Factors Contributing to the Blackspot Bruise Potential of Idaho Potato Fields

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ABSTRACT

Blackspot bruise is a major problem in the fresh market and frozen french fry industry. The blackspot bruise potential of Russet Burbank and Ranger Russet in Idaho potato fields was determined by surveying commercial fields during 1993 and 1994. Management factors were monitored to determine what practices were contributing to blackspot susceptibility in addition to mechanical damage. The survey included 17 Russet Burbank and 3 Ranger Russet fields in 1993, and 28 Russet Burbank and 8 Ranger Russet fields in 1994. The 1993 season was unusually cool and wet whereas 1994 was warmer than normal, resulting in a wide range of environmental conditions for the 2 year study. Blackspot bruise potential was determined at different stages of tuber physiological maturity by collecting samples several weeks prior to normal harvest, immediately before harvest, and after storing sub-samples for several months. The blackspot bruise potential was measured by both impact and abrasive peel tests.

Field maturity was the factor most consistently related to blackspot potential both years. In 1994 a multiple regression of 3 independent variables - field maturity index, specific gravity, and percent available soil water at tuber sampling, compared with the blackspot potential as the dependent variable gave a correlation coefficient of r = 0.73 (p = 0.001). Due to the cool, wet growing season in 1993, there was not enough variability in specific gravity and available soil water among the fields sampled for these factors to correlate with the blackspot potential. The available fertility data, although not complete for all fields, indicated no direct relationship between N, P, or K fertilization and blackspot potential. Preharvest samples in late August had lower blackspot potential than harvest samples in mid September, and storage samples in February had the highest susceptibility. There was a consistent increase in blackspot severity when tubers were equilibrated at 4 C compared with 10 C prior to bruising.

INTRODUCTION

Blackspot bruise or internal bruise continues to be one of the most serious defect problems for the potato industry. Fresh and processing uses are both affected by blackspot bruise (Brook, 1996; Cappellini, 1984), although automated defect removal systems in processing lines have made blackspot easier to deal with in the processing industries. Both shatter bruise and internal blackspot bruise have two primary components, the amount of mechanical damage to the potato tuber, and the susceptibility of the tuber to given levels of mechanical damage. Bruise prevention programs have received a considerable amount of attention from all segments of the potato industry (Kleinschmidt and Thornton, 1991; Smittle *et al.*, 1974). Bruise-free clauses in contracts and intensive antibruise campaigns by university potato specialists and industry fieldmen have done a lot to minimize overall bruise levels. These programs have concentrated on improving handling conditions and equipment operation and have greatly reduced the amount of mechanical damage. In spite of this formidable effort, blackspot bruise is often the predominant defect present on harvested potatoes.

Blackspot susceptibility varies from year to year and with the variety grown. Russet Burbank can range from being relatively resistant to very susceptible. Ranger Russet tends to be more susceptible than Russet Burbank, while

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Shepody and most chipping varieties are less susceptible, although they are often quite susceptible to shatter bruise (Brook, 1996; Pavek *et al.*, 1985; Stark *et al.*, 1985).

This study was undertaken in order to determine what cultural and environmental factors were contributing to the variability in blackspot susceptibility seen from field to field and season to season. Some factors, such as physiological maturity (Stark *et al.*, 1985), dehydration and cold handling temperatures (Thornton and Timm, 1990), solids content (Hudson, 1975; Reeve, 1971), and potassium deficiency (Dwelle *et al.*, 1977) have been recognized as contributing to increased blackspot susceptibility. This study assesses the importance of each of these factors in the overall internal bruise sensitivity of Russet Burbank and Ranger Russet grown in Idaho.

