Final Report

Understanding the role of haulm destruction in the development of pit rot and gangrene during seed multiplication

Ref: R431

Reporting Period: 2010-2011

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Report 2012/4

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1. SUMMARY

Two trials were carried out in 2010 to investigate the effect of a range of haulm destruction programmes on development of pit rot and gangrene. Seed used in both trials was taken from stocks in which pit rot had developed during storage. One trial at Oldmeldrum, Aberdeenshire compared haulm destruction programmes on three varieties, Casablanca, Gemson and Desiree (the last of which also had gangrene infection). In this trial the seed was split into that exhibiting pit rot and that without pit rot. At the second trial at Potatoes in Practice at Dundee, the variety Cara was used but levels of pit rot on the seed was limited.

The objectives of the trials, besides evaluating the effectiveness of haulm destruction programmes, were to follow the development of disease including those caused by the blackleg organism (*Pectobacterium atrosepticum*) and gangrene or gangrene-like pathogens (e.g. *Phoma* spp.) and to examine links between haulm destruction and disease development, especially in the situation where haulm was green at the time haulm destruction treatments were applied..

At the Oldmeldrum trial, seed exhibiting pit rot symptoms emerged and developed slower than seed not exhibiting symptoms. Blackleg developed only in Desiree and was worse where seed exhibited pit rot symptoms. All the haulm destruction treatments resulted in rapid senescence but those involving haulm desiccants were slower that those starting with pulverisation. Skin set was similar with all haulm destruction programmes. Residues of diquat were detected in stolon-end tissue of daughter tubers from two diquat treatments across all three varieties at two sampling dates. This suggested that it had translocated from the vigorous haulm to the developing tubers. Pit rot and gangrene development occurred late in storage and both diseases were worse where diquat was used as the first haulm destruction treatment. The same pattern was evident across all three varieties.

When dead haulm of Desiree was assessed after harvest for colonisation by *Phoma foveata*, that from programmes starting with diquat had greater colonisation. This colonisation was strongly correlated to the level of gangrene that subsequently developed on Desiree tubers.

The trial at PIP gave similar results to that at Oldmeldrum in efficacy of haulm destruction treatments. The periderm thickness of daughter tubers from different haulm destruction programmes were measured in this trial after several months' storage. There was a significant reduction in periderm thickness where full dose diquat was used for haulm destruction compared to where pulverisation was the first treatment.

The trial at Oldmeldrum, in particular, confirmed that the risk of pit rot is limited where pulverisation is used for haulm destruction. There was evidence that diquat, when used under certain conditions as the first treatment in a haulm destruction programme increased the risk of pit rot in susceptible varieties. These conditions include haulm remaining green and vigorously growing at the time of haulm destruction, late mother tuber breakdown spreading *P. atrosepticum* to daughter tubers and a period of soil saturation before harvest resulting in colonisation of lenticels by *P. atrosepticum*. Where haulm is senescing naturally at the time of the first haulm destruction treatment there should be little risk of pit rot developing when diquat is applied as the first haulm

destruction treatment. Increased gangrene may have been the result of greater colonisation of haulm by the pathogen increasing the inoculum burden or an effect on periderm development of the daughter tubers resulting in greater wounding at harvest.

2. INTRODUCTION

In the growing seasons 2007, 2008, 2009 during each of which there was a prolonged wet period and the subsequent storage period there was concern about the increasing occurrence of soft rots, pit rot and gangrene or gangrene-like weak pathogens of tubers in seed crops. Whilst the soft rotting was ascribed to increased bacterial presence on tubers as a result of the wet summers, pit rot was occurring with increasing frequency in some stocks. Anecdotal evidence suggested that pit rot occurrence was linked with the use of diquat as the first haulm destruction treatment. The use of diquat had increased as growers moved away from sulphuric acid as the haulm desiccation option of preference.

There are two causes of the symptom called pit rot. Both are associated with lenticels. One is caused by a lack of CO_2 during storage causing a collapse of tissue at the lenticel and the other as a result of lenticel invasion by *Pectobacterium atrosepticum,* the blackleg organism. In the latter, once the bacteria reaches a threshold level in a lenticel, pectolytic enzymes break through the suberin barrier under the lenticel. The host reacts by producing a secondary wound barrier but the tissue of the lenticel collapses. Sometimes this second barrier is breached and soft rotting ensues. If the second barrier successfully prevents further bacterial development, bacterial numbers in the lesion may decline as a result of the collapse of tissue and a favourable environment for the bacteria to survive in.

The symptoms resulting from each cause are indistinguishable. Pit rot caused by anaerobic storage conditions were those originally associated with storage in pits – hence the name. Under modern storage conditions, symptoms from this cause almost never have *Pectobacterium atrosepticum* associated with them. In addition, anaerobic pit rot can potentially occur in any variety. One severe attack of pit rot found in a ware store in Scotland was in a spray-foam sealed store with a single close-fitting door. The CO_2 levels in this store were such that a gas burner could not be lit and breathing was difficult. Symptoms developed shortly after the elevated CO_2 levels were recognised.

Almost all of the pit rot seen in recent years has had *P. atrosepticum* associated with it. Crop Clinic samples at SAC have confirmed this by placing pit rot tissue onto pectate agar and recording pit development (a depression) in the agar within 24 hours, confirming the association with pectolytic bacteria. In addition, more extensive soft rot has occurred in stocks exhibiting pit rot, also supporting the involvement of *P. atrosepticum*. *P. atrosepticum* can create a pit rot symptom around a powdery scab or common scab lesion.

As a result of reduced generations, shorter growing seasons and particularly the use of 2-aminobutane fumigation, gangrene had declined substantially as a problem in seed potato production. However, in December 2007, the derogation on the use of 2-AB was revoked and the product could no longer be used. This may have provided an opportunity for resurgence of the pathogen (*Phoma foveata*) and similar weak wound pathogens (such as *P. exigua exigua*, *P eupyrena* and *Cylindrocarpon spp*.). These weak pathogens can cause lesions similar in appearance to pit rot initially but are not centred on lenticels and the lesions tend to be deeper than pit rot. Disturbingly, gangrene and gangrene-like weak pathogens were being recorded by some pre-basic growers in second generation stocks which were simply handled into boxes at harvest and not graded. Once again there was anecdotal information that suggested a move from sulphuric acid to diquat was implicated in the increase in disease.

Prior to beginning this project, SAC, using data from crop clinic samples and a phone survey recorded background information on around 30 stocks in which pit rot or gangrene occurred in 2009 produced seed stocks. This evaluation suggested that pit rot occurrence required the following for symptoms to occur

- A variety sensitive to pit rot (at least 12 varieties were reported to have pit rot)
- Crop not senescent at haulm destruction; that is still vigorously growing at the time of haulm destruction. Pre-basic stocks, particularly in years 1 & 2 are frequently showing vigorous growth
- Late mother tuber breakdown spreading *P. atrosepticum* to daughter tubers
- A period of soil saturation before harvest (presumably to spread bacteria)
- Colonisation of lenticels by *P. atrosepticum* (worse where lenticels are proliferated as a result of waterlogging)
- Diquat as the first application for haulm destruction (although a low dose diquat followed shortly by pulverisation did not appear to be such an issue with pit rot)

Generally symptoms were limited until after grading and warming up of tubers

This project reports on a large trial carried out in Aberdeenshire using seed from three stocks which exhibited pit rot and, in one, gangrene, to understanding the role of haulm destruction in the development of pit rot and gangrene during seed multiplication. The trial objectives were:

a) To follow the development of *Pectobacterium atrosepticum* and *Phoma* spp. after planting infected seed through to the end of storage
b) To evaluate the effect of haulm destruction method and condition of haulm at the time of haulm destruction on *P. atrosepticum* and *Phoma* spp. development
c) To establish if diquat or haulm pulverization affect incidence of diseases caused by *P. atrosepticum* and *Phoma* spp.
d) To compare effectiveness of different haulm destruction approaches

This report also includes the results of a parallel trial carried out at the Potatoes in Practice site at Balruddery in 2009. This trial was also funded by the Potato Council.

3. MATERIAL AND METHODS

Two trials were carried out in 2010, one at Oldmeldrum in Aberdeenshire (courtesy of Mr Patrick Sleigh, West Fingask) involving the varieties Cabaret, Gemson and Desiree and a second at Potatoes in Practice (PIP), Balruddery Farm, near Dundee involving the variety Cara. A stock of each variety exhibiting pit rot symptoms was selected for the trials. The stock of Desiree had a low level of gangrene infection also. The treatments applied at each trial site are show in tables 1 & 2.

Both trials were planted late to ensure crops remained green up to the time of haulm destruction. One treatment in each trial had extra nitrogen (40 kg/ha) applied after emergence to increase the vigour of haulm at the time of haulm destruction.

Table 1. Treatments applied at the Oldmeldrum trial to each of the varieties Cabaret, Desiree & Gemson. The trial was grown as a seed crop.

Treat. No.	**Seed tuber condition**	**Nitrogen level**	**Haulm destruction (product dose)**			
			1st timing 8 Sept.	2nd timing (+ 2 days) 10 Sept.	3rd timing (+ 5 days) 13 Sept.	4th timing (+ 8 days) 16 Sept.
1	Seed from affected stock without symptoms *	Normal	Pulverisation+	Carfentra-zone (1.0 l/ha)		
2	Seed from affected stock without symptoms *	Normal	Diquat (1.5 l/ha)		Diquat (2.5 l/ha)	
3	Seed from affected stock without symptoms *	Normal	Diquat (1.5 l/ha)	Pulverisation+		Diquat (2.5 l/ha)
4	Seed from affected stock without symptoms *	Normal + 40 kg/ha	Diquat (1.5 l/ha)		Diquat (2.5 l/ha)	
5	Seed from affected stock with symptoms	Normal	Pulverisation+	Carfentra-zone (1.0 l/ha)		
6	Seed from affected stock with symptoms	Normal	Diquat (1.5 l/ha)		Diquat (2.5 l/ha)	

* With the variety Gemson, the seed was severely affected with pit rot and it was not possible to pick out sufficient tubers without pit rot. In this variety the ‘Without symptoms’ category had tubers with a lower incidence of pit rot.

+ Pulverisation was carried out by 2 row Grimme machine leaving c. 20-25cm stems and placing chopped haulm in-furrow

TABLE 2. TREATMENTS APPLIED AT THE PIP TRIAL USING THE VARIETY CARA. THE CROP WAS GROWN AS A SEED CROP.

		Haulm destruction (product dose)		
Treat. No.	**Nitrogen**	1st timing 24 August	2nd timing (+3 days) 27 August	3rd timing (+ 6 days) 30 August
1	Normal	-	-	-
2	Normal	Pulverisation+	Carfentrazone (1.0 l/ha)	-
3	Normal	Pulverisation+	Diquat (2.5 l/ha)	-
4	Normal	Diquat (1.5 l/ha)	Pulverisation	Diquat (2.5 l/ha)
5	Normal	Diquat (1.5 l/ha)	-	Diquat (2.5 l/ha)
6	Normal	Diquat (1.5 l/ha)	-	Carfentrazone (1.0 l/ha)
7	Normal	Diquat (4.0 l/ha)	-	-
8	Extra N 40kg/ha	Diquat (1.5 l/ha)	-	Diquat (2.5 l/ha)

+ Pulverisation was carried out by 2 row Grimme machine leaving c. 20-25cm stems and placing chopped haulm in-furrow

Products applied in both trials (all as 200 l/ha solution)

Active ingredient	Product	Concentration	Formulation
Carfentrazone-ethyl	Spotlight Plus	60 g/litre	ME
Diquat	Reglone	200 g/l	SL

Agronomic details

Trial designs: Oldmeldrum – Split plot (Variety as main plot and treatments as sub-plots)
PIP – Randomised block

Replication: 4

Plot size: 6.25m x 4 drills

Soil analysis:

	Oldmeldrum	PIP
pH	6.0	6.1
P (mg/kg)	4.1 (Modified Morgan)	40 (Olsen)
K (mg/kg)	133	189
Mg (mg/kg)	172	276

Fertiliser: Fertiliser applications:
Oldmeldrum:
87.5: 87.5: 137.5 kg/ha N:P:K 20 pre-planting
Additional phosphate was applied pre-planting
PIP:
147:147:221 kg/ha N:P:K 20 April 2010
0:0:72 kg/ha N:P:K 20 April 2010

Irrigation: Irrigation was not applied at either trial as is normal practice for seed production. However, rainfall events were frequent from early July onwards (see Results)

Herbicide, Blight and aphid control: Applied as per standard practice to control weeds, blight and aphids

Planting dates: Oldmeldrum – 1-3 June 2010, PIP – 19 May 2010

Harvest dates: Oldmeldrum – 10-12 October 2010, PIP – 28 October 2010

Residue levels of diquat in tubers were assessed by sampling seed size tubers (35x55) at random at different times after the application of diquat in different treatments. Ten tubers per plot, taken from 5 plants were sampled and cores (c. 10mm diameter x 15mm length) taken from the heel end tissue. Within each treatment tested, the cores from each plot were aggregated and sent to Eclipse Scientific, Chatteris, Cambridgeshire for residue testing. The rationale for taking cores at the stolon end was that residues of haulm desiccants are greatest at that point and, with diquat, can cause a stolon end collapse at that point (see Figure 10.). Thus cores of stolon tissue were taken to optimise the chance of detecting residues.

