Effects of Potato Cultivar and Time of Harvest on the Severity of Silver Scurf

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ABSTRACT

Mérida, C. L., Loria, R., and Halseth, D. E. 1994. Effects of potato cultivar and time of harvest on the severity of silver scurf. Plant Dis. 78:146-149.

Economic losses due to silver scurf of potato have increased, possibly because of the development of benzimidazole resistance in the causal agent, *Helminthosporium solani*. In an effort to develop new disease-management strategies, the relative resistance of potato cultivars to silver scurf and the effect of harvest date on disease severity were evaluated. In field studies at two locations, there were significant differences in disease severity (tuber surface area with symptoms) among cultivars. However, differences appeared to be related to physiological maturity of the cultivars: disease severity was greatest on early-maturing cultivars, intermediate on cultivars of medium maturity, and least on late-maturing cultivars. In resistance assays using mature, detached tubers, there were differences among cultivars in disease severity, but not in sporulation. In contrast to field trials, disease severity was not related to cultivar maturity. In separate field experiments, disease severity increased with later harvest dates for all cultivars. However, disease was present on tubers of some cultivars at the earliest harvest date, when vines were still green. These results indicate that disease severity at harvest is correlated to the length of time that tubers are exposed to inoculum in the field. Mature tuber assays may be a more reliable method than field tests for screening potato breeding clones for silver scurf resistance.

Silver scurf, caused by *Helminthosporium solani* Durieu & Mont., is a common disease of potato (*Solanum tuberosum* L.) tubers (2,5) that has dramatically increased in economic importance in the United States during the last 5 yr. This increase may be due to the development of thiabendazole (TBZ) resistance in *H. solani* in North America. Resistance in this fungus was documented in the United States and Canada in 1990 (10,13), but these reports were preceded by a report from England in 1988 (4). TBZ is a benzimidazole fungicide which is used routinely on potato tubers before storage for control of Fusarium dry rot in the United States, and which may have coincidentally provided control of silver scurf until TBZ resistance developed in *H. solani*.

Primary infection of potato tubers by *H. solani* occurs during the growing season (6) when conidia germinate, infect, and colonize the tuber periderm. The seed tuber is considered the primary source of inoculum (6). Infected seed tubers are frequently found in commercial seed lots (12), and the fungus sporulates abundantly on the surface of lesions at high relative humidity. Studies by Santerre (14) in Canada and Jellis and Taylor (6) in England indicate that soilborne inoculum is not important. However, we are reexamining the ability of this fungus to overwinter in the soil. Infection of the tuber periderm can occur as soon as tubers develop (6).

Silver scurf lesions usually are clustered at the stolon end of the tuber and appear as small, pale brown spots at harvest (1,2,11). If tubers are stored for extended periods, these lesions expand and darken because of additional colonization of the tuber periderm by *H. solani*. Individual lesions always have definite margins, but they may coalesce as the disease progresses. The silvery appearance of the older lesions, which gives the disease its name, is most obvious when the tubers are wet (5). The cork cell layers of the tuber periderm may eventually slough off, causing increased water loss from the tuber surface. Tubers are usually stored at high humidity, and *H. solani* can sporulate on the surface of lesions; the dark brown conidia may serve as a source of inoculum for secondary infection cycles in storage.

Benzimidazole fungicides applied as postharvest and seed treatments had provided good control of silver scurf (7) until resistant isolates increased in frequency (13). Alternative disease-control strategies need to be developed to reduce losses to silver scurf. Disease-resistant cultivars or cultural practices that might reduce losses without increasing pesticide usage would be particularly desirable. Relatively little is known about the susceptibility of commercial potato cultivars to silver scurf. In red-skinned cultivars, the pigment in periderm cells colonized by *H. solani* is destroyed (11), causing significant reductions in fresh-market value. Because of this symptom, many red-skinned cultivars have been considered susceptible. In contrast, infection in russet-skinned cultivars is sometimes masked by the dark, thick periderm. Harvest date was shown to affect disease severity in studies conducted in England (3) and France (8). In North America, potato cultivars differ greatly in their physiological maturity. Information about the effect of harvest date on silver scurf severity on these cultivars is needed.

