnostic testing - powdery scab SRUC 2009/10 and 2010/11



- Trend towards 'low' risk samples
    - suggests increased awareness of growers

Barriers to uptake

- Lack of service provision
  - Research providers?
  - Commercial organisations?
  - In-house?
- Provision of testing service without advice
  - Requires advisory input
- Lack of understanding of potential benefits
  - Training
- Cost
  - cost:benefit may not be clear

Predicta Pt (SARDI)

- Assess risk based on soil tests
- Powdery scab, root knot nematode, black dot
- Training workshop – soil sampling and interpretation
- Advisor manual
- Advice for decision making

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