Relative Resistance of Potato Tubers Produced from Stem Cuttings and Seed-Piece-Propagated Plants to *Streptomyces scabies*

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ABSTRACT

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Tubers can be produced from axillary buds on stem cuttings taken from potato plants. Infection of such tubers by *Streptomyces scabies* was compared with infection of tubers produced from seed-piece-propagated plants, using lesion surface area (%) and lesion type as criteria. Under greenhouse conditions, the scab lesions on tubers produced from stem cuttings and seed-piece-propagated plants appeared similar. Nine of 11 isolates of *S. scabies* tested were pathogenic on tubers produced from both stem cuttings and seed-piece-propagated plants of the scab-susceptible potato cultivar Chippewa. Lesion surface area ratings on tubers from stem cuttings grown in the greenhouse and seed-piece-propagated plants grown in naturally infested soil in the field were highest for Chippewa, intermediate for Katahdin, and lowest for Superior. Similar varietal differences in lesion type ratings were expressed in tubers grown from seed-piece-propagated plants in the field. Lesion type ratings on tubers produced from cuttings were lowest for Superior but were similar for Chippewa and Katahdin. The potential for using tubers produced from cuttings to screen potato clones for resistance to common scab and for ecological research on *S. scabies* is discussed.

Streptomyces scabies (Thaxter) Waksman & Henrici, an actinomycete, causes common scab of white potato (*Solanum tuberosum* L.). Infection occurs through the lenticels of developing tubers and initially results in a reddish brown spot on the tuber periderm. Continued colonization of *S. scabies* and development of wound periderm by the host results in the corky raised or pitted lesions characteristic of common scab. This disease occurs in most potato production areas of the world and substantially reduces the market value of infected tubers (9).

Developing potato cultivars with resistance to *S. scabies* is one of the most valuable strategies available for managing common scab (12), and several methods have been proposed for evaluating breeding lines for scab resistance (7). However, most potato breeding programs limit such evaluations to field testing (12), despite the time-consuming nature of such trials and the year-to-year variability in disease reaction primarily caused by environmental conditions.

The potato tuber, a modified stem, usually develops from underground stolons; however, tubers can develop from vegetative buds on the plant (8). The ability of potato stem cuttings to produce tubers from axillary buds is well known (13), and cuttings have been used as a model system for studying tuberization (6) and evaluating the horticultural characteristics of potato clones (5). *S. scabies* has been reported to infect small tubers produced from axillary buds on potato stems (1,3). However, the relative susceptibility of tubers produced from stems and from seed-piece-propagated plants was not evaluated in these studies.

Because this technique has the potential to improve the efficiency of screening procedures used to detect resistant cultivars, the relative susceptibility of tubers produced on cuttings and tubers produced from seed-piece-propagated plants was compared. This was accomplished by evaluating the pathogenicity of several isolates of *S. scabies* on tubers produced from stem cuttings and seed-piece-propagated plants and comparing infection of potato cultivars known to differ in their relative susceptibility to common scab (using both types of tubers).

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MATERIALS AND METHODS

Evaluation of pathogenicity. Eleven isolates of *S. scabies* (Table 1) were used in this study. Inoculum was prepared by adding 5 ml of sterile distilled water to sporulating cultures growing on yeast-malt-extract agar slants. Two milliliters of this aqueous spore suspension were added to Erlenmeyer flasks (500 ml) containing 50 ml of potato-dextrose agar; cultures were then incubated for 2 wk at 30 C. Sterile glass beads were added to flasks and agitated for 2 min to release spores. Sterile distilled water (250 ml) was then added to each flask to form a spore suspension.

Stock plants of the scab-susceptible cultivar Chippewa were grown in the greenhouse from seed pieces planted in 19-cm-diameter pots containing Cornell mix (2), a peat/vermiculite based growing medium. Nutrients in the medium were supplemented with weekly applications of a soluble fertilizer (20-20-20). Greenhouse temperatures were 24 ± 5 C, and daylight was supplemented with high-pressure sodium lights to maintain a photoperiod of 12–18 hr. Stock plants were grown for 4–6 wk before cuttings were taken.

