

Survey: to assess the distribution and impact of potato blackleg and soft rot diseases in Zimbabwe

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Abstract: A survey to assess the distribution and impact of the potato blackleg/soft rot disease complex in Zimbabwe was conducted from September 2009 to June 2010. Sixty-four questionnaires were collected from 9 potato growing areas in Zimbabwe. The farmers are aware of the existence of soft rot post-harvest decay, seed piece decay and blackleg disease. The most predominant management method for the (three) 3 diseases was the use of rotation cycles with various crops. Estimates of economic losses caused by the diseases ranged from <1 to 65% with the average being approximately 23%. The most popular cultivars grown in Zimbabwe are Amethyst and BP1, which were ranked as susceptible by more than 50% of the growers. The disease symptoms are more prevalent at temperatures between 15 - 20 °C with moist or humid conditions.

Keywords: blackleg, research needs, *solanumtuberousum*, soft rot, survey,

I. Introduction

Potato is one of the most popular food crops grown in Zimbabwe as a substitute staple, third after maize and rice (ChigumirawaNgwerume, 2002). It is widely grown because of its varied uses which include chips, crisps, vegetable relish/salad, canning and livestock feed (Manzira, 2010). In Zimbabwe potatoes have become a common household food because they do not require processing and they are consumed as relish with sadza (thick porridge prepared from maize meal) in many marginalized homes. In most backyard gardens, potatoes are a common crop because peels are thrown into the gardens where they sprout and grow into plants which can be harvested.

Potato is the fourth largest yielding crop in the world after wheat, rice and maize (FAOSTAT, 2010). Although potatoes have the potential to produce high yields per area, they are prone to a wide range of pathogens that drastically reduce yield and quality. Pathogens of major importance are *Pectobacterium* and *Dickeya* species, which cause the soft rot/blackleg disease complex. Soft rot bacteria produce large quantities of pectolytic enzymes such as pectinases, pectatelyases, cellulases and proteases which cause tissue maceration (Collmer and Keen, 1986; Pèrombelon, 2002). In Zimbabwe potato growers face the challenge of significant post-harvest losses of tubers ranging from 20 to 80% (ChigumirawaNgwerume, 2002; Manzira, 2010; Ngadzeet al., 2010) leading to significant financial losses.

In the past, the soft rot/blackleg disease complex was vastly underestimated in Zimbabwe. A severe outbreak of potato soft rot disease occurred in some of the potato growing regions of Zimbabwe in the 2008/9 season. The disease caused severe economic losses in the commercial potato production fields, necessitating research on its epidemiology. A survey was thus carried out in the 2009/10 growing season in order to determine the prevalence and impact of the disease complex in Zimbabwe.

Blackleg and soft rot symptoms are not species specific but are dependent on climatic conditions (Hèlias et al., 2000; De Haan et al., 2008). The diseases are caused by soft rot bacteria formerly known as *Erwinia* species. Subsequent revisions have led to the taxonomic reclassification of pectolytic *Erwinia* into several genera. Strains formally described as *Erwiniacarotovorahave* been incorporated into the genus *Pectobacterium*, and strains classified as *Erwiniachrysanthemi* are now assigned to the genus *Dickeya* (Hauben et al., 1998; Gardanet et al., 2003; Samson et al., 2005). The bacteria are Gram-negative, non-spore forming, facultative anaerobes, characterized by the production of large quantities of cell wall degrading enzymes which cause disease (Collmer and Keen, 1986).

Pathogenesis of soft rot pathogens is temperature dependent. *Pectobacteriumatrosepticum* tends to cause blackleg at temperatures <25°C and *Dickeya* spp. at higher temperatures (Pèrombelon, 2002). Some cold tolerant strains have been found which can cause blackleg symptoms in cool, temperate climates. *Pectobacteriumatrosepticum* tends to cause blackleg at temperatures <25°C and *Dickeya* spp. at higher temperatures (Pèrombelon, 2002). Some cold tolerant strains have been found which can cause blackleg symptoms in cool, temperate climates.

Pectobacteriumcarotovorum subsp. *carotovorum* (Pcc) and *Pectobacteriumatrosepticum* (Pa) are the primary causes of soft rot in temperate climates. *Pectobacteriumcarotovorum* subsp. *carotovorum* causes soft rot disease in many plant species and has been isolated from plants with blackleg and aerial stem rot symptoms (Powelson and Apple, 1984). This may be attributed to its survival in many environments (Avrova et al., 2002),

whereas *Pectobacteriumatrosepticum* is largely restricted to potato, usually associated with the blackleg disease (Pérombelon, 2002). Another more virulent strain, *Pectobacteriumcarotovorumsubspbrasiliensis* (Pcb), has been identified as the major cause of blackleg and soft rot diseases in Brazil (Duarte et al., 2004), in South Africa (van der Merwe et al., 2010) and in Zimbabwe (Ngadze et al., 2012b).

