Final Report

Blackleg – A Preliminary Study on Spread in Relation to Haulm Destruction Technique

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1. SUMMARY

A preliminary study was established at short notice to compare blackleg (*Pectobacterium atrosepticum)* contamination after haulm pulverisation and diquat haulm desiccation. At the same time the opportunity was taken to examine the potential that haulm destruction may lead to increased contamination of tubers at the point of stolon attachment (i.e. via the stolon) and to ascertain if weeds in and around potato fields were contaminated with *P. atrosepticum*.

Two fields were identified that had high levels of blackleg – Elgin (61.3% blackleg) and Inchbare (27% blackleg). Within each field two replicates blocks of crop were identified for haulm pulverisation or spraying with diquat as the first treatments of haulm destruction. The site at Elgin was flooded and this site was abandoned for a comparison of haulm destruction treatments. However, tuber samples were taken along with weeds within and around the field. Haulm destruction was carried out at the site at Inchbare, as planned, and tubers were sampled before harvest to test for contamination by *P. atrosepticum*. Weed samples were also taken from the Inchbare field.

At Inchbare, there was no evidence that haulm pulverisation resulted in increased tuber contamination over the diquat treatment. This may have been due to limited rainfall and a sustained period of dry weather after haulm pulverisation. There is a suggestion from blackleg risk assessment tests that greater contamination was present where diquat was applied rather than with the flail treatment, although statistically the comparison was inconclusive. There is also a suggestion that diquat application may increase the level of stolon end contamination of tubers

Despite very high levels of blackleg in the two fields, daughter tuber contamination was unexpectedly low. This may have been due to early mother tuber breakdown. The degree to which *P. atrosepticum* contaminates daughter tubers by moving along the stolon and compared with lenticel contamination is poorly understood. Daughter tubers from the Elgin site where the crop exhibited severe blackleg had no stolon end contamination. By contrast, at Inchbare where the blackleg level was considerably lower, there was much greater stolon contamination. This difference may be due entirely to the variety characteristics

It is not possible to indicate the extent to which haulm pulverisation spreads *P atrosepticum,* although the leaves of some weed species from these fields were found to be contaminated with *P. atrosepticum*.

Despite previous warnings that haulm pulverisation may result in spread of blackleg bacteria and increased tuber contamination, there are situations where haulm pulverisation can be used even where blackleg is present in a crop. However, pulverisation of crops exhibiting blackleg may lead to contamination of nearby high grade seed crops. *P. atrosepticum* was found to contaminate weeds (leaves) in and around the potato crops studied. Persistence of the bacterium on weeds may be another potential source of contamination of high grade seed crops

From consideration of the outcome of this study and other circumstantial evidence, it seems clear that the effect of haulm destruction method may influence diseases other than blackleg. Future R&D is proposed to understand the epidemiology of pathogens

and changes in crop physiology that relate to increased disease risk as a result of haulm destruction methods

2. INTRODUCTION

It has been a surprise how fast seed growers have moved away from using sulphuric acid. It has been an equal surprise how many have moved towards haulm pulverisation prior to haulm desiccation rather than using haulm desiccants alone.

Unfortunately, as a result of two previous wet growing seasons blackleg rose in significance in 2009. Apart from a few very bad stocks, the good growing weather in June and the start of July 2009 tended to hold back symptom expression and most crops passed inspection. However, after second inspection, and with generally wetter weather, blackleg became prominent in seed crops. Indeed, blackleg has been found unexpectedly in early generation pre-basic stocks.

Some seed growers who already owned or recently purchased haulm pulverisers continued to use them even where blackleg was present in crops. This is despite the widely publicised advisory message that haulm pulverisation in seed crops with blackleg will increase contamination and disease risk in subsequent crops.

The advisory message was widely spread by Michel Perombelon 30 years ago (Perombelon *et al*., 1979) after his research indicated a risk. It was so successful a message that haulm pulverisation almost stopped completely in seed crops. At that time, sulphuric acid was an excellent alternative and able to kill haulm and stop tuber growth quickly.

From split field comparisons, and circumstantial evidence, some growers consider that use of diquat as a major component in haulm desiccation may give rise to increased bacterial contamination of seed – and thereby increased soft rotting, pit rot and future blackleg risk.