The objectives of this study were to determine the relative susceptibility of some widely grown commercial potato cultivars to silver scurf, and to evaluate the effect of harvest date on silver scurf severity, using cultivars and breeding clones that differ in physiological maturity.

MATERIALS AND METHODS

Cultivar resistance: field trials. Field trials were established in 1991 at two locations using a split-plot design in which the whole-plot treatments were two inoculum sources and the split-plot treatments were potato cultivars. Seed tubers were certified, but were naturally infected with silver scurf. Tubers were visually scored for disease severity before inoculation and planting. Additional inoculum was used as a whole-plot treatment at each location to compensate for possible differences in seedborne inoculum among cultivars. Location 1 (Freeville, New York) was established in a Howard gravel soil, and location 2 (Ithaca, New York) was established in a Longford Channery silt loam soil. Both sites had been planted to potato during the previous growing season. Eighteen cultivars were planted at location 1; the two inoculum sources were naturally infected seed and naturally infected seed with supplemental in-furrow inoculum. The inoculum was prepared in a 1:1 mixture of vermiculite and oat grains. The oat grains were soaked in water for 24 hr, mixed with vermiculite, and sterilized for 1 hr on three consecutive days. The oat grain medium was inoculated with agar plugs from sporulating colonies of several *H. solani* isolates (3SS-5, 4SS-5, 6SS-1, 7SS-3, 10SS-1, and 15SS-1T1). These isolates had been collected from various locations in New York State and characterized (12). The inoculum was incubated at 22–25 C in the dark for 4–5 wk and shaken repeatedly to redistribute the fungus. Colonization of the mixture was confirmed by subsequently placing grains on V8 agar and observing pathogen growth.

Accepted for publication 8 October 1993.

Twenty cultivars were planted at location 2, and the two inoculum sources were naturally infected seed and naturally infected seed with a supplemental inoculation. Seed tubers were sprayed with an *H. solani* spore suspension (>10^5 spores per milliliter) until runoff and incubated at 22–25 C with high relative humidity (>95%) in the dark until sporulation was observed. Spore suspensions were prepared in sterile water by scraping the surface of 5–6 wk old colonies and filtering the suspension through sterile cheesecloth. The spore concentration was estimated using a hemacytometer.

Treatments were replicated four times at each location. The plots consisted of two rows with 10 plants per row, and were planted with an assist-feed planter. At location 1, the supplemental inoculum was hand spread on top of the seed tubers in the open furrows. The trials at locations 1 and 2 were planted on 14 and 15 May, respectively. Both trials received standard fungicide, insecticide, and herbicide applications, except that no seed treatment or in-furrow insecticides were used. Only the trial at location 1 was irrigated.

Tubers were harvested on 4 October at location 1 and on 26 September at location 2; vines were killed with a chemical desiccant before harvest. Silver scurf severity on tubers was estimated visually as the percent tuber surface area with lesions. At location 1, disease severity was determined 2 wk after harvest, and tubers were washed and stored at 4 C until they were evaluated. At location 2, disease severity was determined 12 wk after harvest, and tubers were stored at 15 C with high relative humidity (80–90%) until evaluated. The data were analyzed by ANOVA, and the means were compared by Fisher's protected LSD in pair-wise comparisons of means ranked from highest to lowest (15).

Cultivar resistance: mature tuber assays. Mature, disease-free tubers of six cultivars were washed and surface-disinfested with 0.5% NaOCl. Tubers were placed in styrofoam boxes with individual cells (cell packs) and sprayed until runoff with an *H. solani* spore suspension (10^5 spores per milliliter) prepared from 4-wk-old colonies as described previously. Control tubers were sprayed with sterile distilled water. Five replicate tubers were placed in separate styrofoam boxes in a completely randomized design. The cell packs were incubated in a growth chamber at 25 C with high humidity (>90%) for 3 wk.

