Phytophthora Rot of Potatoes in Texas Caused by *Phytophthora parasitica* and *P. cryptogea*

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ABSTRACT

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Phytophthora parasitica and *P. cryptogea* were isolated in Texas from potato tubers displaying pink rot symptoms. Pathogenicity tests confirmed that isolates of each species are capable of inducing pink rot. Three cultivars and five advanced breeding lines were susceptible to both species. Artificial inoculation of buds and stems with both species resulted in rotted bud pieces, reduced bud vigor, and stem lesions. Vegetative growth of *P. parasitica* is optimal in vitro at 33 C, whereas that of *P. cryptogea* is 23 C.

Additional key words: *Phytophthora erythroseptica, P. nicotianae* var. *parasitica, Solanum tuberosum*

A tuber rot of potatoes (*Solanum tuberosum* L.) similar to pink rot has been reported by potato producers in the high plains of Texas for several years. Severe losses to the disease have been sporadic; however, diseased tubers have been found in commercial fields in several locations and among culls at packing sheds. Diseased potatoes have been observed primarily in furrow-irrigated fields with clay soils.

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Diseased tubers are spongy and initially discolored around the point of stolon attachment. Later, they become discolored around the buds and lenticels. When cut, the internal tissues appear cream-colored, but they turn salmon pink after 15–20 min of exposure to air; they gradually become darker, turning black after about 1 hr.

Pink rot was first described in 1913 by Pethybridge (6), who identified the causal agent as *Phytophthora erythroseptica* Pethyb. According to Rowe and Nielsen (8), the disease has since been reported from nine states in the United States and 11 other countries in North and South America, Europe, the Middle and Far East, and Australia.

P. erythroseptica is the most frequently reported causal agent of pink rot (8); however, other species have also been isolated from diseased tubers. Drechsler (2) reported a new species of *Phytophthora, P. drechsleri* Tucker (10), as the causal agent of pink rot. *P. megasperma* Drechs. (12), *P. cryptogea* Pethyb. & Laff. (3,9), and *P. parasitica* Dast. (10,11) have also been reported to infect potatoes. Ribeiro (7) indicated that most pathogenic species of *Phytophthora*, except *P. infestans*, produce pink discoloration in infected potatoes. The purpose of this study was to identify two species of *Phytophthora* isolated from diseased potato tubers grown in the high plains of Texas and to test their pathogenicity on potatoes.

MATERIALS AND METHODS

Isolation. Near Hereford, TX, in 1980, diseased potato tubers were collected at harvest from a commercial field where severe losses were experienced. Small

pieces of diseased tuber tissue were placed on cornmeal agar (CMA) supplemented with pimaricin (0.2 ml/L of 2.5% water suspension) and vancomycin (0.2 g/L) (CPV). The tissues were incubated at room temperature until mycelial growth was observed. Hyphal tips were transferred to and maintained on CMA. Sporangial formation and zoospore release were induced in charcoal water amended with pimaricin.

Phytophthora isolates TX 21001 and TX 21002 were selected for pathogenicity tests on three types of potato tissue—germinating buds (eyes), stems of young plants, and mature tubers.

Pathogenicity tests. *Buds.* Three potato cultivars (Norgold Russet, Red LaSoda, and Lemhi Russet) from two sources each and five advanced breeding lines (MNTX 8-57-1 Ru, MNTX 9-46-1 Ru, NDD 143-1 Ru, NDTX 5-15-1 Ru, and TXND 14-1 Ru) were tested. Plugs (1.5 × 3 cm) of tuber tissue containing a single bud were cut from tubers disinfested with 0.5% sodium hypochlorite for 3 min and planted in flats of autoclaved sand. A 5-mm CMA disk (inoculum disk) cut from an actively growing culture of either TX 21001 or TX 21002 was placed against each bud before covering with sand. Disks of sterile medium were controls. Four replicates of six plugs from each cultivar or line were included. Inoculated and control flats were maintained in the greenhouse at 22–28 C. The numbers of green healthy sprouts, discolored sprouts, and rotted bud pieces were recorded weekly for 38 days.