After consultation with Potato Council, and at short notice, SAC set up two split field comparisons to compare blackleg (*Pectobacterium atrosepticum)* contamination after haulm pulverisation and diquat haulm desiccation. SCRI were also involved to examine the potential that haulm destruction may lead to increased contamination of tubers at the point of stolon attachment (i.e. via the stolon) and to ascertain if weeds in and around potato fields were contaminated with *P. atrosepticum*.

The objectives of this project were:

1. To determine if haulm pulverisation spreads blackleg and increases daughter tuber contamination
2. To compare haulm pulverisation with haulm desiccation using diquat
3. To determine the extent to which weed seeds in and around a potato crop with blackleg are contaminated with *P. atrosepticum*

3. MATERIALS AND METHODS

Two fields were identified that had high levels of blackleg. These were at Sherriffston, Elgin (GR NJ250623) courtesy of Higgins GI and Westside, Inchbare, Edzell (GR NO615666) courtesy of Mr Morgan Milne. The incidence of blackleg was determined by counting percentage plants exhibiting blackleg symptoms. Within each field two replicates blocks of crop were identified for haulm pulverisation or spraying with diquat as the first treatments of haulm destruction. Areas treated were at least a sprayer boom width.

The site at Elgin was flooded after 4 inches of rain fell on 3 September and the ground was unfit to travel on. Thus this site was abandoned for a comparison of haulm destruction treatments. The level of blackleg was recorded at the site on 1 September 2009. A sample of 100 tubers were taken from the site in early October to test for stolon end testing and a wide range of weeds from within and around the potato field were dug for testing at SCRI for contamination by *P. atrosepticum*.

Haulm destruction was carried out at the site at Inchbare, as planned. Data was collected at the time of haulm destruction and these details are shown in Table 1.

Date of haulm destruction	7 September 2009
Product and dose of diquat used	Reglone 2.0 l/ha
Make of haulm pulveriser	Grimme KSA 75-2
Performance of pulveriser	Effective pulverisation despite being a 2 row pulveriser. Some overlap noted
Soil wetness	Soil moist at surface and throughout drills
Estimate of temperature	12-15^{o}C
Wind speed	Run of wind for 24 hours on 7 September was 264 km (SCRI data)
General comments	Drills set up west to east
Field number	66
Variety	Estima
Grade of stock planted	SE2
Grade of stock harvested	SE3
Overall application of diquat	12 September 2009 – 5 days after first haulm destruction treatments
Date of harvest	9 October 2009

TABLE 1. DETAILS OF THE INCHBARE SITE AND HAULM DESTRUCTION

On 4 October, prior to the main harvest, three replicate digs of 200 tubers were made in each treatment from which

a. Blackleg risk assessment tests were carried out (SAC) and
b. Stolon end tests for *P. atrosepticum* were made (SCRI)

In addition, a range of weed species were collected on 9 October from within the potato crop and from field boundaries. These were examined by SCRI for contamination by *P. atrosepticum.*

3.1. Blackleg risk assessments (SAC)

SAC carry out blackleg risk assessments routinely. From a 100 tuber sample three sub-samples of 10 tubers are randomly taken. Each sub-sample is washed and weighed and peeled in a commercial abrasion potato peeler. The peeler is thoroughly cleaned between sub-samples. Two gram samples of the peel from each sub-sample is randomly selected and placed in 18ml sterile water and thoroughly mixed. Potatoes are reweighed to determine total amount of peel. The peel/water mixture is serially diluted up to 5 times (1ml in 9ml sterile water on each occasion). From each dilution 1 ml is placed into three separate tubes of potato broth. The tubers are incubated at 26^{o}C (+/- 1^{o}C) for 48 hours. Using a sterile loop, CVP (pectate medium plates) are inoculated from each tube. The plate is incubated for 48 hours at 26^{o}C. Dilutions showing signs of pitting are re-inoculated onto 2 further CVP plates, one of which is incubated at 26+/-1.0^{o}C the other at 33.5^{o}C for a further 48 hours. The number of tubes of each dilution which has given pitting at each temperature is recorded. The concentration of *P. atrosepticum* on the sub-sample is calculated using the most probable number technique and adjusted according to the weight of peel. A positive control is included with each batch of tests. The results are expressed as $\log_{10}$ *P. atrosepticum* per tuber.