Individual tubers were rated visually for percent of the tuber surface covered with sporulating lesions and spores produced per unit area of lesion. Spore production was evaluated by sampling a tuber periderm plug (1.3 cm diameter) from a sporulating lesion. The periderm plug was suspended in sterile distilled water (15 ml), and the surface was scraped with a scalpel to release spores. The spore concentration was estimated with a hemacytometer. Comparisons among cultivars were made by ANOVA, Fisher's protected LSD in pair-wise comparisons of means ranked from highest to lowest (15), and orthogonal contrasts. The experiment was repeated twice.

Harvest date experiments. Field trials were established in 1991 at Savannah, New York, on Matisco muck soil (location 3) and at Freeville on Howard gravel soil (location 4). Naturally infected certified seed tubers were hand planted at both locations. At location 3, four cultivars were planted in two-row plots with 14 plants per row on 14 May. At location 4, eight cultivars were planted in two-row plots with 14 plants per row on 15 May. Both trials were set up as completely randomized designs with four replications. No seed treatments or in-furrow insecticides were used. Standard pesticide applications and cultural practices were used at both locations. Sprinkler irrigation was used at location 4; location 3 was not irrigated.

Ten weeks after planting, four randomly selected plots per cultivar were evaluated for vine senescence, and tubers were hand harvested. The tubers were washed immediately after harvesting, air-dried, and stored in paper bags at 4 C with low relative humidity (<40%). Additional plots were harvested at 2-wk intervals. A total of four (75, 90, 105, and 120 days after planting) and five (75, 90, 105, 120, and 140 days after planting) harvest dates were evaluated at locations 3 and 4, respectively. Two weeks after the last harvest date at each location, the average surface area of tubers covered with lesions in each plot was estimated visually. The data were analyzed by ANOVA and nested ANOVA, and the means were compared by Fisher's protected LSD in pair-wise comparisons of means ranked from highest to lowest (15), and by regression analysis.

RESULTS

Cultivar resistance. Inoculum source did not have a significant effect ($0.5 <$

Table 1. Tuber surface area (%) with silver scurf symptoms for 20 potato cultivars in three maturity classes at two locations during 1991

Cultivar	Maturity class[x]	Lesion surface area (%)	
		Location 1[y]	Location 2[y]
Norland	Early	60.6 ± 4.4 b[z]	42.5 ± 4.7 a[z]
Red Norland	Early	74.4 ± 3.8 a	28.1 ± 3.5 c
Dark Red Norland	Early	61.3 ± 6.1 b	42.5 ± 4.3 a
Superior	Early	7.0 ± 1.2 fg	20.0 ± 4.5 de
Norchip	Early	28.8 ± 3.0 c	35.0 ± 4.3 b
Yukon Gold	Early	Not planted	7.5 ± 1.3 ghi
Coastal Russet	Mid	1.6 ± 0.4 fg	18.1 ± 1.9 ef
Kanona	Mid	4.4 ± 0.4 fg	15.0 ± 1.9 ef
Monona	Mid	30.0 ± 2.3 c	25.0 ± 3.3 cd
Chippewa	Mid	15.0 ± 1.6 d	16.3 ± 2.3 ef
Hampton	Late	Not planted	2.6 ± 0.4 i
Hudson	Late	4.5 ± 1.3 fg	4.0 ± 1.0 i
Kennebec	Late	7.4 ± 1.6 f	6.3 ± 0.8 hi
Rosa	Late	5.0 ± 1.4 fg	16.9 ± 2.8 ef
Katahdin	Late	14.4 ± 1.8 de	5.0 ± 1.2 i
Allegany	Late	7.6 ± 3.0 ef	13.1 ± 2.3 fg
Steuben	Late	3.5 ± 1.1 fg	4.9 ± 1.2 i
Sebago	Late	7.6 ± 1.9 ef	11.9 ± 2.1 fgh
Russet Burbank	Late	0.3 ± 0.2 g	2.5 ± 0.2 i
Elba	Late	3.4 ± 1.1 fg	5.8 ± 1.0 hi

[x] Based on relative maturity of potato cultivars in New York.
[y] Inoculum source and block effects are not significant ($0.5 < P < 0.2$). Locations 1 and 2 are Freeville and Ithaca, New York, respectively.
[z] Means (±SE) (n = 8) with different letters in the same column indicate a significant difference ($\alpha = 0.05$).