Stems. Stems of 21-day-old Norgold Russet potatoes were inoculated with TX 21001 using three techniques. Inoculum or control disks were placed 5 mm below the soil surface and 2–5 mm from 1) an undamaged stem, 2) a 10-mm length of stem punctured five times with a sterile needle, or 3) an undamaged stem of a plant with lateral roots injured by piercing the soil 5 cm from the stem four times to a depth of 10 cm with a 2.5-cm-wide spatula. A plant with two or three stems was used for each of three replicates. All stems were inoculated. Treated plants were maintained in the greenhouse at 24–28 C. Symptoms were observed on plants from each treatment at 13, 19, and 40 days.

Stems of three cultivars and five lines of 25- to 30-day-old potatoes were inoculated with TX 21001 and TX 21002. An inoculum disk was placed 2–5 mm from injured stems as described. Controls were wounded and treated with sterile CMA disks. One plant with two to five stems was used for each replicate. Cultivars and lines were replicated three to six times, depending on material available. All stems were inoculated. Treated plants were maintained in the greenhouse at 22–28 C. An evaluation of disease severity was made 30 days after inoculation.

Tubers. Tubers of Norgold Russet and Red LaSoda potato were inoculated with TX 21001 and TX 21002, *P. parasitica, P. erythroseptica*, and *P. cryptogea* (kindly provided by R. G. Pratt, Mississippi State University). A core (0.8 × 2.5 cm long) was removed from surface-disinfested potatoes with a cork borer. An inoculum or control disk was placed in the well of the tuber, then the core was replaced and sealed with paraffin. Four tubers were used for each treatment. Tubers were placed in individual paper bags and incubated at 24 C. Symptoms were recorded 7 days after inoculation.

Tubers of the three cultivars and five advanced breeding lines were inoculated with TX 21001 and TX 21002 as described earlier. Tubers inoculated with TX 21001 were incubated at 33 C, and those inoculated with TX 21002 were incubated at 26 C. Five tubers of each cultivar or line were inoculated with each isolate. The differences in incubation temperature were used because of differences in the optimum temperature for vegetative growth of these two isolates. External and internal symptoms were recorded 5 days after inoculation.

Temperature studies. Norgold Russet and Red LaSoda tubers were inoculated with TX 21001 and incubated at 20, 27, 32, 34, 35, 36, and 38 ± 1 C. Monona potatoes were inoculated and incubated at 20, 27, and 35 ± 1 C only. Five replicates of each treatment and control were inoculated by the procedures described earlier. Disease development was evaluated 6 days after inoculation.

To determine the optimum temperature for growth of TX 21001 and TX 21002 in vitro, 5-mm mycelial disks were transferred to the center of 90-mm petri dishes containing CMA. Cultures were incubated at temperatures ranging from 20 to 40 C. Five cultures of each isolate were incubated at each temperature and colony diameter was measured daily.

RESULTS

Isolation and identification. *P. parasitica* (*P. nicotianae* var. *parasitica* (Dast.) Waterhouse) and *P. cryptogea* were isolated from tubers from a single potato field near Hereford, TX, in which tuber rot had caused almost complete loss of the crop. The chlamydospores of *P. parasitica* were less than 35 μm in diameter and thick-walled (2.2 μm), hyphal swellings were not observed, and sporangia were papillate and ellipsoid to obpyriform. Hyphal and sporangial morphology of the *P. cryptogea* isolate agreed with the descriptions of Ribeiro (7), Newhook et al (4) and Waterhouse (13). Cultural and morphological characteristics of potato isolates of *P. parasitica* and *P. cryptogea* were similar to the previously identified isolates of these species. Morphological differences were observed between the sporangia of the potato isolates of *P. cryptogea* and *P. erythroseptica*. The sporangia of *P. erythroseptica* were larger (45–64 × 28–46 μm) than those of *P. cryptogea* (39–55 × 24–32 μm), and the shape of the *P. erythroseptica* sporangia varied from ellipsoid to obpyriform, whereas those in *P. cryptogea* were ovoid.