Stem cuttings with three fully unfolded leaves were taken from stock plants. The lowest leaf was removed and the stem cutting was inserted in pots (13 cm in diameter) containing steamed, moist sand so that the attending axillary bud was immersed in the sand. To prevent dehydration, cuttings were kept in a high-humidity chamber for 14 days. Roots often formed on cuttings during this period. Three cuttings were placed in each pot, which was considered an experimental unit. Chippewa tubers, produced from greenhouse-grown plants and free of scab lesions, were surface-sterilized in 0.6% NaOCl for 10 min, rinsed in distilled water, and planted in pots (13 cm in diameter) containing

Table 1. Isolates of *Streptomyces scabies* used in the pathogenicity and cultivar resistance studies and sources of these isolates

Isolate number	Source of isolate
82-01-32	ATCC[a] 15485
82-01-34	ATCC 3352
83-01-03	Scab lesion, Riverhead, NY
83-01-03-R1	Rifampin-tolerant mutant of 83-01-03
83-01-03-R2	Rifampin-tolerant mutant of 83-01-03
83-01-04	Scab lesion, Riverhead, NY
83-01-04-R4	Rifampin-tolerant mutant of 83-01-04
83-01-10	Scab lesion, Riverhead, NY
83-01-10-R1	Rifampin-tolerant mutant of 83-01-10
83-01-12-R2	Rifampin-tolerant mutant, Riverhead, NY
83-01-21-R1	Rifampin-tolerant mutant, Riverhead, NY

[a] American Type Culture Collection, Rockville, MD.

steamed, moist sand. Seed pieces and the bases of stem cuttings were thoroughly drenched with 40 ml of the spore suspension. Three replicate pots of seed pieces and stem cuttings were used for each isolate. Cuttings and seed pieces were watered with Hoagland's nutrient solution as needed. Stem cuttings were harvested 21 days after inoculation, and attached tubers were evaluated for scab infection. Plants produced from seed pieces were harvested about 50 days after inoculation. All tubers in each pot were evaluated for symptoms of common scab by estimating the percentage of the tuber surface infected and rating lesion type using a modification of the scale described by Cetas and Jones (4), where 0 = no lesions, 1 = superficial, 2 = slightly raised or slightly pitted, 3 = pitted, and 4 = deeply pitted. These data were averaged to obtain the mean ratings for lesion surface area and lesion type for the tubers in each pot.

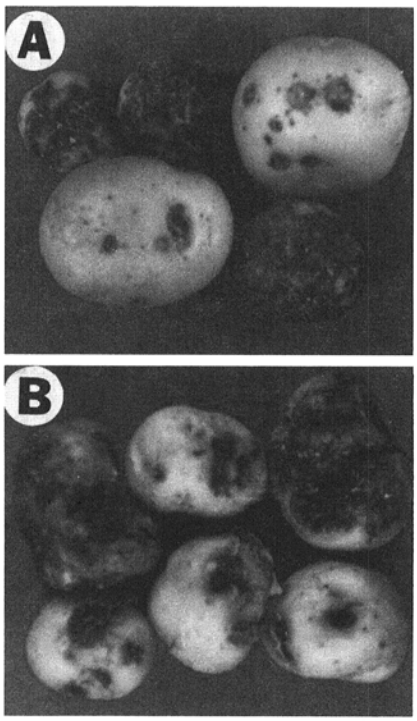


Fig. 1. Symptoms of common scab on tubers produced from **(A)** seed-piece-propagated plants and from **(B)** stem cuttings of the potato cultivar Chippewa.

Evaluation of cultivar resistance. Procedures for producing inoculum and plant material were the same as those described previously unless indicated otherwise. *S. scabies* isolate 83-01-21 was used to inoculate stem cuttings from stock plants of the cultivars Chippewa, Katahdin, and Superior, which are susceptible, moderately susceptible, and moderately resistant, respectively, in disease reaction. Four replicate pots with three cuttings per pot were inoculated with 20 ml of the spore suspension. Potato seed pieces of the cultivars Chippewa and Superior were planted and inoculated using one seed piece per pot and four replicate pots per cultivar. Dilution plating onto yeast-malt-extract agar (Difco) indicated that the inoculum suspension contained 3×10^6 colony-forming units per milliliter. Cuttings and seed pieces were grown in the greenhouse and tubers were evaluated for disease severity. Lesion surface area was rated using a modification of the scale described by Cetas and Jones (4), where 0 = no lesions, 1 = ≤10%, 2 = 11–20%, 3 = 21–40%, 4 = 41–60%, and 5 = >60%. Lesion type was rated as described previously.

Certified seed of the potato cultivars Chippewa, Katahdin, and Superior were planted in field plots naturally infested with *S. scabies*, using 12 replicate plots per cultivar in a randomized complete block design. Ten seed pieces spaced 25 cm apart in the row were planted in each plot. The soil was a sandy loam that had been adjusted to pH 6.0 with lime. To promote infection by *S. scabies*, plots were not irrigated for about 6 wk after tuber initiation (11). Otherwise, cultural practices and pesticide applications were consistent with recommendations for commercial potato production. Plants were grown to maturity, and tubers were harvested, washed, and evaluated for disease severity. Forty tubers from each plot were rated for lesion surface area and lesion type as described previously. All experiments were repeated at least once.