3.2. Stolon End Tests (SCRI)

Stolon end tests were carried out on the tubers harvested from the Inchbare and Elgin sites. At Inchbare there were three replicate digs of 100 tubers for each treatment replicate. However, at Elgin there was only one dig of 100 tubers collected due to flooding. A single test consisted of pooling 50 stolon ends (0.5cm deep cores) from each dig, giving 12 stolon end tests for Inchbare and 1 test for Elgin. The stolon ends were ground to a paste, serially diluted and plated on CVP agar. The plates were incubated at 28°C for 48 h, after which time the resulting colonies were verified by PCR, using the De Boer primers. Results were expressed as average level of stolon end contamination ($\log_{10}$) by *P. atrosepticum*.

3.3. Plant Tests (SCRI)

There were 4 bags of weeds from Inchbare and 5 from Elgin. Three tests were carried out per bag, 2 leaf samples (6 leaves per sample) were randomly taken from the lower canopies of the weeds and one pooled sample of the roots was collected. The leaves and roots were ground using a mortar and pestle and an aliquot was enriched in Pectate Enrichment Media for 3 days, after which time the samples were serially diluted and plated on CVP agar and incubated at 28°C for 48 h. The resulting colonies were verified by PCR using the De Boer primers. The results are expressed as detected (+) or not detected (-) for the presence of *P. atrosepticum.*

3.4. Tuber Peel Tests (SCRI)

Tuber peel tests were only carried out on the tubers harvested from the Inchbare site. Five tubers from the 3 replicate digs were pooled to give one peel test for each treatment. One peel strip was removed from each tuber to include both the heel and rose ends of the tuber and the peels were fed through a Pollähne press and the resulting sap collected. As described above, the sap was serially diluted and plated on CVP agar. The plates were incubated at 28°C for 48 h, after which time the resulting colonies were verified by PCR using the De Boer primers. Results were expressed as average number of *P. atrosepticum* cells per ml of sap.

FIGURE 1. HAULM PULVERISATION AT INCHBARE

FIGURE 2. CONDITION OF HAULM AFTER PULVERISATION

FIGURE 3. PULVERISED PLOTS AT INCHBARE

4. RESULTS

The Inchbare site exhibited 27% plants showing blackleg (mean of 4 counts - 29.7%, 23.1%, 28.1%, 27.3%) and the Morayshire field 61.3% (mean of 3 counts – 46%, 74%, 64%)

There was limited rainfall on the day after haulm destruction on 7 September 2009 at the Inchbare site. Thereafter, the conditions were dry with only traces of rain in the following 14 days (Figure 4).

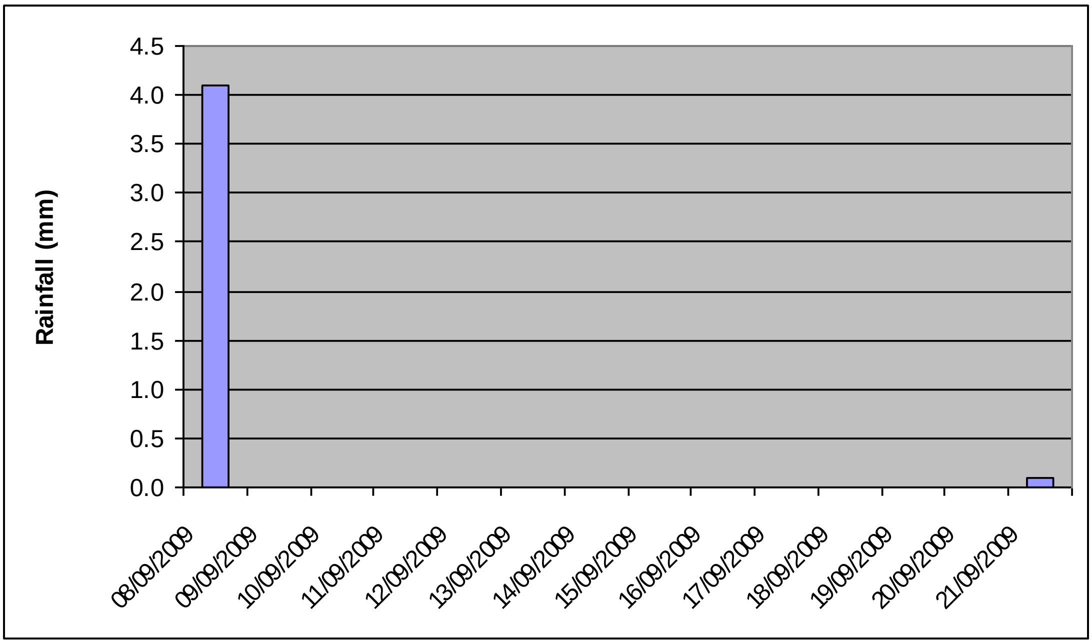

FIGURE 4. RAINFALL FOLLOWING HAULM PULVERISATION AT INCHBARE (SCRI DATA)

4.1. Blackleg risk assessments – Inchbare

Blackleg risk assessment tests were carried out on each of the three replicate tuber digs per treatment replicate. The mean values and standard deviation of the means are shown below in Figure 5.