MATERIALS AND METHODS

The study was conducted in 1993 and 1994. All Russet Burbank fields in 1993 were in south-eastern Idaho within a 60 mile radius of the Aberdeen Research Center (43°N, 113°W). In 1994 additional Russet Burbank fields were sampled in the Burley and Idaho Falls production areas within a 100 mile radius of Aberdeen. This area encompasses about 70% of the commercial potato production in Idaho, with normal growing seasons ranging from 120 to 150 days from planting to vine kill. The Ranger Russet fields in both years were localized in western Idaho within a 25 mile radius of the Parma Research Center.

Many of the Russet Burbank fields sampled each year were part of a fertility and irrigation management survey. Grower and consultant records were used to determine levels of nitrogen, phosphorus, and potassium applied to the fields. In 1993 irrigation and total precipitation were monitored using rain gauges placed at multiple sites in each field. Tensiometers were also placed at the 20-25 cm depth at all of these sites to monitor soil moisture levels. In 1994, many of the fields were not monitored using tensiometers. Therefore, soil moisture content at tuber sampling was determined gravimetrically from soil samples (0-30 cm depth) collected coincident with the blackspot samples. Percent available soil water (ASW) for each soil type was estimated from generalized soil water holding capacity tables using the formula: [% available soil water] = [field capacity] – [permanent wilting point] (McDole *et al.*, 1974). The soil textures for the fields ranged from sands to silt loams.

Tuber samples (50 tubers each) were taken from each of 3 sites in each field in 1993. The within field variability was small compared to the between field variability, so within field data were averaged. In 1994, a single composite sample of about 25 kg was dug from near the four monitoring sites, or from representative areas of the field if no monitoring sites were established.

Samples were equilibrated at 7 C within a few hours after harvest in 1993. Part of each sample was moved to 10 C and part to 4 C 48 hours prior to blackspot evaluation. The remainder was tested after 4 months storage at 7 C and 80% rh. Only one temperature, 7 C, was used for the testing in 1994, which corresponded to the average of the two test temperatures used in 1993. Impact and abrasive peel tests were used to measure the blackspot bruise potential, 10 tubers per test (Pavek *et al.*, 1985). The abrasive peel test used a 0-5 rating system with 0 = no blackening and 5 = all tubers showing intense black discoloration on abraded surfaces. The impact test used a falling 160 g weight mounted on a motorized cam driven lever. Four impacts were made on each tuber near the stem end. The impacted areas were peeled after incubating 7 days at 20 C. The intensity and depth of the blackspot bruises on each tuber were evaluated on a 0-5 scale with 0 = no blackening and 5 = all four impact sites showing a dark blackspot that was larger than the volume of the impact head. The impact and abrasive peel tests were correlated ($r = 0.70$ for 1993, and $r = 0.73$ for 1994 samples; $p = 0.001$). The two estimates of bruise potential were averaged for the analysis presented here, since it was felt that the combined value represented both the tuber reaction to mechanical impact and the maximum biochemical response to tissue disruption.

Field maturity was rated in several ways using vine appearance. The degree of senescence due to both natural and "early dying" causes was rated on a 1-9 scale; 1 being no yellowing/senescing plants in the field, to 9 being >95% of plants in the field dead or dying. Secondly, a direct estimate of the percent dead or dying plants was made in the area of the field from which the samples were taken. This proved to be the simplest and most reproducible estimate of field maturity. In 1994, all tuber samples were also tested with a tuber skin slip pressure measuring device (SEEKONK Precision Torque gauge, Seekonk, MS 02771) (Halderson and Henning, 1993). A maturity index was calculated in 1993 as the sum of the growing season from planting to vine kill in days and the percent dead or dying plants in late August. In 1994, a different maturity index incorporating the tuber skin slip readings was calculated as the sum of the percent% dead or dying plants in late August, the maturity rating x 10, and the skin slip reading x 2. These maturity indices ranged from 115 to 206 in 1993 and from 69 to 270 in 1994.

Specific gravity was determined by the weight in air/ weight in air-weight in water method. Linear regression analyses using single or multiple variables were performed in order to compare related factors. Standard ANOVA procedures were used to test differences between means with individual samples as observational units.