Skin set was measured by sampling 40 tubers from the middle rows of each plot at random and placing in the SAC roller barrel before applying 20 rotations. The percentage of skin removal was assessed on each tuber and tubers assigned to one of 5 categories:

Category	Skin removal
0	0
1	1-25%
2	26-50%
3	51-75%
4	76-100%

A skin set index was calculated as follows:

Skin set index =

No. in category 1 x1 + No. in category 2 x 2 + No. in category 3 x 3 + No. in category 4 x 4
Total number of tubers

At the Oldmeldrum trial, lenticel proliferation was assessed on daughter tubers at different times from the first date haulm destruction treatments were applied onwards. Five progeny tubers per plot were sampled from separate plants on guard rows of treatments 2 & 6. Tubers were taken from same depth as the mother tuber and in the middle of the drill. Visual assessment of % lenticel proliferation in each of 3 categories was made on each tuber: 0 = No proliferation, 1 = Partial proliferation (lenticels showing white but not raised above tuber surface), 2 = Full proliferation (most lentcels white any many raised above tuber surface).

4. RESULTS

4.1. Weather pattern at each trial site

At Oldmeldrum the trial was planted late (early June) to ensure green vigorous haulm at the time of haulm destruction. The weather was warm and dry at planting and emergence was rapid. Significant rainfall fell in mid-July but this had little impact on soil moisture deficit (Figure 1.). Rainfall events continued to occur at frequent intervals and the soil moisture deficit slowly declined but it fell particularly after heavy rain at the end of September which followed completion of haulm destruction treatments. The soil was almost at saturation at this stage.

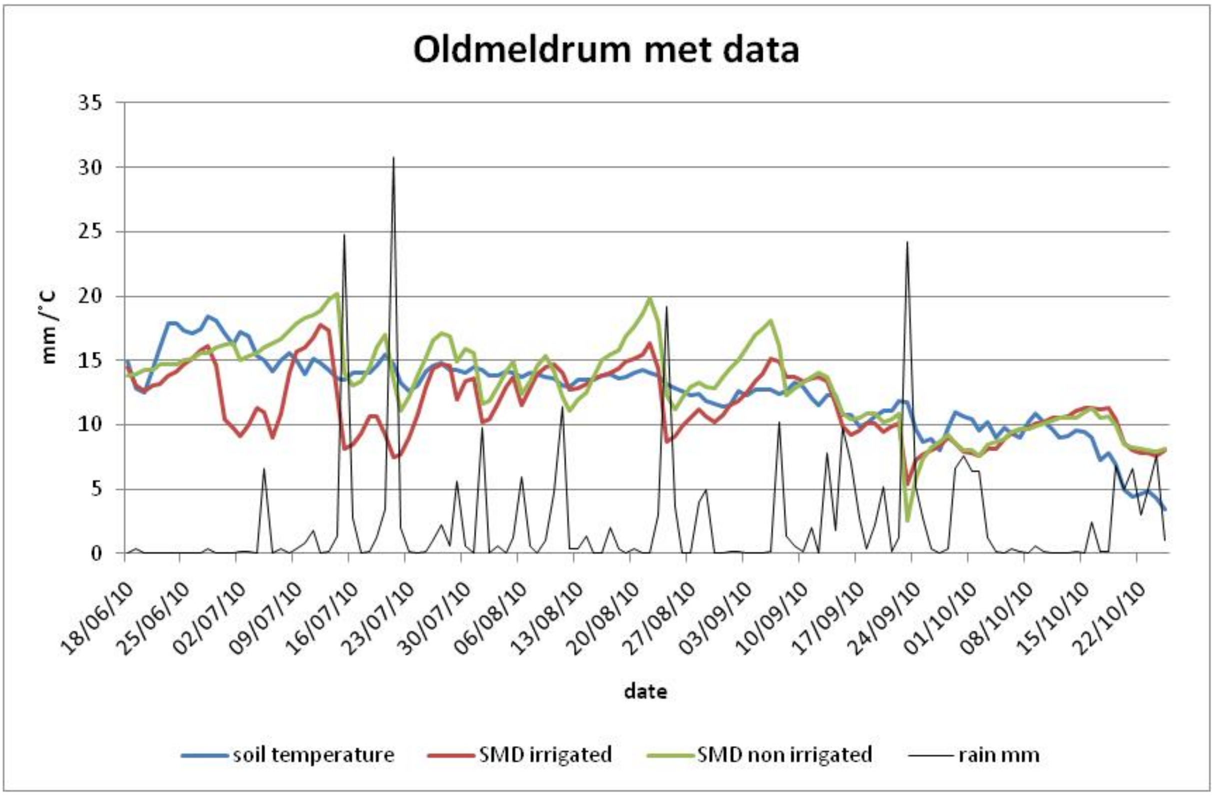
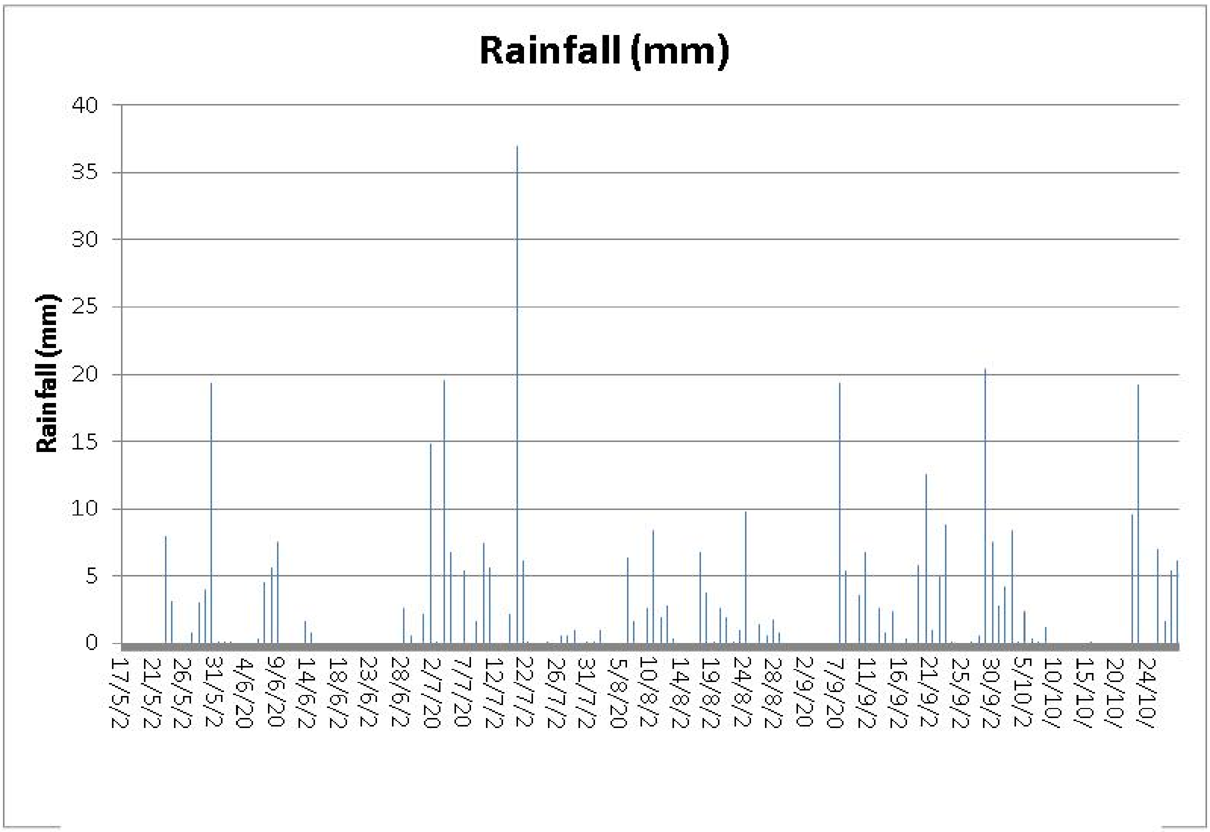


FIGURE 1. WEATHER DATA AT THE OLDMELDRUM SITE 2010

At PIP the trial was planted earlier (mid-May), although the indeterminate and vigorous variety Cara was used and green haulm was prolonged as a result. The weather pattern was similar to that at Oldmeldrum with a warm dry period after planting until mid-July (Figure 2.). The air temperature at PIP was higher than at Oldmeldrum and the period of near saturation in September not as evident.



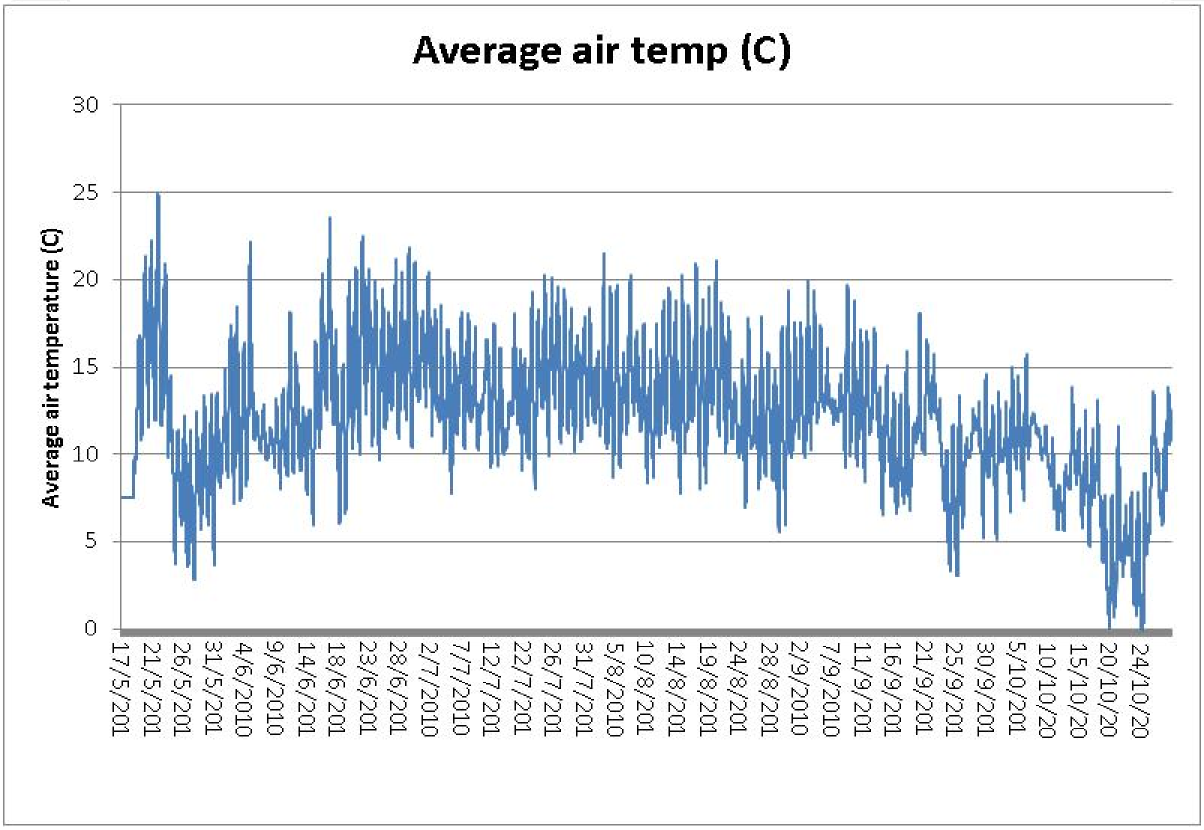


FIGURE 2. WEATHER DATA AT PIP 2010

4.2. Trial results – Oldmeldrum

When seed tubers for the trial were drawn from the original stocks pit rot (as well as gangrene in the case of Desiree) was evident in all three varieties. Pit rot was most extreme in Gemson and least in Cabaret (Table 3.). It proved possible to select tubers of Desiree and Cabaret virtually free of pit rot, but this was not possible for Gemson.