Table 2. Surface area (%) of mature tubers with silver scurf symptoms on six potato cultivars of different maturity classes inoculated with *Helminthosporium solani*

Cultivar	Maturity class[y]	Lesion surface area (%)	
		Experiment 1	Experiment 2
Norland	Early	75.0[z] ± 4.5 a	97.0 ± 1.2 a
Katahdin	Late	56.0 ± 6.7 ab	50.0 ± 7.7 c
NY79	Early	44.0 ± 11.2 b	66.0 ± 10.3 bc
Green Mountain	Late	38.0 ± 8.6 b	78.0 ± 11.5 ab
Chippewa	Early	30.0 ± 8.4 b	10.0 ± 3.8 d
Superior	Early	26.0 ± 9.2 b	12.0 ± 1.2 d

[y] Based on relative maturity of potato cultivars in New York.
[z] Means (±SE) (n = 5) with different letters in the same column indicate a significant difference ($\alpha = 0.05$).

$P < 0.2$) on silver scurf severity at either location; therefore means for inoculum source were pooled (Table 1). Silver scurf severity on seed tubers planted ranged from 0 to 90% and did not correlate with disease severity on tubers at harvest at either location. Cultivar had a significant effect ($P < 0.001$) on the severity of silver scurf symptoms at both locations. Tuber surface area with lesions ranged from 74.3 to 0.25% at location 1 and from 42.5 to 2.5% at location 2. However, a 94% correlation was found in cultivar rank between the two locations.

Disease severity appeared to be inversely related to the physiological maturity class of the cultivars at both locations. Therefore, the cultivars were grouped into three physiological maturity classes (Table 1), and using contrast analysis, it was determined that there was a significant ($P < 0.001$) effect of cultivar maturity on silver scurf severity at both locations. Early-maturing cultivars had, on average, a significantly higher ($P < 0.001$) tuber surface area infected (41.2 and 27.4% for locations 1 and 2, respectively) than midseason cultivars (8.8 and 16.1% for locations 1 and 2, respectively). Midseason cultivars had on average a significantly higher severity rating than late-maturing cultivars (5.9 and 7.4% for locations 1 and 2, respectively).

In the mature tuber experiments, cultivar had a significant effect ($0.005 < P < 0.001$) on the percent surface area with lesions (Table 2). Norland consistently had the highest severity in both experiments, and Superior and Chippewa had the lowest severity. A 71% correlation was observed between cultivar rank in the two mature tuber experiments. A comparison of surface area infected and maturity class of the cultivar indicated that there was no significant relationship between cultivar maturity and severity of silver scurf symptoms in the mature tuber assay. Spore production ranged between 1.3×10^3 and 0.16×10^3 spores per square centimeter and was not affected by cultivar.

Table 3. Effect of harvest date on the tuber surface area (%) with silver scurf symptoms on four potato cultivars and advanced clones at four harvest dates (days after planting) at location 3 (Savannah, New York)

	Days after planting[z]			
Cultivar	**75**	**90**	**105**	**120**
ND2224-5R	7.5 ± 3.5	25.0 ± 0.0	32.5 ± 7.5	60.0 ± 10.0
NDT9-1068-11R	2.0 ± 0.0	12.5 ± 2.5	22.5 ± 2.5	37.5 ± 2.5
Redsen	7.5 ± 2.5	25.0 ± 5.0	37.5 ± 2.5	57.5 ± 7.5
Chieftain	5.0 ± 0.0	22.5 ± 2.5	17.5 ± 7.5	50.0 ± 0.0
LSD ($\alpha = 0.05$)	6.9	12.0	21.9	25.0

[z] Mean surface area infected (±SE) (n = 4) differed significantly ($P < 0.001$) with later harvest date.