RESULTS

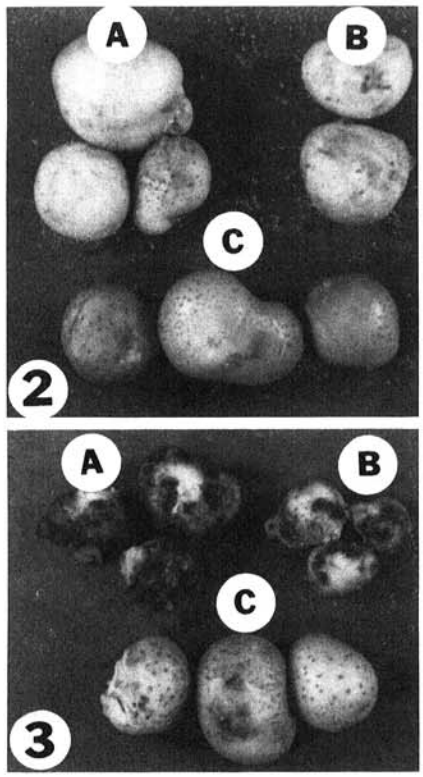
Tubers produced on cuttings appeared similar to those produced from seed-piece-propagated plants. Tuber diameters ranged from 1 to 4 cm, measured from the stem attachment to the apical bud, and were either sessile or produced on a short stolon. Stem cuttings usually produced only one tuber, but occasionally, two tubers were produced from the same node on a single cutting. Seed-piece-propagated plants grown in the greenhouse produced one to seven tubers with an average of three tubers per plant. Common scab symptoms observed on tubers produced from stem cuttings were comparable to those on tubers produced from seed-piece-propagated plants under greenhouse conditions (Fig. 1). Nine of the 11 *S. scabies* isolates tested were pathogenic on tubers produced from stem cuttings of the potato cultivar Chippewa. These nine isolates were also pathogenic on Chippewa tubers produced from seed-piece-propagated plants (Table 2). Lesion surface area ranged from 0 to 64 and 0 to 24% for tubers produced from cuttings and seed-piece-propagated plants, respectively. Lesion type ratings ranged from 0 to 2.3 and 0 to 1.8 for tubers produced from cuttings and seed-piece-propagated plants, respectively. Both seed tubers and stem cuttings inoculated with isolates 82-01-32 and 82-01-34 produced tubers which were free of scab lesions. Uninoculated tubers and cuttings also produced disease-free tubers.

S. scabies isolate 83-01-21 was pathogenic on Chippewa, Katahdin, and Superior tubers produced from cuttings, and uninoculated cuttings produced tubers that were relatively disease-free (Figs. 2 and 3, Table 3). Lesion surface area ratings were highest on Chippewa, intermediate on Katahdin, and lowest on Superior tubers produced from cuttings. Lesion type ratings were lower on Superior than on Katahdin and Chippewa, but ratings on Katahdin and Chippewa were not different. Both lesion surface area and lesion type ratings were lower on Superior than on Chippewa tubers produced from greenhouse-grown, seed-piece-propagated plants (Table 3). Disease ratings on tubers produced from seed-piece-propagated plants grown in the field in naturally infested soil were lowest on Superior, intermediate on Katahdin, and highest on Chippewa (Table 3).

Table 2. Pathogenicity of 11 isolates of *Streptomyces scabies* on tubers produced from stem cuttings or seed-piece-propagated plants of the potato cultivar Chippewa in the greenhouse

	Seed-piece-propagated plants		Stem cuttings	
Isolate	Lesion surface area (%)	Lesion type[a]	Lesion surface area (%)	Lesion type[a]
82-01-32	0 (0)[b]	0.0 (0)	0 (0)	0.0 (0)
82-01-34	0 (0)	0.0 (0)	0 (0)	0.0 (0)
83-01-03	20 (4)	1.5 (0.1)	64 (9)	2.3 (0.2)
83-01-03-R1	4 (3)	1.0 (0.7)	23 (3)	2.3 (0.0)
83-01-03-R2	2 (1)	0.4 (0.1)	4 (1)	1.3 (0.4)
83-01-04	8 (2)	1.8 (0.4)	18 (5)	1.5 (0.4)
83-01-04-R4	3 (2)	1.0 (0.7)	8 (1)	1.6 (0.2)
83-01-10	23 (6)	1.7 (0.2)	4 (2)	1.1 (0.4)
83-01-10-R1	24 (7)	1.8 (0.3)	16 (7)	1.7 (0.6)
83-01-12-R2	2 (2)	0.6 (0.3)	1 (1)	2.1 (0.1)
83-01-21-R1	1 (1)	0.4 (0.3)	1 (1)	0.4 (0.4)
Control	0 (0)	0.0 (0)	0 (0)	0.0 (0)