RESULTS

Vine Maturity, Percent Available Soil Water, and Specific Gravity—In both 1993 and 1994, the fields could be separated into distinct levels of relative blackspot susceptibility by the overall average of impact and abrasive peel test scores of the harvested samples. The average blackspot severity ratings were used to group Russet Burbank fields into resistant (<2.5 blackspot severity rating), moderately susceptible (2.5-3.0), susceptible (3.1-3.5), and very susceptible (>3.5) categories. The principle factors related to blackspot bruise potential are summarized in Table 1a. In 1993 only field maturity showed a definite relationship with blackspot potential. The percent available soil water (ASW) at tuber sampling and the specific gravity showed little variation among fields grouped by blackspot potential. This was probably due to the unusually cool and moderately wet growing season experienced in 1993. However, in 1994, which was a more typical warm and dry season, field maturity, tuber maturity measured by the skin slip pressure procedure, specific gravity, and percent ASW at tuber sampling, all showed a strong relationship to blackspot potential.

Table 2 shows the combined effects of the maturity index, specific gravity, and available soil water on blackspot susceptibility of the 28 Russet Burbank fields sampled in 1994. A multiple regression of specific gravity and the maturity index with blackspot index as the dependent variable gave a correlation coefficient of $r = 0.59$ ($p = 0.001$). When % ASW at tuber sampling was included in the multiple regression analysis, the correlation coefficient increased to $r = 0.73$ ($p = 0.001$). Fields with lower percent ASW were generally sands or loamy sands having lower water holding capacities. Soil water holding capacity alone was negatively correlated with blackspot susceptibility ($r = -0.48$; $p = 0.01$).

Eight Ranger Russet fields were available for comparisons from full season (harvest) samples in 1994. Three fields were in the moderately susceptible blackspot severity group (2.4-3.4 blackspot index) versus 5 fields in the very susceptible category (3.7-4.5). The Ranger Russet fields showed the same relationship of maturity and specific gravity to blackspot potential as the Russet Burbank fields in 1994. But the maturity was considerably lower than that of Russet Burbank for a given level of blackspot susceptibility (Table 1b

TABLE 1a.—*Field maturity, percent available soil water at tuber sampling, and specific gravity in relationship to the blackspot severity for Russet Burbank fields in 1993 and 1994. Fields are grouped by blackspot severity ratings.*

Blackspot Severity Group[1]		Number of Fields	Field Maturity[2] (%)[3]	Available Soil Water at Tuber Sampling (%)[2]	Specific Gravity[2]
1993					
Resistant	<2.5	2	17±11[4]	78±25	1.086±.007
M-Suscept.	2.5 to 3.0	5	33±13	80±18	1.087±.002
Susceptible	3.1 to 3.5	5	48±26	72±14	1.084±.002
V-Suscept.	>3.5	5	59±25	76±12	1.086±.004
1994					
Resistant	<2.5	8	54±34	51±24	1.074±.004
M-Suscept.	2.5 to 3.0	8	59±29	41±19	1.077±.005
Suscept.	3.1 to 3.5	7	61±28	33±15	1.081±.005
V-Suscept.	>3.5	5	89±17	34±20	1.083±.007

[1]Average of impact and abrasive peel ratings 0 = no blackspot, 5 = maximum blackspot severity; M = moderately, V = very.
[2]Average value for all fields in blackspot severity group.
[3]% dead plants in field in late August.
[4]Standard deviation from the mean value.

TABLE 1b.—*Field maturity, percent available soil water at tuber sampling, and specific gravity in relationship to the blackspot severity for Ranger Russet fields in 1994. Fields are grouped by blackspot severity ratings.*

Blackspot Severity Group[1]		Number of Fields	Blackspot Score	Field Maturity[2] (%)[3]	Available Soil Water at Tuber Sampling (%)[2]	Specific Gravity[2]
M-Suscept.	2.4 to 3.4	3	2.8±0.6	5±0[4]	77±23	1.084±.006
V-Suscept.	3.7 to 4.5	5	4.0±0.4	30±12	82±27	1.088±.004

[1]Average of impact and abrasive peel ratings 0 = no blackspot, 5 = maximum blackspot severity; M = moderately, V = very.
[2]Average value for all fields in blackspot severity group.
[3]% dead plants in field in late August.
[4]Standard deviation from the mean value.