Table 4. Effect of harvest date on the tuber surface area (%) with silver scurf symptoms on eight potato cultivars and clones at five harvest dates (days after planting) at location 4 (Freeville, New York)

	Days after planting[z]				
Cultivar	**75**	**90**	**105**	**120**	**140**
ND2224-5R	0.0 ± 0.0	2.5 ± 0.9	2.8 ± 0.8	4.5 ± 0.5	15.0 ± 2.0
Norland	2.3 ± 0.3	3.5 ± 1.0	11.3 ± 2.4	22.5 ± 6.0	35.0 ± 7.4
Redsen	0.0 ± 0.0	0.8 ± 0.3	3.0 ± 1.2	3.0 ± 1.2	7.0 ± 1.8
Yukon Gold	0.8 ± 0.5	1.0 ± 0.6	6.5 ± 2.2	7.5 ± 2.8	13.8 ± 1.3
Chieftain	1.3 ± 0.8	3.3 ± 2.3	1.8 ± 0.3	6.0 ± 1.4	8.8 ± 2.7
Monona	3.5 ± 1.0	9.5 ± 0.5	23.8 ± 4.3	21.3 ± 3.8	23.8 ± 3.2
NDT9-1068-11R	0.3 ± 0.3	0.0 ± 0.0	0.5 ± 0.3	1.5 ± 0.5	2.8 ± 0.9
Katahdin	0.0 ± 0.0	0.5 ± 0.3	2.3 ± 0.5	4.0 ± 1.0	9.0 ± 3.8
LSD ($\alpha = 0.05$)	1.4	2.8	5.8	8.1	10.1

[z] Mean surface area infected (±SE) (n = 4) differed significantly ($P < 0.001$) with later harvest date.

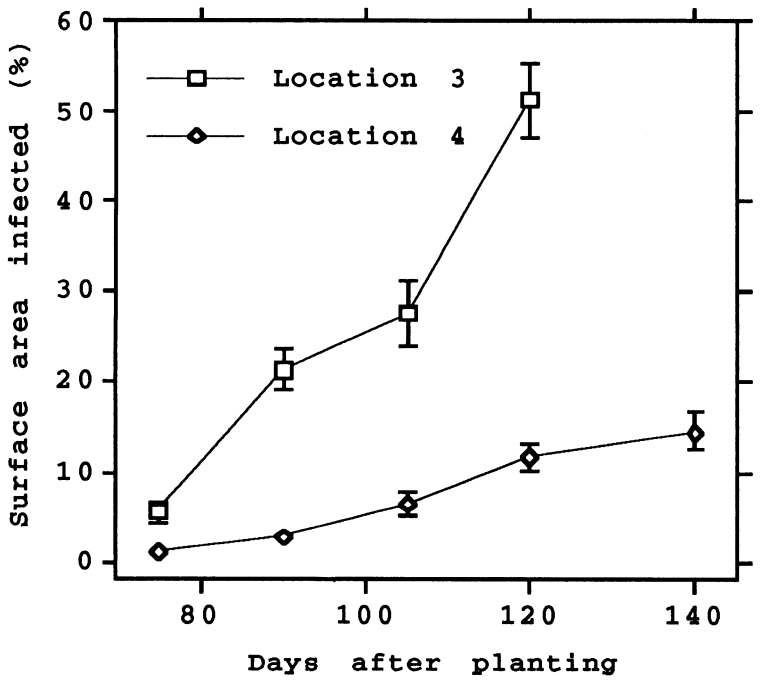

Fig. 1. Effect of harvest date on the mean tuber surface area (%) with silver scurf symptoms on all cultivars at different harvest dates (days after planting) at locations 3 and 4 (Savannah and Freeville, New York, respectively).