In the first replicate, tests indicated tuber contamination by *P. atrosepticum* with the diquat treatment was much greater than that of the flail treatment. There were no differences between treatments in the second replicate. Because this field was a commercial crop, it was not possible to include an untreated control. Thus comparisons are strictly between the treatments applied. The lower and upper thresholds for blackleg risk in SAC blackleg risk assessment tests are $\log_{10}2.5$ and $\log_{10}4.0$ respectively.

There was a pattern of higher tuber contamination from diquat replicate 1 to flail replicate 2. The level of stolon contamination detected at SCRI is shown in Table 2. At Inchbare, apart from diquat in replicate one where *P. atrosepticum* was detected in all three replicate tuber samples, the bacterium was detected in a single sample of replicate 1 of the flail treatment and a single sample of replicate 2 diquat treatment. Stolon end contamination was not detected in tubers from the Elgin site.

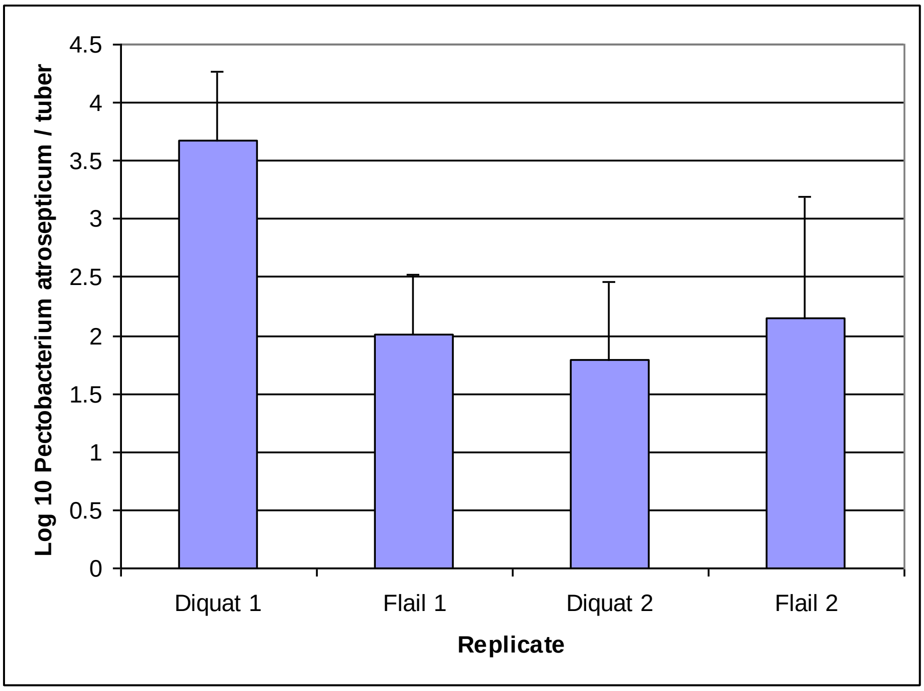

FIGURE 5. MEAN AND STANDARD DEVIATION COUNTS FOR P. ATROSEPTICUM IN SAC BLACKLEG RISK ASSESSMENT TESTS

Replicate	Treatment	Average level of stolon end contamination log10
1	Diquat	5.95
1	Flail	2.39
2	Diquat	1.39
2	Flail	0
	Elgin	0

TABLE 2. STOLON CONTAMINATION AT THE TWO FIELD SITES

The stolon end contamination results follow the same pattern of contamination as the blackleg risk assessment results.

4.2. Presence of *P. atrosepticum* in weeds

The results of extraction of *P. atrosepticum* from roots and leaves of weeds are shown in Table 3. The results are expressed as detected (+) or not detected (-). *P. atrosepticum* was detected in 1/10 leaf samples from Elgin and 3/8 samples from Inchbare. The bacteria were not detected on root tissue.