Erwiniachrysanthemi has been reported to be the causal agent of aerial stem rot and wilt disease on potatoes. Taxonomic alteration has separated *E. chrysanthemi* into six species which all fall in the genus *Dickeya*. The strains which infect potato have been classified into several of these six species (Samson et al., 2005). These include *Dickeyadadanii*, *Dickeyazeae*, *Dickeyaparadisiaca*, *Dickeyachrysanthemi*, *Dickeyadianthicola* and *Dickeyadiffenbachiae*.

Latent infection of potato tubers by the soft rot pathogens is widespread and disease tends to develop when host resistance is impaired (Pérombelon and Kelman, 1980) or when environmental conditions are favourable (Pérombelon, 2002). Bacterial cells remain dormant but numbers can fluctuate depending on tuber storage conditions, increasing under moist and decreasing under dry conditions (Pérombelon, 2002). The bacteria can survive for several months in the soil, long enough to bridge the gap between cropping seasons (Pérombelon, 2002). The main environmental factor for a shift from latency to disease development is the presence of water on tubers, which triggers disease development. The film of water on the tubers leads to anaerobiosis and tissue maceration.

In Zimbabwe *Pectobacteriumatrosepticum* and *Pectobacteriumcarotovorum* subspecies *carotovorum* have been listed as the major pathogens causing blackleg and tuber soft rot diseases respectively (Masuka et al., 1998) and recently *P. carotovorum* subspecies *brasiliensis* and *D. dadantii* have been isolated from potato tubers with typical soft rot symptoms (Ngadzeet al., 2010; Ngadze et al., 2012b). Although *Pectobacteriumwasabiae*, *Dickeyazeae*, *Dickeyachrysanthemi* and *Dickeyadianthicola* have not been identified in Zimbabwe as causal agents of the blackleg/soft rot complex, their existence in the country should not be ignored.

Zimbabwe is divided into five natural regions or agro-ecological zones with rainfall as the main criterion of division. Agricultural production potential of any area in Zimbabwe is dependent on its agro-ecological classification (Table 1, Fig. 1). Potato seed is mostly produced in Nyanga (Region I) and Harare (Region II) whereas table potato is grown throughout the country as long as there is adequate water for supplementary irrigation. The objective of the study was to investigate the farmer's knowledge of soft rot and blackleg diseases, the importance of research to effectively control the disease complex and the perceptions and comments of potato growers regarding the disease in Zimbabwe.

II. Materials And Methods

A survey was conducted from September 2009 to June 2010 in three of the five Natural Regions (NR) of Zimbabwe. The survey was carried out in nine potato growing areas, namely, Chinhoyi, Darewndale, Gweru, Harare, Marondera, Mazowe, Nyanga, Shamva and Shurugwi. These areas are representative of the 3 Natural regions selected for the survey. A questionnaire was distributed to seed and table potato growers. Table potato farmers were comprised of large scale and small scale resettled farmers. A random sample of growers in each region completed the questionnaire and the number of participants from each region ranged from 15 to 30 based on the number of growers in each region. The questionnaire was divided into four main sections drawn up to determine (i) environmental conditions (average daily maximum temperatures in summer and winter and rainfall) in each region (ii) crop production practices (irrigation, type of seed and cultivars planted) (iii) crop protection including control method; application method for the different fungicides used to control various diseases; impact of blackleg and soft rot on yield of potato; pre- and post-harvest yield losses and (iv) general crop production practices. Farmers were asked to rank potato cultivars for blackleg, pre- and post-harvest soft rot susceptibility on a scale of 1 to 3 with 3 being susceptible, 2 moderately susceptible and 1 resistant. Farmers were also requested to make suggestions about research priorities and general comments about their perceptions of the disease.

Responses were summarized in a table format for statistical analysis and frequencies for the various parameters were calculated using the SPSS statistical package (SPSS statistics 17.0). The frequencies of answers pertaining to irrigation, chemical control and preference of cultivars were tested using the analysis of proportions.

III. Results

Sixty-four questionnaires were collected from three Natural Regions surveyed. The number of completed questionnaires from each region were as follows Natural Region I (20), Natural Region II (26) and Natural Region III (18)(Table 2).