TABLE 3. DISEASE ASSESSMENTS ON SEED PRIOR TO PLANTING AT OLDMELDRUM

	Stock	Cabaret		Desiree		Gemson	
		No symptoms	Symptoms	No symptoms	Symptoms	No symptoms	Symptoms
C scab	Incid. (%)	6	6	6	6	36	36
	Sev. (%)	tr	tr	0.2	0.2	1.5	1.5
P scab	Incid. (%)	14	14	4	4	34	34
	Sev. (%)	0.6	0.6	0.1	0.1	2.3	2.3
S. scurf	Incid. (%)	94	94	100	100	88	88
	Sev. (%)	18.9	18.9	28	28	16.5	16.5
B dot	Incid. (%)	92	92	46	46	0	0
	Sev. (%)	9.4	9.4	3	3	0	0
Gangrene	Incid. (%)	0	0	0	5	0	0
Pit rot	Incid. (%)	0	40	0	35	12	76

Three pits on six tubers of each stock exhibiting pit rot were tested for the presence of pectolytic bacteria by plating a small piece of sub-surface pit tissue after surface sterilisation onto CVP agar. Where pectolytic bacteria were present a pit formed in the agar within two days. Pectolytic bacteria were confirmed as present in 7/18 pits (39%), 10/18 pits (56%) and 8/18 pits (44%) on Cabaret, Desiree and Gemson respectively. It was assumed that the pectolytic bacteria was *Pectobacterium atrosepticum*.

The seed with pit rot emerged later and developed ground cover slower than seed pit rot free (Figure 3. and Table 4.). The effect was least with Gemson where selection of pit rot free tubers was less successful.

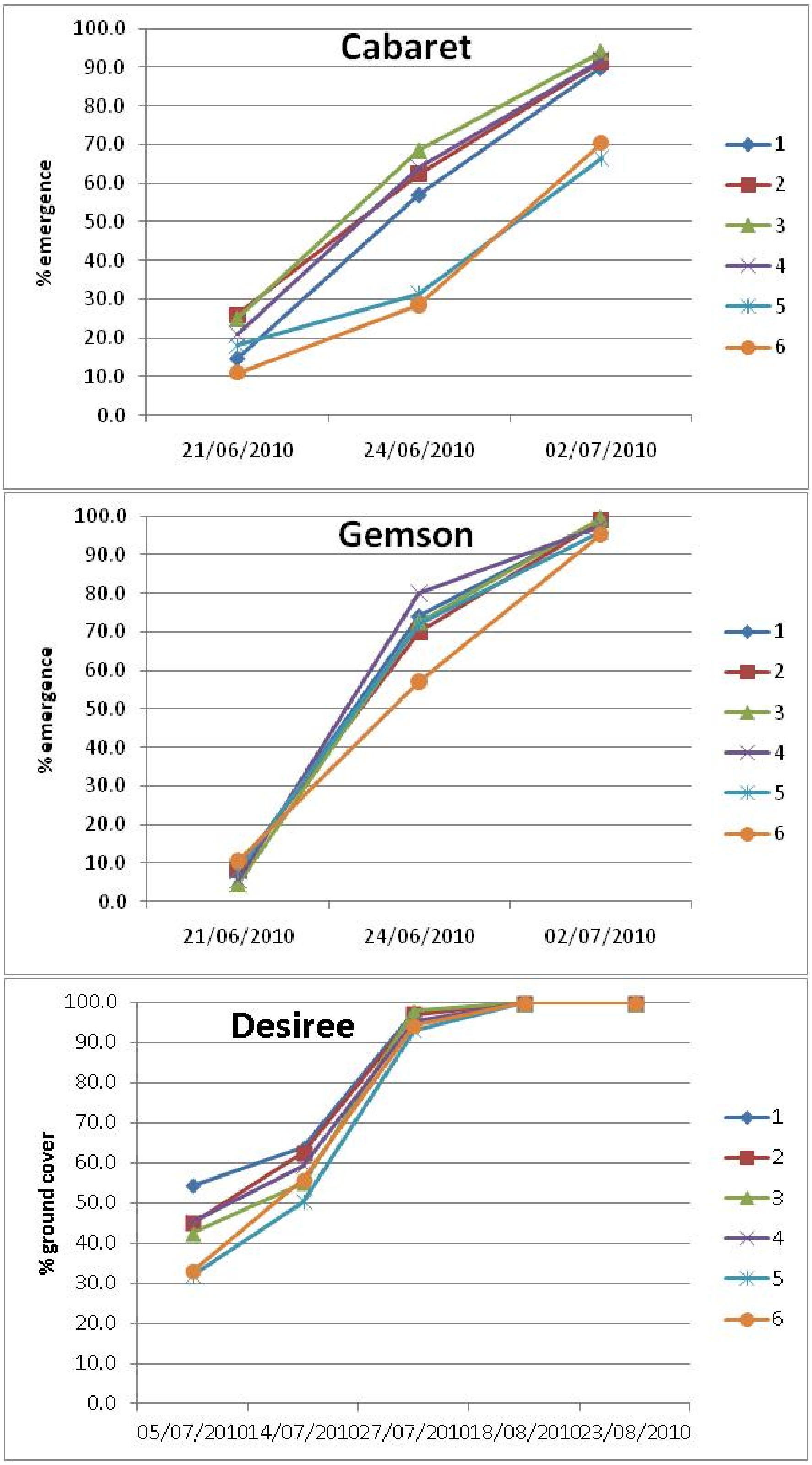


FIGURE 3. EMERGENCE OVER TIME OF THREE VARIETIES. TREATMENTS 5 AND 6 WERE PLANTED WITH SEED EXHIBITING PIT ROT SYMPTOMS

There was an associated delay in achieving 100% ground cover where pit rot symptoms were present on seed (Figure 4. and Table 5.)

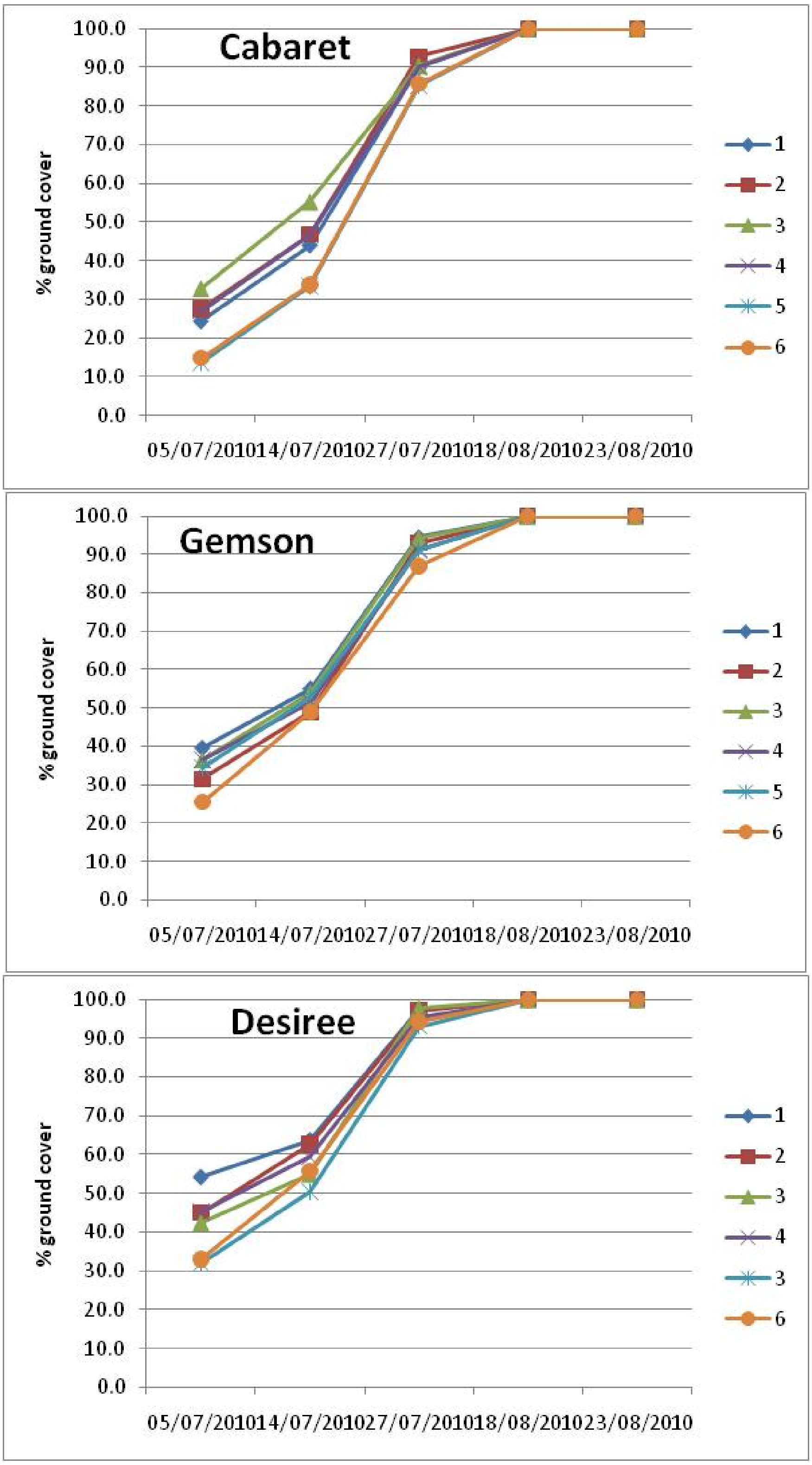


FIGURE 4. GROUND COVER OVER TIME OF THREE VARIETIES. TREATMENTS 5 AND 6 WERE PLANTED WITH SEED EXHIBITING PIT ROT SYMPTOMS

Blackleg occurred at low levels (<0.5% plants) with Cabaret and Gemson (both rated 8 for resistance to blackleg) even where seed with pit rot was planted (Table 6). Blackleg was most evident in the variety Desiree reaching 8% incidence. Seed exhibiting pit rot developed the most blackleg.