Root Grind Enrich		**Leaf Grind Enrich**	
Elgin sample 1	-	Elgin sample 1a	-
Elgin sample 2	-	Elgin sample 1b	+
Elgin sample 3	-	Elgin sample 2a	-
Elgin sample 4	-	Elgin sample 2b	-
Elgin sample 5	-	Elgin sample 3a	-
Inchbare sample 1	-	Elgin sample 3b	-
Inchbare sample 2	-	Elgin sample 4a	-
Inchbare sample 3	-	Elgin sample 4b	-
Inchbare sample 4	-	Elgin sample 5a	-
		Elgin sample 5b	-
		Inchbare sample 1a	+
		Inchbare sample 1b	-
		Inchbare sample 2a	-
		Inchbare sample 2b	-
		Inchbare sample 3a	-
		Inchbare sample 3b	+
		Inchbare sample 4a	+
		Inchbare sample 4b	-

+ = positive for Pba, - = negative for Pba

TABLE 3. RESULTS OF TESTING FOR THE PRESENCE OF *P. ATROSEPTICUM* IN WEEDS IN AND AROUND TWO FIELDS WITH HIGH LEVELS OF BLACKLEG

5. DISCUSSION

5.1. Study disussion

After this project had stated but prior to haulm destruction treatments being applied, the north of Scotland experienced a single day of heavy rainfall (50-100mm) on 3 September. This event effectively prevented the haulm treatments proceeding at the Elgin site. In two crops where blackleg was severe, this rainfall event would have enhanced the spread of bacteria from rotting mother tubers and from rotting stems to daughter tubers.

The haulm destruction treatments were applied at Inchbare 4 days after the heavy rain event. If pulverisation has the potential to spread *P. atrosepticum*, the organism's survival and contamination of daughter tubers will depend on environmental conditions. The soil conditions on the day of the pulverisation were damp and it can be assumed there was a relatively high humidity. The bacteria probably would have been spread with the pulverisation and under high humidity survived for a period of time. The following day several mm of rain fell. This may have washed some bacteria into the soil but the amount of rain may have been insufficient to increase the level of tuber contamination. Following this limited rainfall event on 8 September the weather was relatively dry for a fortnight. Further contamination of daughter tubers and survival of the bacteria on the haulm would have been limited.

Tubers from each site were sampled around 1 month after the rainfall event. The blackleg risk assessment test results indicate that pulverisation did not increase daughter tuber contamination over the diquat treatment. This supports the view that the weather conditions after pulverisation were unsuitable for long term survival of bacteria and daughter tuber contamination.

At the Inchbare site, despite the heavy rain in early September and the high level of blackleg, the levels of daughter tuber contamination were relatively low. This may have been due to early mother tuber breakdown and inadequate spread of bacteria to developing daughter tubers. Toth *et al*. (2004) found that daughter tuber contamination increased steadily with time after harvest. However, Perombelon (1976) found that daughter tuber contamination could be erratic and related to environmental conditions.

There is a suggestion from the blackleg risk assessment results that greater contamination was present where diquat was applied rather than with the flail treatment, although statistically the comparison was inconclusive. There is a also a suggestion that diquat application may increase the level of stolon end contamination of tubers. It is entirely possible that the first replicate of the diquat treatment was on a part of the field that was more moisture retentive and thus naturally resulted in greater spread of bacteria. However, an examination of the trial site, which was level, showed no suggestion of this and the incidence of blackleg assessed across the trial area in early September showed little difference between locations.

It is not possible to indicate the extent to which haulm pulverisation spreads *P. atrosepticum,* although the leaves of some weed species from the edges and within the two fields were found to be contaminated with *P. atrosepticum*. The extent of spread, survival and persistence on weeds between crops needs to be established as this may represent a source of contamination in a subsequent crop

Michel Perombelon's warning about blackleg spread following haulm pulverisation was an important one. However, with years of further experience, the crude recommendation not to pulverise crops should be amended. Firstly, if a crop has no blackleg present in it, logically there is little danger that pulverisation will spread the organism and result in increased tuber contamination. Secondly, bacterial spread from rotting haulm is probably a less significant source of daughter tuber contamination than rotting mother tubers. Thirdly, at the time Michel Perombelon carried out his work on haulm pulverisation the machinery for pulverisation was unsophisticated. Today, bespoke haulm pulverisers contain the haulm and deposit it in the furrow. The risk of spread of bacteria across a great distance is considerably limited. Finally, it seems clear that even where blackleg is present in a crop, haulm pulverisation may have little impact on daughter tuber contamination where environmental conditions following pulverisation are unfavourable for the bacteria. The results from this small project support this contention.