[a] Lesion type was rated on a scale of 0–4, where 0 = no lesions, 1 = superficial, 2 = slightly raised or slightly pitted, 3 = pitted, and 4 = deeply pitted.
[b] Data represent means and standard errors for three replicates.



Figs. 2 and 3. Potato tubers produced from stem cuttings of three potato cultivars. **(2)** Uninoculated cuttings of the potato cultivars (A) Chippewa, (B) Katahdin, and (C) Superior. **(3)** Inoculated cuttings, showing the relative susceptibility of the cultivars: (A) Chippewa, most susceptible; (B) Katahdin, moderately susceptible; and (C) Superior, moderately resistant to *Streptomyces scabies*.

Table 3. Severity of common scab as indicated by lesion surface area (LS) and lesion type (LT) ratings on potato tubers produced from stem cuttings (SC) in the greenhouse, and from seed-piece-propagated plants (SP) in the greenhouse and in the field

Cultivar	Inoculated with *Streptomyces scabies*	SC greenhouse		SP greenhouse		SP field	
		LS[a]	LT[b]	LS	LT	LS	LT
Superior	+	0.5 (0.3)	0.6 (0.3)	1.4 (0.6)	0.8 (0.2)	0.01 (0.02)	0.2 (0.1)
	−	0.0 (0.0)	0.0 (0)	0.2 (0.1)	0.2 (0.1)	...	...
Katahdin	+	4.0 (1.0)	3.0 (0)	...	...	0.6 (0.1)	1.4 (0.1)
	−	0.0 (0)	0.0 (0)	...	...	...	...
Chippewa	+	4.9 (0.1)	3.0 (0)	3.2 (1.3)	2.0 (0.5)	1.0 (0.1)	2.2 (0.1)
	−	0.1 (0.1)	0.3 (0.3)	0.0 (0.0)	0.0 (0.0)	...	...

[a] Lesion surface area was rated on a scale of 0–5, where 0 = no lesions, 1 = ≤10%, 2 = 11–20%, 3 = 21–40%, 4 = 41–60%, and 5 = >60%. Data represent means and standard errors for four replicates.
[b] Lesion type was rated on a scale of 0–4, where 0 = no lesions, 1 = superficial, 2 = slightly raised or slightly pitted, 3 = pitted, and 4 = deeply pitted. Data represent means and standard errors for four replicates.

DISCUSSION

The resistance of potato clones to tuber infection by *S. scabies* appears to be expressed in tubers produced from stem cuttings. This technique may therefore be useful in screening potato clones for resistance to this pathogen. Disease-resistant cultivars are extremely important to management of common scab, and many potato breeding programs strive to eliminate clones that are highly scab-susceptible early in the selection process. However, screening for scab resistance is almost entirely limited to field testing in the United States (12). The stem cutting technique might allow early screening of potato clones in the greenhouse, thus eliminating more costly and time-consuming field evaluations at this stage of clone evaluation. Cuttings could be taken from plants when seed tubers are being increased or when other greenhouse evaluations are being conducted. Stem cuttings also take up less space in the greenhouse than do seed-piece-propagated plants, and tuber infection can be rated within a few weeks of inoculation, which is as much as a month sooner than with seed-piece-propagated plants. However, it may not be possible to predict differences in the field performance of cultivars on the basis of lesion type on tubers produced from cuttings.

Cuttings also may be useful in population dynamics studies where the pathogenicity of *S. scabies* isolates must be tested, such as those conducted by Labruyère (10). Nonpathogenic isolates of *S. scabies* are common in soil and constitute a variable proportion of the population (10). Because there is no way to distinguish between pathogenic and nonpathogenic isolates on growth media, pathogenicity tests must be done to obtain data on the population dynamics of pathogenic isolates in natural soil. Pathogenicity testing could be accomplished much more efficiently with tubers produced from cuttings than from tubers produced from seed-piece-propagated plants. Cuttings may also be useful as a model system for studying the effects of edaphic factors or cultivar resistance on the population dynamics of *S. scabies* on, and infection of, the tuber surface.

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