TABLE 4. EMERGENCE ASSESSMENTS IN THE TRIAL AT OLDMELDRUM

		21/06/2010	24/06/2010	02/07/2010
Rating Date		21/06/2010	24/06/2010	02/07/2010
Rating Type		Emergence	Emergence	Emergence
Rating Unit		%	%	%
TABLE OF Variety Means				
A	Cabaret	19.3	52.0	84.1
B	Gemson	7.4	70.9	97.8
C	Desiree	39.8	84.4	92.8
TABLE OF Treatment Means				
1	Without symptoms, N, Pulv., Spotlight T2	21.8	74.7	94.8
2	Without symptoms, N,Diquat T1, Diquat T3	27.3	73.5	95.8
3	Without symptoms, N, Diquat T1, Pulv T2, Diquat T4	22.2	75.7	97.2
4	Without symptoms, N+40/ha, Diquat T1, Diquat T3	24.2	78.7	94.8
5	With symptoms, N, Pulv. T1, Spotlight T2	16.7	58.2	82.3
6	With symptoms, N, Diquat T1, Diquat T3	20.8	54.0	84.2
TABLE OF Variety x Treatment Means				
A1	Cabaret	14.5	57.0	90.0
A2	Cabaret	26.0	62.5	91.5
A3	Cabaret	25.0	68.5	94.0
A4	Cabaret	21.0	64.0	92.0
A5	Cabaret	18.0	31.5	66.5
A6	Cabaret	11.0	28.5	70.5
B1	Gemson	7.5	74.0	99.0
B2	Gemson	8.5	70.0	99.0
B3	Gemson	4.5	72.5	99.5
B4	Gemson	5.5	80.0	97.5
B5	Gemson	8.0	72.0	96.0
B6	Gemson	10.5	57.0	95.5
C1	Desiree	43.5	93.0	95.5
C2	Desiree	47.5	88.0	97.0
C3	Desiree	37.0	86.0	98.0
C4	Desiree	46.0	92.0	95.0
C5	Desiree	24.0	71.0	84.5
C6	Desiree	41.0	76.5	86.5
	Variety means LSD & significance	7.1 ***	4.7 ***	2.1 ***
	Treatment means LSD & significance	9.2 ns	6.6 ***	3.3 ***
	Variety x treatment means LSD & significance	16.0 ns	11.4 ***	5.1 ***

TABLE 5. GROUND COVER ASSESSMENTS IN THE TRIAL AT OLDMELDRUM

		05/07/2010	14/07/2010	27/07/2010	18/08/2010	23/08/2010
Rating Date		05/07/2010	14/07/2010	27/07/2010	18/08/2010	23/08/2010
Rating Type		Ground cover	Ground cover	Ground cover	Ground cover	Ground cover
Rating Unit		%	%	%	%	%
TABLE OF Variety Means						
A	Cabaret	23.3	43.3	89.0	100.0	100.0
B	Gemson	34.0	51.9	91.8	100.0	100.0
C	Desiree	42.0	57.8	95.8	100.0	100.0
TABLE OF Treatment Means						
1	Without symptoms, N, Pulv., Spotlight T2	39.3	54.3	94.0	100.0	100.0
2	Without symptoms, N,Diquat T1, Diquat T3	34.7	52.8	94.3	100.0	100.0
3	Without symptoms, N, Diquat T1, Pulv T2, Diquat T4	37.3	54.8	94.2	100.0	100.0
4	Without symptoms, N+40/ha, Diquat T1, Diquat T3	36.3	52.4	92.1	100.0	100.0
5	With symptoms, N, Pulv. T1, Spotlight T2	26.6	45.5	89.8	100.0	100.0
6	With symptoms, N, Diquat T1, Diquat T3	24.4	46.2	89.0	100.0	100.0
TABLE OF Variety x Treatment Means						
A1	Cabaret	24.3	44.0	90.0	100.0	100.0
A2	Cabaret	27.5	46.8	92.8	100.0	100.0
A3	Cabaret	32.8	55.3	90.5	100.0	100.0
A4	Cabaret	27.0	46.5	90.0	100.0	100.0
A5	Cabaret	13.5	33.5	85.3	100.0	100.0
A6	Cabaret	14.8	33.8	85.8	100.0	100.0
B1	Gemson	39.5	55.0	94.5	100.0	100.0
B2	Gemson	31.5	49.0	93.0	100.0	100.0
B3	Gemson	36.5	54.0	94.3	100.0	100.0
B4	Gemson	36.5	51.5	91.0	100.0	100.0
B5	Gemson	34.3	52.8	91.3	100.0	100.0
B6	Gemson	25.5	49.0	87.0	100.0	100.0
C1	Desiree	54.3	63.8	97.5	100.0	100.0
C2	Desiree	45.0	62.5	97.0	100.0	100.0
C3	Desiree	42.5	55.0	97.8	100.0	100.0
C4	Desiree	45.3	59.3	95.3	100.0	100.0
C5	Desiree	32.0	50.3	93.0	100.0	100.0
C6	Desiree	33.0	55.8	94.3	100.0	100.0
	Variety means LSD & significance	8.1 **	4.7 ***	3.7 *	-	-
	Treatment means LSD & significance	5.8 ***	4.6 ***	2.7 ***	-	-
	Variety x treatment means LSD & significance	10.1 ns	8.0 **	4.7 ns	-	-

TABLE 6. DEVELOPMENT OF BLACKLEG IN THE TRIAL AT OLDMELDRUM

Pest Scientific Name		Blackleg (*Pectobacterium atrosepticum*)					
Rating Date		14/07/2010	19/07/2010	27/07/2010	06/08/2010	18/08/2010	23/08/2010
Rating Type		NO./50	NO./50	NO./50	NO./50	NO./50	NO./50
TABLE OF Variety Means							
A	Cabaret	0.1	0.2	0.3	0.3	0.3	0.5
B	Gemson	0.0	0.1	0.1	0.1	0.2	0.2
C	Desiree	0.3	0.6	1.3	1.7	1.8	2.0
TABLE OF Treatment Means							
1	Without symptoms, N, Pulv., Spotlight T2	0.3	0.4	0.6	0.8	1.0	1.2
2	Without symptoms, N,Diquat T1, Diquat T3	0.1	0.2	0.3	0.4	0.4	0.6
3	Without symptoms, N, Diquat T1, Pulv T2, Diquat T4	0.1	0.2	0.3	0.3	0.3	0.5
4	Without symptoms, N+40/ha, Diquat T1, Diquat T3	0.1	0.1	0.2	0.2	0.2	0.3
5	With symptoms, N, Pulv. T1, Spotlight T2	0.2	0.5	1.0	1.2	1.3	1.4
6	With symptoms, N, Diquat T1, Diquat T3	0.2	0.4	1.1	1.3	1.3	1.3
TABLE OF Variety x Treatment Means							
A1	Cabaret	0.3	0.3	0.3	0.3	0.5	0.8
A2	Cabaret	0.3	0.5	0.8	0.8	0.8	0.8
A3	Cabaret	0.0	0.0	0.0	0.0	0.0	0.5
A4	Cabaret	0.0	0.0	0.0	0.0	0.0	0.3
A5	Cabaret	0.0	0.3	0.5	0.5	0.5	0.5
A6	Cabaret	0.0	0.0	0.0	0.0	0.0	0.0
B1	Gemson	0.3	0.3	0.3	0.3	0.5	0.5
B2	Gemson	0.0	0.0	0.0	0.0	0.0	0.0
B3	Gemson	0.0	0.3	0.3	0.3	0.3	0.3
B4	Gemson	0.0	0.0	0.0	0.0	0.0	0.0
B5	Gemson	0.0	0.3	0.3	0.3	0.3	0.3
B6	Gemson	0.0	0.0	0.0	0.0	0.0	0.0
C1	Desiree	0.5	0.8	1.3	2.0	2.0	2.3
C2	Desiree	0.0	0.0	0.3	0.5	0.5	1.0
C3	Desiree	0.3	0.3	0.5	0.8	0.8	0.8
C4	Desiree	0.3	0.3	0.5	0.5	0.5	0.8
C5	Desiree	0.5	1.0	2.3	2.8	3.0	3.5
C6	Desiree	0.5	1.3	3.3	3.8	4.0	4.0
	Variety means LSD & significance	0.3 ns	0.5 ns	0.7 **	0.6 **	0.6 ***	0.8 **
	Treatment means LSD & significance	0.3 ns	0.4 ns	0.7 *	0.8 *	0.9 *	1.0 ns
	Variety x treatment means LSD & significance	0.5 ns	0.7 ns	1.2 **	1.4 **	1.5 **	1.7 *

At the time the first haulm destruction treatments were applied, some senescence was evident in all three varieties (Figure 5. & Table 7.). Pulverisation resulted in rapid senescence (treatments 1, 3 & 5). There was little difference between haulm desiccation only treatments, even where extra nitrogen was applied and these were slower to reach full senescence than treatments involving haulm pulverisation.

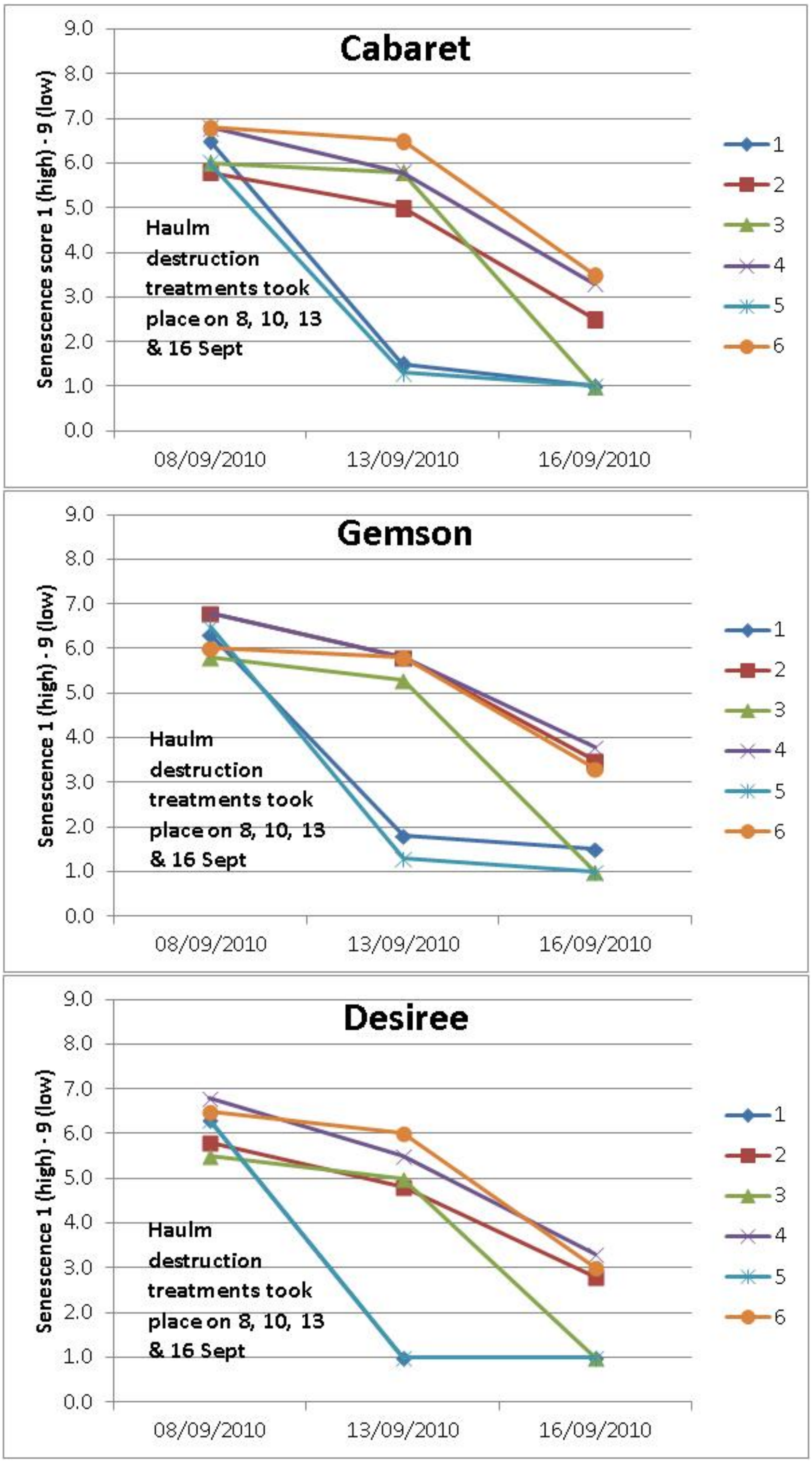


FIGURE 5. CHANGES IN SENESCENCE OVER TIME IN THREE VARIETIES WITH SIX DIFFERING HAULM DESTRUCTION TREATMENTS

Despite differences in haulm senescence between treatments, there were no significant differences in tuber skin set between different haulm destruction treatments at two dates of assessment using the SAC damage barrel for testing (Figure 6. & Table 8.)