Where pulverisation of crops exhibiting blackleg may be of concern is where they release aerosol droplets containing bacteria which spread downwind to contaminate high grade seed stocks. It is possible that this mechanism of spread, linked to increased use of pulverisers, may explain why high grade seed crops are exhibiting more blackleg.

There are other potential sources of contamination of high grade seed crops and one of these may be persistence of *P. atrosepticum* on weeds either within a field or at the boundary. The presence on weeds has been confirmed in this small project.

The degree to which *P. atrosepticum* contaminates daughter tubers by moving along the stolon and compared to through lenticel contamination is poorly understood. In this study, the tubers at the site where the crop exhibited 60% blackleg had no stolon end contamination. By contrast, at Inchbare where the blackleg level was considerably lower, there was much greater stolon contamination. This difference may be due entirely to variety characteristics. A tuber with stolon end contamination may be more prone to breakdown after planting than one with lenticel contamination. With the latter the bacteria has to breakthrough a suberised layer compared to the stolon end contamination where the bacteria are within the tuber's vascular tissue.

The short term nature of this project did not permit tubers to be stored and evaluated after a storage period. As described below this might have increased our understanding of whether there is a link between haulm destruction method and *P. atrosepticum* related diseases such as pit rot and soft rot, which have been so prevalent in the 2009/10 storage season.

Following the experimental work reported here considerable thought has been given to the issues relating to haulm destruction methods and disease development. It seems clear that the effect of haulm destruction method may influence diseases other than blackleg. These include gangrene and other wound pathogens. Below is an overview of current issues relating to haulm destruction and disease development.

5.2. Haulm destruction and disease development – an overview

In the seed potato industry there have been two significant changes in the last few years which may be affecting seed health. Firstly, 2-aminobutane (2AB) has been withdrawn as a fungicide option for the control of gangrene and skin spot. This fumigant was particularly effective at restricting disease development where either of these diseases developed during multiplication. Secondly, sulphuric acid as a haulm desiccant has been withdrawn and steadily replaced either by alternative chemical-only desiccant options involving diquat and/or carfentrazone or by a haulm pulverisation and follow-up desiccant option. With both these approaches, haulm kill may be slower and thus stems remain greener for longer than with sulphuric acid allowing colonisation by fungi and bacteria.

In the last three years there has been a resurgence of gangrene (*Phoma foveata*) and weak gangrene-like wound pathogens such as *Phoma eupyrena, Phoma exigua* and *Cylindrocarpon spp.* Gangrene has occurred unexpectedly and severely in early generation stocks (e.g. PB2). Over the same period, there has been a general rise in levels of skin spot and an apparent increase in the occurrence of blackleg (*Pectobacterium atrosepticum*) especially the related tuber diseases of soft rot and pit rot. The increase in these pathogens has coincided with a series of seasons when, at least in part, there was a very wet period, and perhaps in 2009 in relation to later harvesting. However, there is a strong suspicion that disease increase can be related to the two significant industry changes described above.

There is circumstantial evidence from a number of growers that swapping from sulphuric acid as the haulm desiccant to diquat has led to increased tuber diseases especially gangrene, gangrene-like rots and blackleg diseases (especially pit rot). This latter disease has been particularly prominent in the last two seasons as increasingly growers have moved away from sulphuric acid. Where haulm pulverisation has been used for haulm destruction there appears to be little disease development.

There is speculation as to the reason for increased disease when diquat is used for haulm destruction. The crops most affected appear to be specific varieties late planted, late maturing or receiving high N levels where the haulm is still actively growing at the time of haulm destruction. The SAC crop clinic has been involved with ware crops where diquat was applied to vigorous haulm and resulted in tuber damage. With seed crops, the mechanism may be different. Diquat is still effective in killing haulm but it may be having a physiological effect on tubers. This might be an effect on host resistance or on aspects of tuber physiology such as rate of skin set, skin thickness or rate of lenticel retraction after inversion following a wet period. The issues with diquat appear to be largely confined to northern Scotland. In England, similar problems do not occur and this suggests they may be related to temperature or day length affecting crop physiology.