TABLE 2.—*Linear regression analyses of the blackspot bruise rating as the dependent variable, with field maturity index, specific gravity, and percent available soil water as the independent variables. Russet Burbank 1993 and 1994; Ranger Russet 1994.*

Variety and Year	Observations	Correlation Coefficient R	R^2	P value
Russet Burbank 1993				
Blackspot vs. Maturity	17	0.61	0.37	0.01
Russet Burbank 1994				
Blackspot vs. Maturity	28	0.46	0.21	0.01
Blackspot vs. Maturity and Specific Gravity	28	0.46	0.21	0.01
Blackspot vs. Maturity, Specific Gravity, % ASW[1]	28	0.59	0.35	0.001
Ranger Russet 1994				
Blackspot vs. Maturity	8	0.55	0.30	0.1
Blackspot vs. Maturity Specific Gravity	8	0.56	0.31	0.1

[1]% ASW = % available soil water.

compared with Table 1a). The correlation coefficient for blackspot as a function of maturity index was r = 0.55 (p = 0.1) and as a function of maturity and specific gravity r = 0.56 (p = 0.1) Table 2.

Plant Nutrient Level—Some of the Russet Burbank survey fields were part of a separate study for which a great deal of soil fertility, petiole, and tuber nutrient information, and seasonal water application data was accumulated. However, this type of information was not available for all fields in the blackspot study. For the fields with this information, no consistent relationship between blackspot susceptibility, percent phosphorous or percent potassium was evident (Table 3). This is probably due to the uniform use of soil and plant tissue testing and appropriate fertilization by the growers, so that nutrient deficiencies did not occur.

Overall, the Russet Burbank fields with higher blackspot susceptibility ratings had higher vine nitrate levels in late July and early August, even though many of these fields were also dying more quickly by late August (Table 3). This may be explained by higher mid to late-season nitrogen applications on the sandy fields that were more prone to early dying. In 1994, petiole nitrate levels dropped in mid July in many fields, and growers attempted to bring nitrate levels back to sufficiency levels with relatively heavy nitrogen applications. The

TABLE 3.—*Vine nutrient levels in 18 fields of Russet Burbank grouped by blackspot susceptibility, 1993 and 1994.*

Blackspot Susceptibility Group[1]		Number of Fields	Average Blackspot Score[1]	Late Season Vine Nutrient Level[2]		
				ppm NO_3-N	%P	%K
Resistant	<2.5	5	2.2±0.2[3]	6,700±2,300	0.25±0.05	6.3±0.9
M-Suscept.	2.5-2.9	4	2.7±0.2	13,800±12,900	0.26±0.06	7.7±3.0
Suscept.	3.0-3.5	6	3.2±0.1	11,220±8,400	0.28±0.04	6.1±1.3
V-Suscept.	>3.5	3	4.0±.01	26,500±800	0.27±0.10	6.7±3.1

[1]Average of impact and abrasive peel ratings; 0 = no blackspot, 5 = maximum blackspot severity; M = moderately, V = very.
[2]Average of 3 late season samples (July 29, Aug. 12, and Aug. 25) of vines not petioles.
[3]Standard deviation from the mean value.

high vine nitrate levels in some of the samples probably reflected this.