Isolates TX 21001 and TX 21002 were selected as representatives of *P. parasitica* and *P. cryptogea*, respectively, for further study. At least one other unidentified *Phytophthora* species was observed in infected tubers.

Pathogenicity tests. *Buds.* Significantly more buds rotted after inoculation with TX 21002 (160 of 264) than with TX 21001 (33 of 264). For the control, 2 of 264 were rotted. Discoloration of surviving buds was observed among all treatments, with the greatest percentage of darkened buds occurring among those inoculated with TX 21002 (65%), the least among the controls (45%), and an intermediate amount among those inoculated with isolate TX 21001 (57%). There was a difference in the number of green healthy buds among cultivars (Table 1). The cultivar × isolate interaction was not significant. Differences in the mean number of healthy buds per

Table 1. Mean number of healthy buds among bud pieces of cultivars and lines inoculated with TX 21001 and TX 21002 38 days after inoculation

Cultivar or line	Mean number of healthy buds[x]
Red LaSoda (A)[y]	3.6 a[z]
Red LaSoda (B)	3.1 ab
TXND 14-1 Ru	2.7 abc
MNTX 9-46-1 Ru	2.5 abc
NDTX 5-15-1 Ru	2.2 bcd
Norgold Russet (A)	1.9 bcd
MNTX 8-57-1 Ru	1.8 cd
Norgold Russet (B)	1.7 cd
NDD 143-1 Ru	1.6 cd
Lemhi Russet (A)	1.5 cd
Lemhi Russet (B)	1.1 d

[x] Pooled means of four replicates of six buds inoculated with *Phytophthora parasitica* (TX 21001) and four inoculated with *P. cryptogea* (TX 21002) per cultivar. Cultivar × isolate interaction was not significant.

[y] (A) and (B) represent two sources of the three cultivars.

[z] Means of eight replicates of six bud pieces per replicate. Means followed by the same letter do not differ significantly at $P = 0.05$ according to Duncan's multiple range test.

Table 2. Mean length of lesions on Norgold Russet potato stems inoculated with TX 21001 in the greenhouse

Inoculation treatment	Mean length of lesions (mm)		
	13 Days[a]	19 Days	40 Days
Unwounded	0[b]	9	0
Wounded stem	12	35	23
Wounded roots	0	13	30

[a] Days after inoculation.

[b] Mean length (mm) for three replicates.

replicate were significant among those inoculated with TX 21002 (0.1 bud), those inoculated with TX 21001 (2.2 buds), and the controls (3.3 buds).

Stem. Average lesion size varied with the technique used to inoculate potato stems with TX 21001 (Table 2). Stem injury resulted in a more rapid development of lesions and wounding of either stems or roots promoted infection by TX 21001. We did not observe wilting or any other foliar symptom.

Severity of disease caused by the two isolates of *Phytophthora* and the response of the cultivars and lines to the stem inoculations differed (Table 3). Isolates did not differ in aggressiveness.

Tubers. With mature tubers, external and internal symptoms varied according to the isolate. Because of the difference in external symptoms expressed in inoculated Norgold Russet and Red LaSoda tubers, each was evaluated with a different rating scale (Table 4). Purple discoloration of the periderm around buds and lenticels of inoculated tubers was more distinct on Red LaSoda than on Norgold Russet, whereas a degeneration of buds was more evident on Norgold Russet tubers than on Red LaSoda. In both cultivars, external symptoms on tubers inoculated with TX 21001 resembled those of tubers inoculated with *P. parasitica*, and symptoms of tubers inoculated with TX 21002 resembled those caused by *P. cryptogea* and *P. erythroseptica*.