Phoma spp. and other weak pathogens have the ability to spread in aerosol droplets during periods of wet weather and colonise bases of dying stems with 50% of contamination occurring between haulm destruction & harvest (Carnegie *et al*., 1987). Pycnidia forming on stem bases release many spores which can be washed down, contaminate and infect daughter tubers at harvest. Thus it is possible that stems remaining green and fleshy after use of alternative methods of haulm destruction to sulphuric acid have become colonised and this may be one cause of the recent increase in disease.

Blackleg spread was found to occur in aerosols after haulm pulverisation (Perombelon *et al*., 1979) and this resulted in the advisory message that blackleg infected crops should not be pulverised. However, the recent increase in haulm pulverisation as a result of the loss of sulphuric acid may well be resulting in increased bacterial tuber contamination and subsequent rotting in store. If many seed growers turn to pulverisation instead of using diquat for haulm destruction, there may be an increase in blackleg and related diseases.

The principle source of skin spot inoculum is seed. Routine treatment of early generations of susceptible cultivars with 2AB effectively limited ingress by the pathogen until later years of multiplication. Once 2AB was withdrawn there has been a potential build up of infection throughout the multiplication chain. Reliance on tuber fungicide treatment at grading has not proved very effective since effective application is difficult to achieve. The potential to apply fungicide treatments such as Storite Super on the harvester has proved effective for some growers in limiting wound diseases such as gangrene and dry rot.

All the diseases described here are difficult to eradicate from seed stocks, once established, and can be spread rapidly and infect healthy tubers during grading. If infection occurs in pre-basic years of multiplication, and effective control measures are not applied, there is a risk that high standards of seed production currently experienced are threatened. Immediate action is required to clarify the health risks related to methods of haulm destruction currently available and to provide clear guidelines that will protect the health of the seed industry in northern Britain.

6. Conclusions

- Despite very high levels of blackleg in two fields, daughter tuber contamination was unexpectedly low. This may have been due to early mother tuber breakdown.
- There was no evidence that haulm pulverisation resulted in increased tuber contamination over the diquat treatment. This may have been due to limited rainfall and a sustained period of dry weather after haulm pulverisation
- There is a suggestion in the field comparison from the blackleg risk assessment results that greater contamination was present where diquat was applied rather than with the flail treatment, although statistically the comparison was inconclusive
- There is a suggestion in the field comparison that diquat application may increase the level of stolon end contamination of tubers
- It is not possible to indicate the extent to which haulm pulverisation spreads *P. atrosepticum,* although the leaves of some weed species from these fields were found to be contaminated with *P. atrosepticum*. The extent of spread, survival and persistence on weeds between crops needs to be established as this may represent a source of contamination in a subsequent crop
- Despite previous warnings that haulm pulverisation may result in spread of blackleg bacteria and increased tuber contamination, there are situations where haulm pulverisation can be used even where blackleg is present in a crop. However, pulverisation of crops exhibiting blackleg may lead to contamination of nearby high grade seed crops
- *P. atrosepticum* was found to contaminate weeds (leaves) in and around potato crops exhibiting blackleg. Persistence of the bacterium on weeds may be another potential source of contamination of high grade seed crops
- The degree to which *P. atrosepticum* contaminates daughter tubers by moving along the stolon and compared with lenticel contamination is poorly understood. Daughter tubers from a site where the crop exhibited 60% blackleg had no stolon end contamination. By contrast, at Inchbare where the blackleg level was considerably lower, there was much greater stolon contamination. This difference may be due entirely to the variety characteristics
- From consideration of the outcome of this study and other circumstantial evidence, it seems clear that the effect of haulm destruction method may influence diseases other than blackleg. Future R&D is proposed to understand the epidemiology of pathogens and changes in crop physiology that relate to increased disease risk as a result of haulm destruction methods

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8. FUTURE R&D

A scientific investigation is required to understand the relationship between haulm destruction and disease development. This will involve understanding any effect on tuber physiology. There is a need to examine aspects of the epidemiology of the pathogens leading to tuber contamination as well as following different methods of haulm destruction. This is important to identify how high grade seed becomes contaminated initially. There is a need to establish best practice guidelines in limiting the occurrence of gangrene and other wound pathogens and blackleg for the seed potato industry.