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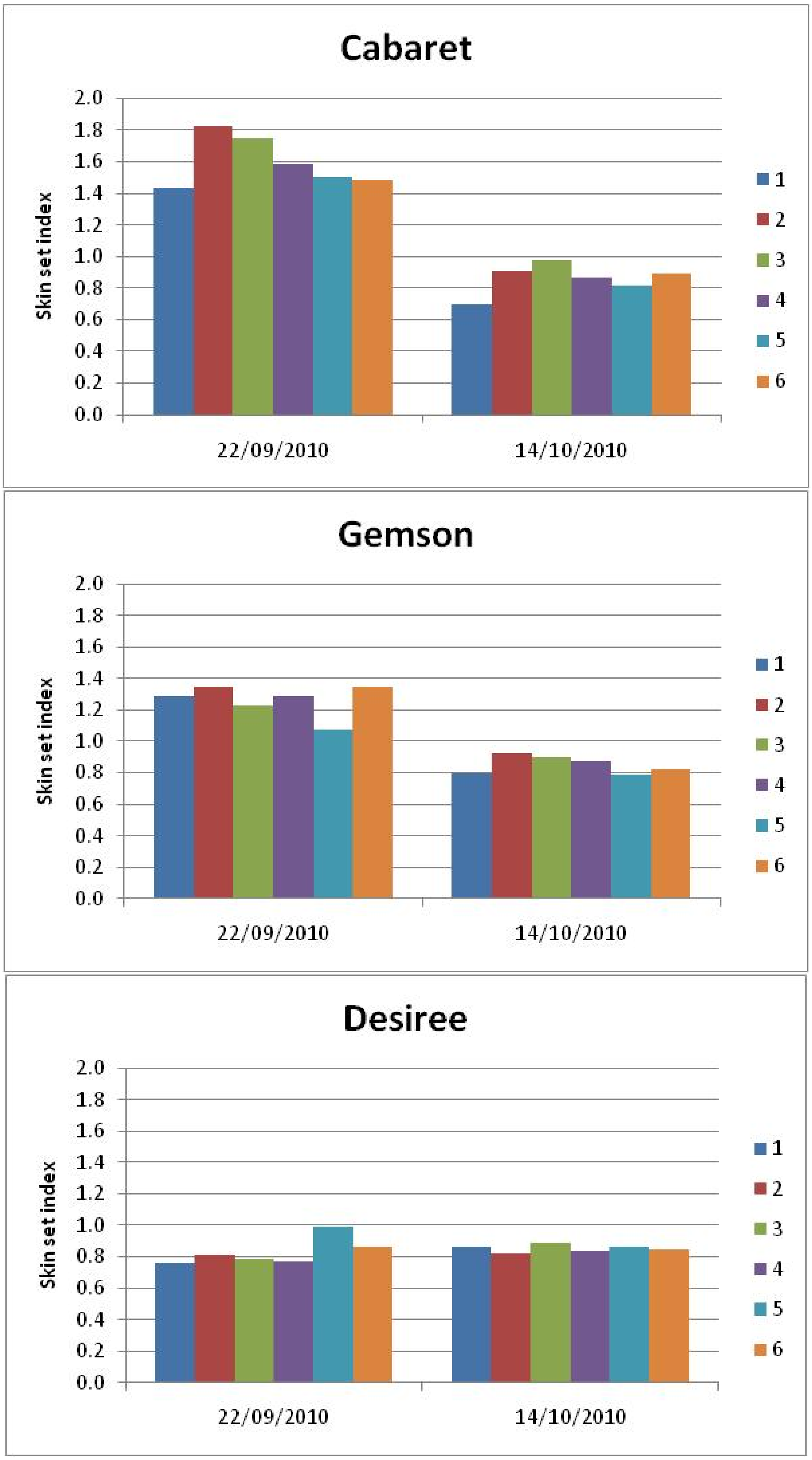

FIGURE 6. SKIN SET INDEX AT TWO DATES OF ASSESSMENT 14 & 36 DAYS AFTER T1 HAULM DESTRUCTION TREATMENTS IN THREE VARIETIES. MAXIMUM INDEX IS 4.

TABLE 7. HAULM SENESCENCE AT AND AFTER HAULM DESTRUCTION TREATMENTS WERE APPLIED AT THE OLDMELDRUM TRIAL

Rating Date			08/09/2010	13/09/2010	16/09/2010
Rating Type			Haulm senescence	Haulm senescence	Haulm senescence
Rating Unit			1-9	1-9	1-9
TABLE OF A MEANS					
	A	Cabaret	6.3	4.3	2.0
	B	Gemson	6.3	4.3	2.3
	C	Desiree	6.2	3.9	2.0
TABLE OF Treatment Means					
	1	Without symptoms, N, Pulv., Spotlight T2	6.3	1.4	1.2
	2	Without symptoms, N,Diquat T1, Diquat T3	6.1	5.2	2.9
	3	Without symptoms, N, Diquat T1, Pulv T2, Diquat T4	5.8	5.3	1.0
	4	Without symptoms, N+40/ha, Diquat T1, Diquat T3	6.8	5.7	3.4
	5	With symptoms, N, Pulv. T1, Spotlight T2	6.3	1.2	1.0
	6	With symptoms, N, Diquat T1, Diquat T3	6.4	6.1	3.3
TABLE OF Variety x Treatment Means					
	A1	Cabaret	6.5	1.5	1.0
	A2	Cabaret	5.8	5.0	2.5
	A3	Cabaret	6.8	5.8	3.3
	A4	Cabaret	6.0	5.8	1.0
	A5	Cabaret	6.0	1.3	1.0
	A6	Cabaret	6.8	6.5	3.5
	B1	Gemson	6.3	1.8	1.5
	B2	Gemson	6.8	5.8	3.5
	B3	Gemson	5.8	5.3	1.0
	B4	Gemson	6.8	5.8	3.8
	B5	Gemson	6.5	1.3	1.0
	B6	Gemson	6.0	5.8	3.3
	C1	Desiree	6.3	1.0	1.0
	C2	Desiree	5.8	4.8	2.8
	C3	Desiree	5.5	5.0	1.0
	C4	Desiree	6.8	5.5	3.3
	C5	Desiree	6.3	1.0	1.0
	C6	Desiree	6.5	6.0	3.0
		Variety means LSD & significance	0.5 ns	0.4 ns	0.4 ns
		Treatment means LSD & significance	0.4 **	0.5 ***	0.4 ***
		Variety x treatment means LSD & significance	0.8 ns	0.8 ns	0.7 ns

Table 8. Assessments of skin set after haulm destruction treatments were applied at the Oldmeldrum trial

Rating Date		22/09/2010	22/09/2010	14/10/2010	14/10/2010
Rating Type		Skin set	Skin set	Skin set	Skin set
Rating Unit		Index	% incidence	Index	% incidence
TABLE OF Variety Means					
A	Cabaret	1.598	95.4	0.858	85.8
B	Gemson	1.263	89.8	0.852	85.2
C	Desiree	0.831	67.7	0.854	85.4
TABLE OF Treatment Means					
1	Without symptoms, N, Pulv., Spotlight T2	1.163	82.1	0.788	78.8
2	Without symptoms, N,Diquat T1, Diquat T3	1.329	86.7	0.887	88.8
3	Without symptoms, N, Diquat T1, Pulv T2, Diquat T4	1.254	83.8	0.921	92.1
4	Without symptoms, N+40/ha, Diquat T1, Diquat T3	1.217	84.6	0.858	85.8
5	With symptoms, N, Pulv. T1, Spotlight T2	1.188	83.3	0.821	82.1
6	With symptoms, N, Diquat T1, Diquat T3	1.233	85.4	0.854	85.4
TABLE OF Variety x Treatment Means					
A1	Cabaret	1.438	87.5	0.700	70.0
A2	Cabaret	1.825	97.5	0.913	91.3
A3	Cabaret	1.588	97.5	0.863	86.3
A4	Cabaret	1.750	96.3	0.975	97.5
A5	Cabaret	1.500	96.3	0.813	81.3
A6	Cabaret	1.488	97.5	0.888	88.8
B1	Gemson	1.288	90.0	0.800	80.0
B2	Gemson	1.350	95.0	0.925	92.5
B3	Gemson	1.225	90.0	0.900	90.0
B4	Gemson	1.288	93.8	0.875	87.5
B5	Gemson	1.075	76.3	0.788	78.8
B6	Gemson	1.350	93.8	0.825	82.5
C1	Desiree	0.763	68.8	0.863	86.3
C2	Desiree	0.813	67.5	0.825	82.5
C3	Desiree	0.788	65.0	0.888	88.8
C4	Desiree	0.775	62.5	0.838	83.8
C5	Desiree	0.988	77.5	0.863	86.3
C6	Desiree	0.863	65.0	0.850	85.0
	Variety means LSD & significance	0.361 **	14.4 **	0.101 ns	10.1 ns
	Treatment means LSD & significance	0.242 ns	9.0 ns	0.098 ns	9.8 ns
	Variety x treatment means LSD & significance	0.419 ns	15.6 ns	0.169 ns	16.9 ns

% incidence = % tubers exhibiting scuffing, Index = 0-4

Lenticel proliferation was measured on the same diquat haulm destruction programme applied to seed planted with and without pit rot symptoms (Table 9.) There was little proliferation across the three varieties and differences were not clear. However, Desiree showed the greatest level of proliferation in two of three assessments and there was a suggestion that proliferation was greater with seed showing pit rot symptoms.

Residues of diquat were detected in stolon-end tissue of daughter tubers from two diquat treatments across all three varieties at two sampling dates, 5 and 12 days after diquat was first applied (Table 10.). The residue levels were less than the MRL for diquat in potato tubers but the presence of residues was relatively consistent.

Pit development was limited when the first assessment was made in December, 3 months after harvest. However, at the end of March, six months after harvest and following grading and storage in ambient conditions, pit rot had developed substantially in all three varieties (Table 11.). There were significant differences between varieties, between treatments and between treatments within varieties (severity only). These are shown graphically in Figure 7. Where pulverisation was the first treatment of haulm destruction there was a significant reduction in pit rot incidence and severity when measured across all three varieties and for severity within varieties. Similarly, gangrene incidence on tubers was significantly greater on haulm destruction treatments where diquat was the first element of the programme, when taken across all three varieties (Table 11.).

When Desiree haulm was assessed for colonisation by *Phoma foveata*, there were marked differences between treatments, although the differences were not significant in most comparisons. The haulm destruction programmes that had the least colonisation were those that began with pulverisation (treatments 1 & 5) (Figure 8.).

TABLE 9. LENTICEL PROLIFERATION AT THREE DATES FROM HAULM DESTRUCTION ONWARDS AT THE OLDMELDRUM TRIAL

		8 September			22 September			12 October		
Variety	**Treat.**	**0**	**1**	**2**	**0**	**1**	**2**	**0**	**1**	**2**
Cabaret	2	95.8	0.0	4.3	99.6	0.1	0.4	97.2	0.0	2.9
Cabaret	6	97.0	0.0	3.1	99.9	0.1	0.1	97.6	0.0	2.5
Gemson	2	91.8	0.5	7.7	99.7	0.0	0.3	91.2	0.0	8.9
Gemson	6	93.0	0.0	7.1	99.4	0.1	0.6	83.0	0.0	17.0
Desiree	2	81.8	0.0	18.2	99.3	0.1	0.7	92.3	0.0	7.7
Desiree	6	82.0	0.5	17.5	99.1	0.1	0.9	75.4	0.0	24.7

0=no proliferation; 1=partial proliferation; 2=full proliferation

TABLE 10. RESIDUES (MG/KG) OF DIQUAT DETECTED IN STOLON END CORE TISSUE OF DAUGHTER TUBERS SAMPLED AT DIFFERENT TIMES AFTER THE FIRST DIQUAT HAULM DESTRUCTION APPLICATION (T1) IN TWO HAULM DESTRUCTION PROGRAMMES. ND = NONE DETECTED. MRL FOR DIQUAT IS 0.05 MG/KG.