Time of harvest experiments. Harvest date had a significant effect ($P < 0.001$) on silver scurf severity at both locations (Tables 3 and 4) and for each cultivar ($P < 0.001$ and $P = 0.003$ for locations 3 and 4, respectively). Regression analysis indicated a significant ($P < 0.001$) increase in disease severity with later harvest dates at both locations. The red-skinned breeding line NDT9-1068-11R had the lowest silver scurf severity ratings at all harvest dates and both locations. Disease severity levels were lower at location 4 than at location 3; however, the ranking of the cultivars was similar in both locations. Disease severity was lowest at the early harvest dates for all cultivars; although *H. solani* was present on the tubers of most cultivars at the earliest harvest date (Fig. 1), when the vines were still green. Vines of all cultivars at both locations were dead at the final harvest dates, and disease was highest at these dates. Plant senescence at the time of harvest varied with cultivar and location. Although disease severity generally increased with higher senescence ratings, there was not a significant relationship between plant senescence and disease severity (*data not shown*). Cultivar had a significant ($P < 0.001$) effect on disease severity within each harvest date.

DISCUSSION

Significant ($P < 0.001$) differences were observed among the cultivars at

both locations in the field trials; however, differences appeared to be confounded by cultivar maturity. All cultivars were planted and harvested at the same time. However, since tuberization is a function of cultivar maturity, tubers are produced on early-maturing cultivars first. The earlier the cultivar tuberized, the longer tubers were exposed to inoculum. Edaphic conditions are generally favorable for spore germination and infection throughout the growing season. Therefore, differences in disease severity among cultivars with early, middle, and late maturity may be due primarily to differences in the length of time the tubers were exposed to inoculum. Because additional inoculum did not affect disease severity, it is unlikely the availability of inoculum over time was a limiting factor in infection of late-maturing cultivars. However, tuber infection may have occurred from overwintering soilborne inoculum, since plots were established on nonrotated field sites (9).

These results have implications for field screening of breeding populations for silver scurf resistance. Since breeding populations are often variable in physiological maturity, late-maturing clones might appear to be resistant if planted and harvested at the same time as early-maturing clones. This is particularly important in breeding programs that utilize wild *Solanum* species, which often tuberize very late. Mature tuber assays may be a more reliable way to identify silver scurf resistance in breeding populations. Superior consistently ranked lower in disease severity than did Norland in these assays, and results were comparable to those from the field trials. Both Norland and Superior are early cultivars, but disease severity was higher on Norland than on Superior in both locations.

It appears that potato cultivars do differ in their susceptibility to infection and colonization of periderm cells by *H. solani*. However, the level of resistance that exists in the cultivars we examined is not adequate to provide economical control of this disease. Very high levels of resistance are necessary, because silver scurf continues to develop as a post-harvest disease in storage. For example, the cultivar Russet Burbank appeared to be very resistant to infection in our field studies. However, unacceptably high levels of the disease do develop on this cultivar during the storage period, which can be more than 9 mo. Sporulation did not differ among the cultivars in the mature tuber assay, and we have seen profuse sporulation on all of the cultivars incubated at high humidity. Selection for *Solanum* germ plasm that suppresses sporulation of the pathogen on tubers may be a good strategy for finding silver scurf resistance.

Early harvest greatly limited the severity of silver scurf on tubers, probably by reducing the time that tubers were exposed to inoculum. Research conducted in England and France also found that higher disease levels were correlated with later harvest dates. Hide and Boorer (3) showed that disease levels increased during storage regardless of harvest date, but disease severity after storage was correlated to severity at harvest.

Tuber infection of some cultivars occurred before the earliest harvest date in July, when the vines were still green and tubers were immature. Jellis and Taylor (6) also observed tuber infection early in the growing season. Several factors must be considered when determining the most appropriate time to harvest a potato crop, one of which is tuber periderm maturity. Therefore, although timely harvest of the crop will help to manage silver scurf, the disease cannot be avoided entirely by early harvest.

ACKNOWLEDGMENTS

This research was supported in part by the USDA/ARS Potato Research Grants Program. We thank Carol MacNeil for assistance with field research.

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