When tubers inoculated with any of the five isolates were cut open, symptom development was similar to that previously described for pink rot of potato (8). Internal tissues were initially cream-colored. With exposure to air, tissues gradually turned salmon pink (noticeable after only 1 min) and became intensely discolored after about 20 min. Tissues exposed longer became darker pink, then dark brown to black after 1 hr or more. Tissues were odorless unless invaded by secondary microorganisms. Discoloration of tissues inoculated with TX 21001 and *P. parasitica* often developed in distinct mottled patterns, whereas the discoloration of tissues inoculated with TX 21002, *P. cryptogea*, and *P. erythroseptica* was more diffuse (Fig. 1). Distinct patterns of discoloration were also more common in inoculated Norgold Russet tubers than in Red LaSoda tubers. Internal tissues just below the periderm were darkened irregularly.

Symptoms resembling pink rot developed in tubers of all cultivars and lines inoculated with TX 21001 and TX 21002. External symptoms were similar to those described earlier. Extent and intensity of discoloration of internal tissues varied with cultivar (Table 5). Differences in extent and intensity of discoloration persisted at each stage of symptom development. Bacterial soft rot was a common problem in tubers inoculated with TX 21001 because of the higher temperature used.

Temperature studies. Disease development was more advanced in tubers inoculated with TX 21001 when incubated at 35–36 C than at 20–32 or 38 C. The optimum temperature for vegetative growth was about 32–33 C for TX 21001 and 23 C for TX 21002 (Fig. 2). No growth was observed above 38 C for isolate TX 21001 or above 32 C for isolate TX 21002. Cardinal temperatures reported for TX 21001 and TX 21002 agree with those reported for *P. parasitica* and *P. cryptogea*, respectively (7).

Table 3. Disease severity of potato stems inoculated with TX 21001 and TX 21002

Cultivar or line	Disease severity[y] TX 21001	TX 21002
NDTX 5-15-1 Ru	4.7 a[z]	5.0 a
NDD 143-1 Ru	4.4 a	4.7 a
Norgold Russet	4.3 a	3.0 abc
TXND 14-1 Ru	1.7 b	3.3 ab
MNTX 8-57-1 Ru	0.9 b	2.5 bc
Red LaSoda	1.5 b	0.7 c
MNTX 9-46-1 Ru	0.8 b	0.8 c
Lemhi Russet	0.3 b	0.9 c

[y] Disease severity rated on a 0–5 scale: 0 = no disease symptoms, 1 = small lesion, 2 = enlarged lesion, 3 = enlarged lesion and wilting, 4 = lesion girdling stem and severe wilting, and 5 = necrosis of stem.
[z] Means of three to six replicates. Means in a column followed by the same letter do not differ significantly at $P = 0.05$ according to Duncan's multiple range test.

Table 4. External symptoms of Red LaSoda and Norgold Russet potato tubers inoculated with five *Phytophthora* spp. isolates and incubated 7 days at 24 C

Isolate	External surface area diseased (%) (Red LaSoda)	Disease severity[y] (Norgold Russet)
P. cryptogea	31.2 a[z]	3.0 a
TX 21002	30.0 a	2.9 a
P. erythroseptica	20.0 a	2.2 b
TX 21001	7.5 b	2.0 bc
P. parasitica	6.2 b	1.5 c
Control	0.0 b	0.0 d

[y] Disease severity based on a scale of 0–5: 0 = no symptoms, 1 = discoloration of ≤50% of buds, 2 = discoloration of >50% of buds, 3 = severe discoloration and periderm discoloration around buds, 4 = discoloration of periderm on 50% of the tuber surface, and 5 = discoloration of periderm on 50% of the surface area.
[z] Means of four replicates. Means in a column followed by the same letter do not differ significantly at $P = 0.05$ according to Duncan's multiple range test.