Crop production. Sixty-eight percent of the respondents irrigate their potato crop; of these 53.1% irrigate once a week, 15.6% twice a week and the remaining 31.3% follow other irrigation. . The other irrigation schedules mentioned were 2-3 times per week, only in the early part of the season and when necessary. The proportions of growers who followed the different irrigation schedules were significantly different. The comparison of growers who irrigated weekly versus those who irrigated twice differed significantly ($Z = 4.75$; $P = 0.000$). The proportion of farmers who irrigated weekly significantly differed from that of growers who followed other irrigation schedules ($Z = 2.51$; $P = 0.012$). The proportion of growers who irrigated twice significantly differed from that of farmers who followed other irrigation schedule ($Z = -2.10$; $P = 0.036$) (Table 3). Ninety-two percent of the respondents use certified seed while the remainder retained their own seed.

Control practices. The predominant method for controlling blackleg and soft rot diseases was a 1-2 or 4-5 year crop rotation cycle with Katambora Rhodes grass, maize, beans, onion, ryegrass or left fallow. With regard to chemical control, the growers were aware that chemical control is not effective in controlling blackleg and soft rot diseases, but they used fungicides to control other diseases in the field and in storage. The second widely used method was fungicide application, which was used by 45.3% of the respondents for the control of various diseases in the field and in storage. Twenty-five percent of the farmers dust the tubers in storage, 5.4% dip the tubers in fungicide solution prior to planting and 14.9% spray the plants in the field in order to reduce incidences of fungal diseases. The proportion of respondents who used dust formulations differed significantly from those who dipped tubers prior to planting ($Z = 3.02$; $P = 0.002$). There was no significant difference in the proportion of respondents who used dust versus spray and dip versus spray (Table 4).

Major potato cultivars grown in Zimbabwe. The majority of the growers (81%) planted Amethyst with more than 75% of these respondents planting in excess of 10 ha to Amethyst. BP1 and Montclare were also popular, planted by 58% and 32% of the respondents, respectively. A small proportion of the farmers, 6% and 2% grow Pimpernel and Garnet respectively. The proportion of respondents who planted Amethyst, BP1 and Montclare were significantly different. The proportion of respondents who planted Amethyst versus BP1 differed significantly ($Z = 2.98$; $P = 0.003$). The proportion of respondents who planted Amethyst versus those who planted Montclare differed significantly ($Z = 6.35$; $P = 0.000$). The proportion of respondents who planted BP1 significantly differed from that of those who planted Montclare ($Z = 2.93$; $P = 0.003$). The other cultivars Mondial, Hertha, KY20 and Mnandi were grown by between 1% and 3% of the farmers.

Estimated economic losses. Economic losses due to blackleg, soft rot and seed piece decay ranged from <1% to 65%, with the average being 23% (Table 3). Only 56% of the respondents answered this question.

Ranked susceptibility of cultivars. BP1, the second most popular cultivar, was rated as the most susceptible variety. Eighty-one percent of the respondents answered this question; 70% ranked BP1 as the most susceptible, 33.8% as moderately susceptible and only 6.2% as resistant. Amethyst, the most popular variety, was ranked as susceptible by 60.5%, moderately susceptible by 24.8% while 4.7% ranked it as resistant. Montclare, which is grown by 15% of the respondents, was ranked as resistant by 6.2% while the remaining 9.4% ranked it as moderately susceptible. Pimpernel and Garnet were ranked as resistant by all the respondents and they are grown on contract for the company which produces potato crisps.

Areas of research requested by farmers. The section was completed by 85% of the respondents and 75% of them highlighted that there was a need for research on the disease in Zimbabwe. Some of the respondents cited more than one research area. The areas of research requested by growers were summarized as follows (numbers of respondents citing area of research is shown in parenthesis):

- Effective control methods (45)
- Evaluation/selection of resistant cultivars (20)
- Breeding for resistance (15)
- Survival period of the causal pathogens in soil and alternate hosts (30)

General comments of respondents. Comments were summarized as follows:

- Soft rot and blackleg disease prevalence increasing especially during wet periods followed by warm to dry temperatures.
- Soft rot incidence higher in potatoes harvested from wet soil.
- Enclosed storerooms result in higher soft rot incidence than open sheds
- Few tubers rot in storage but after emergence plants show symptoms of wilting
- A high proportion of tubers rot during transportation especially when covered