	Cabaret		Gemson		Desiree		Days after first diquat application
Date	**Treat 2**	**Treat 4**	**Treat 2**	**Treat 4**	**Treat 2**	**Treat 4**	
13/09/2010	0.02	nd	0.02	0.01	0.03	0.02	5
20/09/2010	Nd	0.01	0.03	0.02	0.02	Nd	12
Average	0.01	0.005	0.025	0.015	0.025	0.01	

TABLE 11. PIT ROT AND GANGRENE DEVELOPMENT ON HARVESTED TUBERS AT THE OLDMELDRUM TRIAL SITE

Pest Name		Pit rot				Gangrene
Rating Date		14/12/2010	14/12/2010	18/03/2011	18/03/2011	18/03/2011
Rating Unit		Mean pits/tuber	% Incidence	% Severity	% Incidence	% Incidence
TABLE OF A MEANS						
1	Cabaret	0.53	19.5	0.28	16.7	2.3
2	Gemson	2.21	39.2	1.25	37.3	4.9
3	Desiree	0.41	19.8	0.18	10.1	3.6
TABLE OF B MEANS						
1	Without symptoms, normal, Pulv, Spotlight T2	0.93	24.0	0.13	11.8	0.3
2	Without symptoms, normal,Reglone T1, Reglone T3	1.70	32.3	0.83	26.2	6.3
3	Without symptoms, normal, Reglone T1, Pulv T2, Reglone T4	1.31	31.7	0.64	24.3	3.2
4	Without symptoms, normal+40 kgN/ha, Reglone T1, Reglone T3	0.92	22.7	0.60	24.3	4.7
5	With symptoms, normal, Pulv T1, Spotlight T2	0.58	20.7	0.14	12.0	0.5
6	With symptoms, normal, Reglone T1, Reglone T3	0.86	25.7	1.08	29.5	6.7
TABLE OF AB MEANS						
1	Cabaret	0.42	16.0	0.07	9.0	1.0
1	Cabaret	0.92	20.0	0.53	21.5	7.0
1	Cabaret	0.62	21.0	0.37	18.5	1.5
1	Cabaret	0.30	12.0	0.21	12.5	3.0
1	Cabaret	0.40	27.0	0.15	16.0	0.0
1	Cabaret	0.53	21.0	0.37	22.5	1.5
2	Gemson	1.96	36.0	0.26	21.5	0.0
2	Gemson	3.72	58.0	1.75	45.5	8.5
2	Gemson	2.79	51.0	1.36	43.5	4.0
2	Gemson	2.19	40.0	1.42	50.0	6.5
2	Gemson	1.06	20.0	0.25	17.5	1.5
2	Gemson	1.53	30.0	2.46	46.0	9.0
3	Desiree	0.40	20.0	0.06	5.0	0.0
3	Desiree	0.46	19.0	0.22	11.5	3.5
3	Desiree	0.51	23.0	0.19	11.0	4.0
3	Desiree	0.27	16.0	0.16	10.5	4.5
3	Desiree	0.29	15.0	0.02	2.5	0.0
3	Desiree	0.51	26.0	0.41	20.0	9.5
	Variety means LSD & significance	1.04 **	16.3 *	0.25 ***	7.7 ***	3.8 ns
	Treatment means LSD & significance	0.88 ns	12.6 ns	0.33 ***	10.3 **	2.6 ***
	Variety x treatment means LSD & significance	1.53 ns	21.8 ns	0.58 ***	17.9 ns	4.4 ns

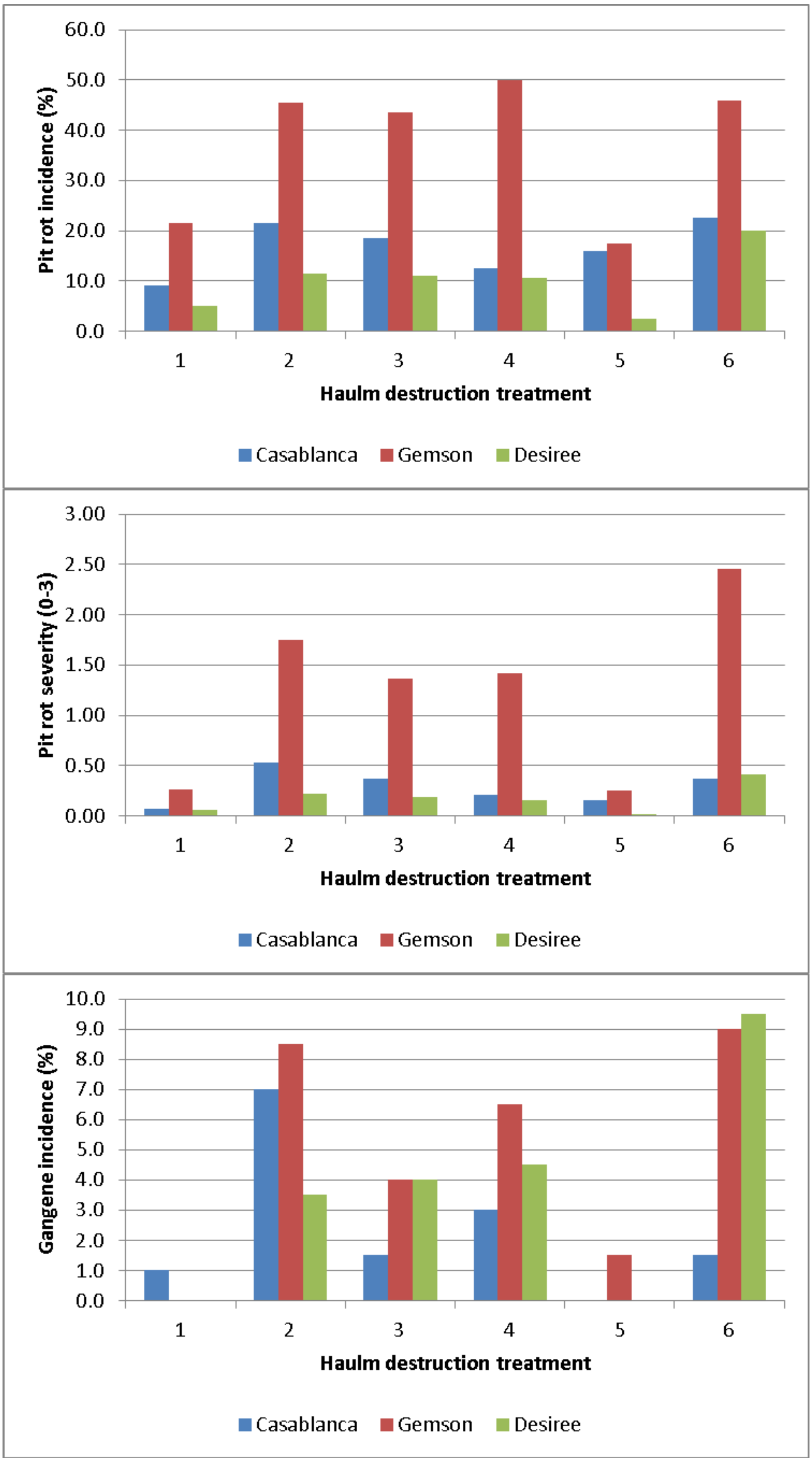

FIGURE 7. PIT ROT INCIDENCE AND SEVERITY AND INCIDENCE OF GANGRENE IN DAUGHTER TUBERS OF THREE VARIETIES AFTER SIX MONTHS STORAGE

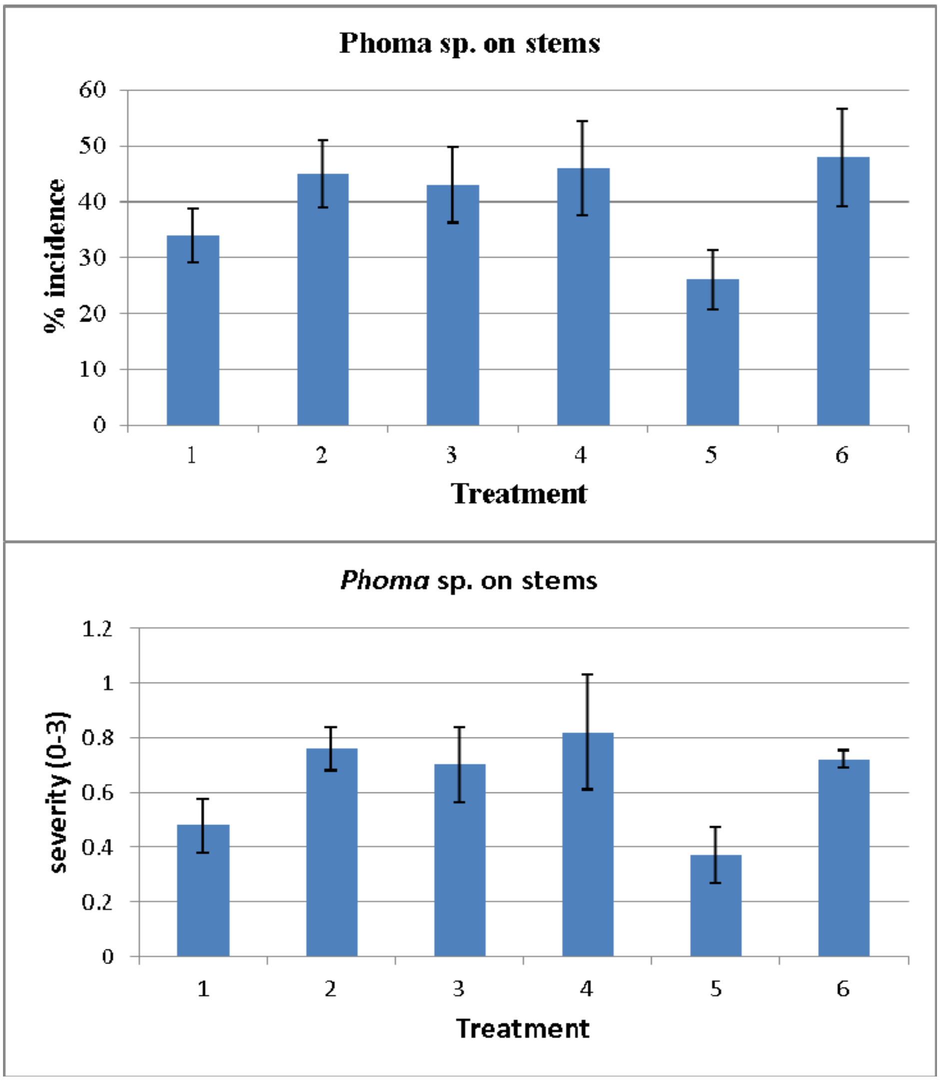

FIGURE 8. INCIDENCE AND SEVERITY (0-3 SCORE) FOR COLONISATION OF STEM BASES OF DESIREE BY *PHOMA FOVEATA*. BARS INDICATE SE'S.

4.3. Trial results from PIP

The seed used for the trial at PIP exhibited very little pit rot (Table 12.). The seed was planted as sampled from the stock.

TABLE 12. DISEASE ASSESSMENT ON SEED PRIOR TO PLANTING

		Cara
Common scab	Incidence (%)	2
	Severity (%)	tr
Powdery scab	Incidence (%)	86
	Severity (%)	4.6
Silver scurf	Incidence (%)	54
	Severity (%)	8.1
Black scurf	Incidence (%)	74
	Severity (%)	2.5
Gangrene	Incidence (%)	0
Pit rot	Incidence (%)	6

Emergence was uniform across the trial (Table 13.). Ground cover was uniform across the trial until haulm destruction treatments were applied (Table 14.).

Haulm senescence was rapid where haulm pulverisation treatments were applied (Table 14.). Decline in senescence was significantly slower where haulm desiccants were applied. Where extra nitrogen was applied, the effect of haulm desiccant on senescence was slower initially but subsequently was similar to haulm desiccants at normal nitrogen levels. The full dose diquat appeared to have a greater effect on senescence initially (although non-significant) but the split dose applications proved quicker at haulm senescence and reduction of ground cover ultimately.

There were no differences in skin set between haulm destruction treatments at two times of assessment (Table 15.) and these were not significantly different from the treatment where senescence occurred naturally.