Temperature and Time of Sampling—Cold tuber temperatures at the time of bruising increased the blackspot severity as rated by the abrasive peel test. All samples from the 1993 survey were evaluated after equilibrating at 2 temperatures (4 and 10 C). The blackspot severity rating was consistently higher in samples at 4 compared with 10 . The overall blackspot severity rating increased from **3.4** at 10C to **4.0** at 4C for the samples tested in 1993 (significantly different, P = 0.05). This temperature effect was independent of the blackspot potential of the individual fields since nearly all samples showed a similar increase in susceptibility at 4 .

In the two to three week period between preharvest and harvest sampling, the overall blackspot susceptibility increased. The blackspot potential of preharvest (immature) tubers in 1993 averaged **2.7** while mature tubers at normal harvest averaged **3.0** (not significant, P>0.05). In 1994, preharvest samples averaged **2.2** while harvest samples averaged **2.9** (significantly different, P = 0.01). The number of fields showing very high blackspot potential (indices above 3.5 rating) increased from 0 to 5 fields between preharvest and harvest sampling each year. A subsample was stored at 7 C for 4 months in 1993, and the average blackspot severity for these samples increased from **3.1** to **4.1** (significantly different, P = 0.01). There were five of 17 fields rated as very susceptible (indices above 3.5 rating) prior to storage, whereas after 4 months at 7 C, eleven of the 17 fields had very high blackspot potential.

The overall average blackspot severity rating for Russet Burbank fields at harvest was **3.1** in 1993 versus **2.6** in 1994.

This may be attributed to the sampling of a larger and more representative number of fields in 1994, including six from the Burley, ID, area which were consistently low in blackspot severity ratings. Blackspot severity ratings for three of the eight Ranger fields were over 4.0 in 1994, while in 1993 the small sample of 3 fields all had low blackspot potential, and the highest rating was 3.0.

DISCUSSION

Maximum blackspot bruise susceptibility occurred in tubers from fields that were more mature, roughly 70% dead vines in late August for Russet Burbank and 20% dead vines for Ranger Russet. Tubers were more susceptible when the specific gravity was relatively high, above 1.080 for Russet Burbank and above 1.085 for Ranger. The percent available soil water at tuber sampling was lower in the most blackspot susceptible Russet Burbank fields compared with the more resistant fields. Tubers evaluated after equilibrating at 4 C showed substantially higher blackspot severity than those bruised from 10 C, and there was an increase in blackspot susceptibility during a 4 month storage period at 7 C compared with the same samples prior to storage.

The small number of fields of Ranger Russet that were available and the normal variability in results from field surveys make it difficult to verify conclusions statistically. However, the same general relationship of increased blackspot sensitivity with increasing field maturity was observed each year with Russet Burbank and in 1994 in the eight Ranger fields. Field maturity averaged much lower in 1993, and specific gravities were consistently higher compared with 1994. Yet a number of these fields still showed extremes of blackspot resistance and susceptibility, and the relationship to maturity was quite good (Table 1a). The influence of higher specific gravity and lower percent available soil water on blackspot susceptibility appeared to be an interaction with the tuber maturity.

These observations are consistent with recommendations for producing bruise free potatoes (Brook, 1996; Kleinschmidt and Thornton, 1991; Smittle, 1974) with the added emphasis on the importance of tuber maturity as a fundamental factor in determining the potential for blackspot. There was no evidence from this study that changing plant nutrients from the established sufficiency range would improve blackspot resistance.

Bruise management is directly related to equipment operation and handling conditions. The importance of reducing the number and severity of tuber impacts cannot be over emphasized. However, some production factors can also be managed to help reduce the susceptibility of tubers to blackspot bruise. Harvesting potatoes from vines that were relatively immature at time of vine kill is one of the most important management considerations to minimize blackspot. Ranger Russet appears particularly prone to becoming more blackspot sensitive once vines begin senescing. Harvesting tubers from relatively immature vines can reduce blackspot potential but may result in more sugar accumulation problems in storage if the higher xsucrose pool is not managed properly during the post vine kill and early storage period (Sowokinos and Preston, 1988). This consideration would be less important for fresh market storage.

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