IV. Discussion

Although the majority of growers plant certified seed, this is not likely to affect the disease situation in the country as the potato seed certification scheme relies solely on visual inspection of the crop in the field and the tubers after harvesting. Many commercial seed grade stocks are contaminated (or latently infected) with bacteria found mainly in the lenticels and suberized wounds on tubers (Pérombelon and Kelman, 1980). Tuber contamination can occur before, during or after harvest and several sources of contamination have been identified which include tubers, irrigation water, machinery and insects. Detection and identification of soft rot pathogens in all potato growing regions is hampered by lack of reliable and sensitive diagnostic tools to detect the latent infections in seed (Czajwoskiet al., 2009). The yield losses caused by blackleg and soft rot will not be reduced until the latent infections can be detected in seed lots.

It was interesting to note that both cultivars Amethyst and BP1, ranked by the majority of farmers and by Ngadze et al. (2012a) as susceptible are still widely grown. The choice of these two cultivars might be attributed to physiological characteristics and yield. The yield for these cultivars has been reported to be in excess of 30 tonnes ha⁻¹ under good management practices (Manzira, 2010). Pimpernel and Garnet which were ranked as resistant cultivars are grown by a few farmers who are contracted by the companies which use them for making crisps. These two cultivars are not preferred by consumers because of their poor culinary properties. They are not as high yielding as Amethyst and BP1 (Manzira, 2010).

From the responses, it was evident that the growers were aware of blackleg and soft rot diseases and this survey has confirmed reports of yield losses as high as 90% if tubers are not handled properly (ChigumirawaNgwerume, 2002, Manzira, 2010). The differences in estimated yield losses between natural regions could be attributed to a number of factors such control practices, cultivars grown, different perceptions about the disease and different climatic conditions. According to the results obtained in this study, the highest yield losses due to the soft rot/blackleg complex were recorded in Darwendale followed by Mazowe and Harare. All these areas fall in Natural Region II, characterised by average maximum summer temperatures of 21 – 25 °C and average maximum winter temperatures of 10 - 15 °C. *Pectobacteriumcarotovorum* subspecies *carotovorum*, *P. carotovorum* subspecies *brasiliensis* and *Dickeyadadantii* were identified as the causal agents of the blackleg/soft rot disease complex (Ngadze et al., 2012b). The region receives an average annual rainfall of 750 - 1000 mm and 70% of the farmers irrigate their crop. Marondera, an area found in the same natural region, recorded lower disease incidences because it is much colder than the other areas in the same region. The average yield losses in Natural Region II ranged from 9 to 40% and countrywide the average yield losses are around 23%. Yield losses were also reported to be high in Chinhoyi and Shamva (Natural Region III). The rainfall received in this region is not adequate for potato production and all the farmers irrigate their crop. Most of the respondents in this region irrigated their crop more frequently than respondents from the other regions. Nyanga, found in Natural Region I has the lowest disease incidence. Disease incidence and severity of blackleg and soft rot diseases depend on temperature and free water (Pérombelon, 2002; Toth et al., 2003). Conditions optimal for blackleg and soft rot development are between 15 and 25 °C with prevailing wet conditions.

Some of the research areas requested by farmers covered information already known by scientists, for example, the issue pertaining to survival of the pathogen in the soil and alternate hosts. This shows that there is a knowledge gap that can be bridged by scientists networking and collaborating with the farmers. Farmers should participate in some of the trials dealing with evaluation of cultivars for resistance to the pathogens and selection of effective control strategies. This exercise is important since chemical control is not effective in controlling soft rot pathogens, control strategies rely on cultural practices and Integrated Pest Management (IPM) strategies. Good disease management practices are based on farmers' level of knowledge and ability to make control decisions effectively in implementing IPM strategies (McRoberts et al., 2003). The success of IPM system depends on regular transfer of knowledge between scientists, agronomists and growers to ensure early disease prediction, effective implementation of sustainable practice and continual improvement of management practices (Ingram, 2008).

Research in Zimbabwe should focus on identification of effective control strategies and epidemiological studies in order to understand the disease development process in the country. Since blackleg and soft rot diseases originate from infected seed tubers, research should focus on the development of reliable and sensitive pathogen detection techniques which can be used in the screening of seed tubers. The research should also focus on the development and screening of resistant cultivars.

Acknowledgements

The authors would like to thank the extension officers and industry representatives who helped in the distribution and collection of questionnaires, as well as the growers who completed questionnaires.

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TABLE 1 Rainfall characteristics of the five agro-ecological zones of Zimbabwe and suitable agricultural activities (adapted from FAO sub-regional office for East and Southern Africa, 2000).