Blackleg progressed slowly but steadily in all treatments to around 3% plants showing at least one rotted stem (data not shown). Pit rot and gangrene were not at commercially significant levels in this trial (Table 16.) and there were no significant differences after 6 months storage and subsequent grading.

There was an effect of full dose diquat on skin thickness when compared to treatments involving pulverisation (Table 17.). However, the full dose diquat treatment (7) had a similar skin thickess to that of the untreated (treatment 1).

Samples sent for analysis recorded diquat in daughter tubers 16 days after the first application but it was not detected on an earlier sampling occasion (Table 18.).

Table 13. Emergence assessments in the trial at PIP

Rating Date		10/06/2010		16/06/2010		24/06/2010	
Rating Type		Emergence		Emergence		Emergence	
Rating Unit		%		%		%	
1	Nil	58.2	a	95.5	a	95.5	b
2	Pulverisation fb carfentrazone (2)	53.5	a	98.5	a	99.0	a
3	Pulverisation fb diquat (2)	56.0	a	98.5	a	98.5	ab
4	Diquat fb pulverisation fb diquat	53.6	a	96.5	a	99.5	a
5	Diquat fb diquat (5)	52.0	a	95.5	a	99.5	a
6	Diquat fb carfentrazone (5)	57.6	a	98.5	a	100.0	a
7	Diquat (Full)	47.5	a	99.0	a	99.5	a
8	Diquat fb diquat (5) +N	56.0	a	94.0	a	97.5	ab
LSD (P=.05)		16.71		3.77		2.52	
CV		20.29		2.64		1.74	
Means followed by same letter do not significantly differ (P=.05, Student-Newman-Keuls)							

Table 14. Assessment of ground cover and haulm senescence before and after haulm destruction at the trial at PIP

Rating Date		14/07/2010		24/08/2010		30/08/2010		30/08/2010		02/09/2010		09/09/2010		09/09/2010	
Rating Type		Ground cover		Haulm senescence		Haulm senescence		Ground cover		Haulm senescence		Haulm senescence		Ground cover	
Rating Unit		%		1-9		1-9		%		1-9		1-9		%	
1	Nil	98.3	a	8.0	ab	7.3	a	83.0	a	8.0	a	7.0	a	85.3	a
2	Pulverisation fb carfentrazone (2)	100.0	a	8.0	ab	1.0	d	1.0	c	1.3	d	2.0	c	0.0	b
3	Pulverisation fb diquat (2)	99.3	a	8.0	ab	1.0	d	0.0	c	1.0	d	1.8	c	0.0	b
4	Diquat fb pulverisation fb diquat	99.8	a	8.5	a	1.0	d	2.0	c	1.5	d	1.3	c	0.3	b
5	Diquat fb diquat (5)	100.0	a	8.5	a	3.5	c	17.3	b	2.5	cd	1.8	c	0.0	b
6	Diquat fb carfentrazone (5)	99.3	a	7.3	b	3.3	c	24.8	b	3.3	bc	1.5	c	0.0	b
7	Diquat (Full)	99.5	a	8.8	a	3.3	c	14.3	bc	4.3	b	3.8	b	11.8	b
8	Diquat fb diquat (5) +N	99.8	a	8.3	ab	4.5	b	28.8	b	2.5	cd	1.8	c	0.3	b
LSD (P=.05)		1.59		0.78		0.63		12.01		1.10		1.02		8.57	
CV		1.08		6.5		13.94		38.19		24.58		26.81		47.82	
Means followed by same letter do not significantly differ (P=.05, Student-Newman-Keuls)															

TABLE 15. ASSESSMENT OF SKIN SET AND YIELD AFTER HAULM DESTRUCTION TREATMENTS AT THE PIP TRIAL

Rating Date	10/09/2010		10/09/2010		29/10/2010		29/10/2010		18/11/2010	
Rating Type	Skin set		Skin set		Skin set		Skin set		Yield	
Rating Unit	Index		% Tubers		Index		% Tubers		kg/plot	
1 Nil	2.18	a	100.0	a	1.225	a	100.0	a	48.35	a
2 Pulverisation fb carfentrazone (2)	2.01	a	100.0	a	1.113	a	100.0	a	35.53	bc
3 Pulverisation fb diquat (2)	1.48	a	97.5	a	1.150	a	100.0	a	34.40	bc
4 Diquat fb pulverisation fb diquat	1.93	a	100.0	a	1.263	a	100.0	a	35.78	bc
5 Diquat fb diquat (5)	2.03	a	100.0	a	1.075	a	100.0	a	27.43	c
6 Diquat fb carfentrazone (5)	2.08	a	98.8	a	1.175	a	100.0	a	34.98	bc
7 Diquat (Full)	1.93	a	100.0	a	1.138	a	100.0	a	37.90	b
8 Diquat fb diquat (5) +N	2.34	a	100.0	a	1.075	a	100.0	a	29.95	bc
LSD (P=.05)	0.670		2.07		0.1443		0.00		5.594	
CV	22.84		1.41		8.52		0.0		10.7	
Means followed by same letter do not significantly differ (P=.05, Student-Newman-Keuls)										

TABLE 16. ASSESSMENT OF PIT ROT AND ON HARVESTED TUBERS AT THE PIP TRIAL

Pest Name	Pit rot		Pit rot		Pit rot		Pit rot		Gangrene	
Rating Date	14/12/2010		14/12/2010		18/03/2011		18/03/2011		18/03/2011	
Rating Unit	No.pits/tuber		% incidence		% surface area		% incidence		% incidence	
1 Nil	0.16	ab	13.0	a	0.065	a	6.0	a	1.0	a
2 Pulverisation fb carfentrazone (2)	0.10	ab	9.0	a	0.020	a	2.0	a	0.0	a
3 Pulverisation fb diquat (2)	0.18	ab	13.0	a	0.020	a	2.0	a	0.0	a
4 Diquat fb pulverisation fb diquat	0.14	ab	12.0	a	0.035	a	2.5	a	0.0	a
5 Diquat fb diquat (5)	0.37	a	23.0	a	0.050	a	4.5	a	0.0	a
6 Diquat fb carfentrazone (5)	0.06	b	6.0	a	0.080	a	6.5	a	0.0	a
7 Diquat (Full)	0.19	ab	15.0	a	0.045	a	2.5	a	0.0	a
8 Diquat fb diquat (5) +N	0.14	ab	10.0	a	0.080	a	6.0	a	1.0	a
LSD (P=.05)	0.179		11.58		0.0878		6.65		1.5	
CV	72.65		62.38		120.92		112.99		409.41	
Means followed by same letter do not significantly differ (P=.05, Student-Newman-Keuls)										

Table 17. Assessment of skin thickness following different haulm destruction treatments at the PIP trial

Pest Name		Skin thickness	
Rating Unit		Microscope graticules	
1	Nil	14.8	a
2	Pulverisation fb carfentrazone (2)	18.55	b
3	Pulverisation fb diquat (2)		
4	Diquat fb pulverisation fb diquat	19.1	b
5	Diquat fb diquat (5)		
6	Diquat fb carfentrazone (5)		
7	Diquat (Full)	14.6	a
8	Diquat fb diquat (5) +N		
LSD (P=.05)		1.183	
Means followed by same letter do not significantly differ (P=.05, Student-Newman-Keuls)			

Table 18. Residues (mg/kg) of diquat detected in stolon end core tissue of daughter tubers sampled at different times after diquat haulm destruction application (T1). Nd = none detected. MRL for diquat is 0.05 mg/kg.

	Cara		**Days after diquat application**
Date	**Treat 5**	**Treat 8**	
07/09/2010	Nd	Nd	14
09/09/2010	0.01	0.02	16

5. DISCUSSION

The involvement of *P. atrosepticum* (the blackleg bacterium) with the pit rot syndrome is re-enforced in this project. Firstly, *P. atrosepticum* was isolated from pit rot symptoms onto CVP pectate medium in the three stocks used in the Oldmeldrum trial as well as in many crop clinic cases at SAC. Secondly, in the Oldmeldrum trial, pit rot, and in the case of Desiree, blackleg was worse where seed tubers with pit rot symptoms were planted. In addition, the conditions for *P. atrosepticum* contamination of daughter tubers and subsequent pit rot development conformed to the characterisation described in the Introduction. That is mother tuber breakdown was late (after a dry start to the growth period) and spread to daughter tubers was enhanced by a period of near soil saturation prior to harvest. Lenticel proliferation, another condition for pit rot development was not as extensive as experienced in previous seasons.

Blackleg developed only in one variety in the Oldmeldrum trial, Desiree, reaching a maximum of 8% plants affected by the last assessment in mid-August. The other two varieties, Casablanca and Gemson exhibited very low levels of blackleg but this is consistent with their high resistance rating of 8. However, resistance rating for blackleg is not an indicator that tuber contamination by *P. atrosepticum* does not occur or that other manifestations of disease, such as pit rot, caused by the bacterium may not occur. The graph below (Figure 9.) shows results from blackleg risk assessments in 2010 carried out by SAC. High levels of *P. atrosepticum* contamination were found to occur in varieties at all blackleg resistance ratings tested.

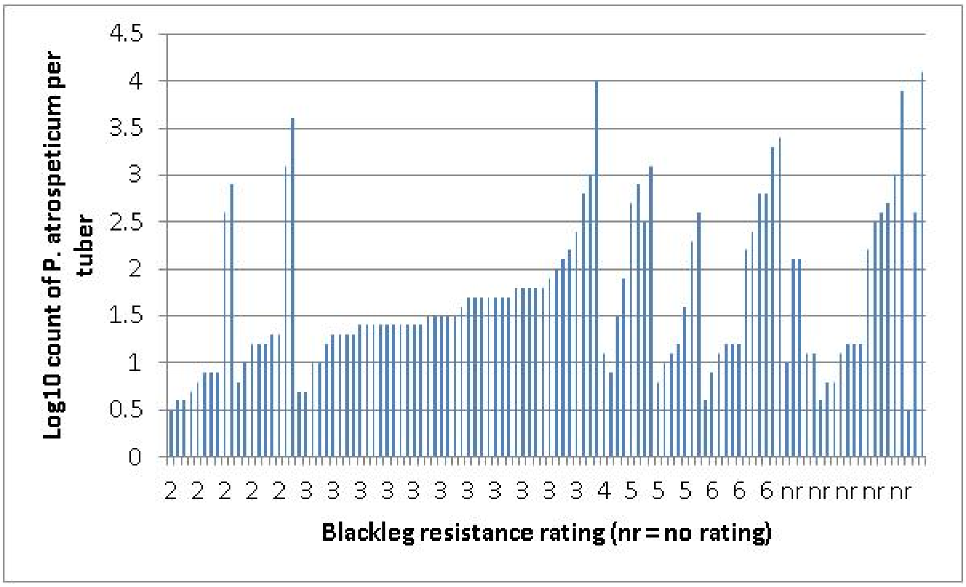

FIGURE 9. *P. ATROSEPTICUM* CONTAMINATION OF STOCKS OF A RANGE OF VARIETIES WITH DIFFERENT RESISTANCE RATING TO BLACKLEG TESTED IN BLACKLEG RISK ASSESSMENT TESTS AT SAC IN 2010.

Pit rot in the trial at PIP was less likely as low levels of pit rot were present on the original stock and environmental conditions were less favourable for spread of *P. atrosepticum*.

In the Oldmeldrum trial, pit rot, whilst present on tubers at low levels after harvest (in December), only developed to a significant extent after six months storage, grading and holding at warmer, ambient temperatures subsequently. It is presumed that the effect of grading and warmer conditions permitted the bacterium to multiply and once sufficient numbers were present break through the suberin layer beneath lenticels to create a pit. It is possible that changes in tuber metabolism as a result of grading and warming reduces the resistance to invasion of bacteria.

This pattern of late development of pit rot, post grading and warming, mirrors the commercial situation. In previous years, crop clinic samples with pit rot initially came from seed graded and dispatched in December and January and then held in warm chitting houses. The same seed stocks, ungraded in cold store at the seed farm were unaffected at that time. Later, pit rot developed on seed farms as the same seed stocks were graded and held for planting.