DISCUSSION

Pathogenicity tests demonstrated that *P. parasitica* and *P. cryptogea* isolated from diseased potato tubers in the high plains area of Texas are capable of inducing pink rot of potato. Tucker (11), in 1933, reported that *P. parasitica* isolates he had identified earlier (10) were from isolations made by Drechsler (2) from rotted tubers from Kentucky and Oklahoma. He further stated that most strains caused rapid rot of inoculated tubers. Whether these *P. parasitica* isolates caused typical pink rot symptoms is not known. Cairns and Muskett (1), in 1933, reported that two cultures of *P. parasitica* from tomato failed to cause pink rot in inoculated tubers. Rowe and Schmitthenner (9) also failed to induce pink rot by artificial inoculation of tubers with *P. parasitica* from tomato. Foliar blight of potato caused by *P. parasitica* was described by Person and Nielsen (5). In our studies, *P. parasitica* was isolated from diseased tubers displaying pink rot symptoms, and pathogenicity tests confirmed the species' ability to cause typical pink rot symptoms.

P. cryptogea has been reported by other workers to be a causal agent of pink rot (3,9). Ribeiro (7) stated that pink coloration develops in potato tubers inoculated with most pathogenic species of *Phytophthora*, except *P. infestans*, which causes brown rot. His list of 13 pathogenic species includes *P. cryptogea* and *P. parasitica*.

The two species of *Phytophthora* isolated from diseased tubers in Texas have distinctly different optimum temperatures for vegetative growth. The *P. parasitica* isolate was favored by higher optimum temperatures than the *P. cryptogea* isolate. We believe *P. parasitica*

Table 5. Disease severity in tubers of cultivars and advanced breeding lines inoculated with TX 21001 and TX 21002 and incubated 5 days at 33 and 26 C for the respective isolates

Cultivar or line	Disease severity[y] TX 21001	TX 21002
Norgold Russet	2.72 a	2.38 bc[z]
Red LaSoda	2.44 ab	2.88 ab
NDD 143-1 Ru	2.37 abc	1.88 bcd
NDTX 5-15-1 Ru	1.67 abc	3.12 a
TXND 14-1 Ru	1.33 bc	1.38 d
MNTX 9-46-1 Ru	1.17 bc	1.50 cd
Lemhi Russet	1.25 c	3.00 ab
MNTX 8-57-1 Ru	1.00 c	2.75 ab

[y] Disease severity rated on a scale of 0–5: 0 = no symptoms and ratings of 1–5 indicate increasing intensity of pink discoloration of cut tissues exposed to the air.
[z] Means of five replicates. Means in a column followed by the same letter do not differ significantly at $P = 0.05$ according to Duncan's multiple range test.