Agro-ecological zone	Area (km ²)	% of total	Rainfall Characteristics	Agricultural activities
I	7,000	2	More than 1050mm per annum with some rain in all months	Specialized and diversified farming region. Suitable for forestry, temperate fruit and intensive livestock production
II	58,600	15	700-1050mm confined to summer. Infrequent heavy rainfall. Subject to seasonal droughts	Flue-cured tobacco, maize, soybean, cotton, sugar beans and coffee can be grown. Sorghum, groundnuts, seed maize, wheat and barley are also grown. Wheat and barley grown in winter under irrigation. Mixed cropping with poultry, beef and dairy production common.
III	72,900	18	500-700mm per annum. Infrequent heavy rainfall. Subject to periodic seasonal droughts, prolonged mid season dry spells and unreliable starts of the season.	A semi intensive farming area. Smallholder farmers occupied 39% of this area and most of the land was used for extensive ranching before resettlement in 2000. Maize production dominated commercial production. Irrigation played an important role in sustaining crop production in commercial farming areas.
IV	147,800	38	450-600mm per annum	Suitable for extensive ranching and wildlife management. Too dry for successful crop production of most crops suitable for sorghum and millets and other drought tolerant crops. Maize is commonly grown by smallholder farmers. Sugar cane and cotton are produced under irrigation in large estates.

V	104,400	27	Normally less than 500mm per annum	Extensive ranching and wildlife management are the most suitable activities.
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Total 390,700 100

TABLE 2The number of completed questionnaires received from the different areas surveyed.

Natural Region	Area surveyed	Number of questionnaires
I	Nyanga	20
II	Harare	10
	Marondera	5
	Mazowe	7
	Darwendale	4
III	Shamva	7
	Chinhoyi	3
	Shurugwi	3
	Gweru	5

TABLE 3Comparison of proportions of respondents who used the different irrigation schedules

Comparison	z	P
Weekly (34) vs twice (10)	4.75	0.000
Weekly (34) vs others (20)	2.51	0.012
Twice (10) vs others (20)	-2.10	0.036

TABLE 4Comparison of proportions of respondents who used the different chemical control methods

Comparison	z	P
Dust (16) vs dip (4)	3.02	0.002
Dust (16) vs spray (10)	1.33	0.184
Dip (4) vs spray (10)	1.72	0.086

TABLE 5Comparison of proportions of respondents who planted different cultivars

Comparison	z	P
Amethyst (52) vs B P1 (37)	2.98	0.003
Amethyst (52) vs Montclare (21)	6.35	0.000
B P1 (37) vs Montclare (21)	2.93	0.003

TABLE 6Mean estimated yield losses due to pre- and post-harvest soft rot and blackleg losses in potato growing regions of Zimbabwe.

Potato growing Region	Soft rot seed piece decay post planting (%)	Blackleg (Pectobacterium wilting) (%)	Soft rot postharvest (%)
Nyanga	2	5	10
Harare	21	10	20
Marondera	8	3	5
Mazowe	20	8	35
Darwendale	40	10	65
Shamva	8	15	20
Chinhoyi	10	<1	20
Gweru	<1	2	10
Shurugwi	0	1	5

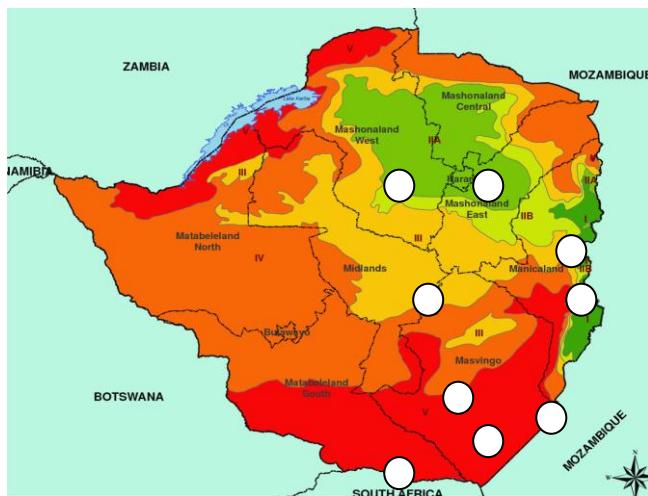


Figure 1 Map showing the natural regions of Zimbabwe. Areas surveyed are shown by white circles. (Adapted from <http://relifweb.int/sites>)