Whilst it seems evident that the higher the level of *P. atrosepticum* contamination of seed the greater the risk of pit rot in varieties prone to this disease symptom, the potential for rapid multiplication under warm humid conditions may preclude the requirement for high levels of contamination to be a pre-requisite. Blackleg risk assessments such as those carried out by SAC may have a role in predicting risk of pit rot but other factors may be involved.

Once pit rot symptoms develop, blackleg risk assessment tests at SAC indicate that *P. atrosepticum* contamination may not be high. This suggests that the collapse of tissue in pits may make conditions less suitable for bacterial survival.

It has been suggested that presence of *P. atrosepticum* in lenticels alone is insufficient for pit rot to develop. Of course where lenticels contamination is extremely high, pit rot may be inevitable. However, there was anecdotal information from growers in Scotland that other factors may be involved in the pit rot syndrome. One of these was the use of diquat, a haulm desiccant, as the first part of a haulm destruction programme. There were reported instances where diquat desiccated seed crops from one stock resulted in pit rot whereas pulverised crops grown of same stock (irrespective of subsequent desiccant treatment) did not.

The trial at Oldmeldrum reported in this project appears to support the contention that diquat may be a factor in pit rot development. However, the use of diquat *per se* cannot be sufficient to result in pit rot. Other factors must be involved. If this were not the case, disease issues as a result of the use of diquat for haulm destruction would be much more frequent.

In both trials reported in this project, but particularly the one at Oldmeldrum, diquat residues were detected in daughter tubers. The residue levels were below the MRL for diquat in tubers but the consistent detection suggests that diquat was translocated down the haulm to the tubers. This translocation may have affected the physiology of the daughter tubers. Such a change in physiology would be difficult to detect but there was a suggestion in the trial at PIP that periderm development might be affected. In this trial, periderm thickness was significantly less where a full dose of diquat was applied. Other attempts to identify effects of diquat residues in daughter tubers such as delays in skin set or lenticel proliferation were not successful. It is accepted that the dataset for skin thickness is a limited one and further testing is required to confirm this effect.

One of the common features around the occurrence of pit rot in the 2008-2010 seasons has been its presence in late harvested crops and in those where the haulm was green and showing little senescence at haulm destruction. Haulm destruction in seed crops, by their nature, is often made when haulm is still green. In some indeterminate varieties new growth is often maintained almost irrespective of fertiliser use and haulm may remain persistently green up to haulm destruction.

Vigorously growing haulm may translocate haulm desiccant chemicals to daughter tubers. The product label for the herbicide glufosinate-ammonium is explicit that senescence should be present in the upper third of crops before use. In addition, new growth should have ceased. Instances of damage to tubers have been recorded where this herbicide was applied to green haulm. There is also evidence that crops growing vigorously and remaining green at haulm desiccation may translocate diquat. For example, in one crop clinic case at SAC, a vigorously growing ware crop treated with (arguably) too much nitrogen and which was fully green at the time of haulm destruction with 2.0 l/ha of a diquat product as the first of two diquat treatments resulted in substantial stolon end collapse. The stolon collapse (Figure 10) was never confirmed as caused by diquat by chemical analysis but the symptoms accord with those ascribed to such damage. Similar instances have been reported by agronomists, albeit very rarely.

FIGURE 10. SUSPECT DIQUAT DAMAGE AS A RESULT OF DIQUAT DESICCANT TREATMENT OF A VIGOROUSLY GROWING WARE CROP

Therefore, it would seem that where crops have started senescing (in the way described on the glufosinate-ammonium label) the risk of translocation would be low. Provided seed (and ware) growers keep to recommended nitrogen levels, senescence should be underway in most crops by the time haulm destruction is required. Unfortunately, in the absence of irrigation, a dry start to a growing season usually means that nitrogen is not taken up by the plant early. Seasons like 2010 where the first two months were dry would effectively reduce early nitrogen uptake. Later uptake when rainfall resumed would mean crops staying greener longer. Pre-basic growers, who plant mini-tubers or who plant later or whose stocks are more vigorous as a result of being ‘young’ may also face haulm destruction of crops which are green. Some pre-basic growers have faced issues of pit rot (and gangrene – see below) in recent years.

Even where crops are green and vigorously growing at the time of haulm destruction, the occurrence of pit rot is not certain unless *P. atrosepticum* is also present and contaminating lenticels. This is most likely where mother tuber breakdown is late and soil conditions are wet prior to harvest permitting spread of the bacterium to lenticels in daughter tubers. Such a situation occurred at the Oldmeldrum trial. It follows that in dry autumn conditions, diseases like pit rot are unlikely to be an issue.

For pit rot to develop, it appears that a number of conditions require to be met before the disease occurs.

Whilst 2010 was yet another season when conditions for pit rot were met, because of the widespread uptake of pulverisation by the seed industry (even if preceded by a low dose diquat), the occurrence of pit rot has been limited.

It is interesting to note that despite differences in the rate of haulm senescence where treatments including pulverisation were compare to desiccant only treatments, in both trials skin set was not significantly different between any treatment.

There has been a suggestion that elevated CO_2 levels post-harvest may influence *P. atrosepticum* development in lenticels and thus the occurrence of pit rot. It is well known that respiration of tubers is increased during harvesting and without ventilation CO_2 levels may be elevated. *P. atrosepticum* can grow and multiply in anaerobic conditions. However, normal practice by most growers, but particularly seed growers, would be to ventilate immediately after harvest, often using positive ventilation. In this instance, unless there was a lot of soil in boxes, elevated CO_2 levels would seem unlikely. In addition, if early elevated CO_2 levels are a factor in the development of the pit rot syndrome, it seems odd that symptoms largely appear after storage and grading. However, the potential involvement of CO_2 in the pit rot syndrome has not been fully examined and deserves further evaluation.

For some seed producers, gangrene and gangrene-like pathogens have been a concern. Their occurrence has also been anecdotally linked to diquat use. In this project, haulm was removed at harvest from the trial at Oldmeldrum from the variety which, when planted, exhibited gangrene lesions – Desiree. Examination and confirmation microscopically indicated that haulm desiccated using diquat had been colonised by *Phoma foveata* significantly more than that pulverised. This greater colonisation may have been the effect of slower senescence and desiccation allowing time for greater colonisation. Whether an effect of diquat on daughter tuber physiology is involved in increased gangrene is unclear but a thinner periderm as detected at the PIP site would result in wounding being easier and infection more likely.

Greater colonisation of haulm tissue by *P. foveata* would mean that more spores were washed down into the soil with a greater potential risk of disease development. Gangrene was present on Desiree at the last assessment in March and there was a strong correlation between the mean level of stem colonisation (incidence and severity) and the incidence of gangrene on tubers (Table 19.) which strongly suggests a link between increased colonisation and subsequent gangrene development.

TABLE 19. CORRELATION MATRIX BETWEEN MEAN INCIDENCE AND SEVERITY ON STEMS OF *P. FOVEATA* COLONISATION AFTER HAULM DESTRUCTION AND MEAN INCIDENCE OF GANGRENE ON TUBERS AFTER 6 MONTHS STORAGE

	Incidence of *P. foveata* colonisation of stems	Severity of *P. foveata* colonisation of stems	Incidence of gangrene on tubers
Incidence of *P. foveata* colonisation of stems	1.00		
Severity of *P. foveata* colonisation of stems	0.96	1.00	
Incidence of gangrene on tubers	0.83	0.71	1.00

5.1. How effective was haulm destruction by the different methods?

The two trials compared a range of typical haulm destruction programmes. Naturally, haulm senescence was more rapid where pulverisation occurred. Haulm desiccant-only programmes were also effective at haulm destruction, albeit slightly slower than where pulverisation was involved. There were no significant differences recorded between the two methods in rate of skin set and thus all programmes represent suitable haulm destruction approaches.

When choosing a method of haulm destruction, disease issues require to be taken into consideration. Where a crop is vigorously growing and green at the time of haulm destruction, and environmental conditions favour late mother tuber breakdown and spread of *P. atrosepticum* to daughter tubers, pulverisation would appear to be the most appropriate method. This approach is especially suited to seed crops. If crop senescence is well underway and risks from *P. atrosepticum* are considered low, any haulm destruction method would be suitable.

What remains uncertain for seed growers is the risk of spread of *P. atrosepticum* both within and between crops where pulverisation is used and blackleg is present in a crop. A small study carried out in 2009 (Wale & Toth, 2010) suggested that, within a crop, haulm pulverisation did not increase the burden of daughter tuber colonisation (the mother tuber being the major source of *P. atrosepticum* inoculum). However, the conditions after pulverisation were relatively dry and survival of bacteria on the soil or pulverised haulm is likely to have been limited. Perhaps of greater concern might be the spread of *P. atrosepticum* in aerosols to high grade (pre-basic stocks) from a pulverised crop where blackleg was present. The risk of this has not been fully evaluated. However, the advice to pulverise in dry conditions should limit spread of the blackleg bacterium. In the small 2009 study, *P. atrosepticum* was detected colonising some weeds present around the edge of fields where a potato crop with blackleg was present. If bacteria survive on perennial weeds these may also provide a mechanism for colonisation of pre-basic stocks.

6. CONCLUSIONS

- In a trial involving three varieties with known susceptibility to pit rot, the extent of pit rot developing at the end of storage was consistently, and often significantly greater in haulm destruction programmes where diquat was the first treatment.
- Although pit rot still occurred when pulverisation was the first haulm destruction treatment, it was at a lower level than where diquat was used.
- In the trial, haulm destruction treatments were applied to vigorously growing haulm.
- These findings support commercial and anecdotal experience that diquat as the first haulm treatment in some circumstances increased development of pit rot compared to pulverisation
- In the same trial, on a single variety, where diquat was the first haulm destruction treatment, colonisation of stem bases by *Phoma foveata* was greater than where pulverisation was the first treatment. Subsequently, the level of gangrene developing in the harvested crop was also greater where diquat was the first haulm destruction treatment.
- Whether a causal relationship exists between diquat as the first haulm treatment and subsequent disease development is unclear. However, there was consistent evidence that where diquat was applied to vigorously growing haulm, the chemical could be translocated to tubers.
- There is evidence to support the suggestion that diquat when used under certain conditions as the first treatment in a haulm destruction programme may be translocated to daughter tubers. Although no causal link has been established, this may contribute to an increased risk of pit rot in susceptible varieties.
- Whether translocation of diquat has any effect on tuber susceptibility is not known but in a second trial, there was evidence to suggest that diquat may affect skin thickness.
- Where haulm is senescing naturally at the time of the first haulm destruction treatment experience suggests that there should be little risk of pit rot developing when diquat is applied as the first haulm destruction treatment
- The results from this project suggest that an increased risk of pit rot may result when diquat is used as the first haulm destruction treatment under the following conditions:
  - The variety is susceptible to pit rot
  - Crops are green and vigorously growing at the time of haulm destruction
  - Late mother tuber breakdown has occurred resulting in spread of *P. atrosepticum* to daughter tubers
  - There is a period of soil saturation before harvest resulting in colonisation of lenticels by *P. atrosepticum*
- All haulm destruction programmes evaluated resulted in effective haulm destruction and there were no differences in skin set.

7. FUTURE RESEARCH AND DEVELOPMENT NEEDS:

- To evaluate the effect of different haulm destruction methods on disease development post-harvest in the seed crop situation, especially in relation to blackleg

- To evaluate a pre-haulm destruction treatment with a disinfectant to reduce inoculum on haulm and thereby spread to daughter tubers
- To evaluate the spread of *P. atrosepticum* from blackleg plants to healthy plants as a result of different haulm destruction treatments

8. REFERENCES

Wale, S; Toth, I (2010) Blackleg – a preliminary study on spread in relation to haulm destruction technique. PCL project.

9. PROJECT DELIVERABLES

To a large extent, the uptake of pulverization has resulted in a major reduction in pit rot. Whether the same can be said for gangrene and gangrene-like pathogens is not known. The uptake of pulverization rather than use of diquat as the first haulm destruction treatment probably arose out of the publicity generated on the subject in 2009 and 2010. The author of this report spoke extensively at grower meetings to summarise the knowledge at that time. These trials confirm the advice given was appropriate.