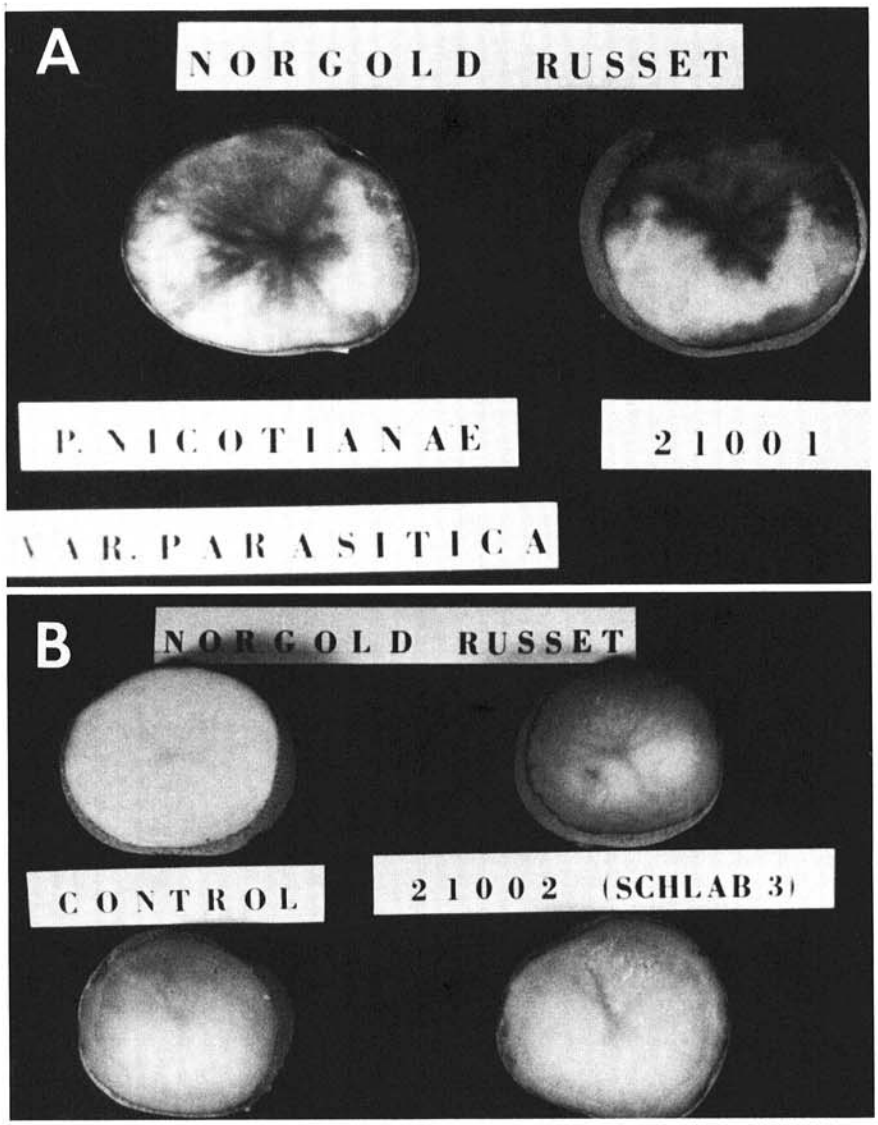

Fig. 1. Pattern of discoloration of internal potato tuber tissues inoculated with **(A)** TX 21001 and *Phytophthora parasitica* and **(B)** TX 21002, *P. cryptogea*, and *P. erythroseptica*.

is important in the epidemiology of Phytophthora rot in the high plains of Texas, where potatoes are harvested in July and August when air and soil temperatures are high.

In two pathogenicity tests, symptoms caused by *P. cryptogea* were more severe than those caused by *P. parasitica*. In these tests, temperatures were closer to the optimum temperature of *P. cryptogea*. *P. parasitica* was shown to cause the greatest amount of damage at 34–36 C.

Stem lesions, bud destruction, and reduced bud vigor were observed after artificial inoculation; however, disease incidence and severity were variable. Foliage of stem-inoculated potato plants wilted when lesions girdled the stems, but no symptom was observed on stolons, roots, or small immature tubers when the experiments were terminated. Pink rot typically develops in the field 2–3 wk before harvest, often after the foliage has been killed chemically or shredded. The two most common cultivars of potato produced in the high plains of Texas, Norgold Russet and Red LaSoda, are susceptible to both species of *Phytophthora* tested. Lemhi Russet and advanced breeding lines, which all have russet-type tubers, are also susceptible, although variation in the severity of symptoms was observed. Potential for genetic improvement of resistance to the complex of *Phytophthora* species causing tuber rot exists.

This is apparently the first report of Phytophthora rot in the Texas high plains. Potato producers, however, report that a tuber rot fitting the description of pink rot has occurred in this region for several years. Awareness of the cause of this disease in the high plains of Texas will aid in making recommendations for cultural practices that will lessen potential for losses.

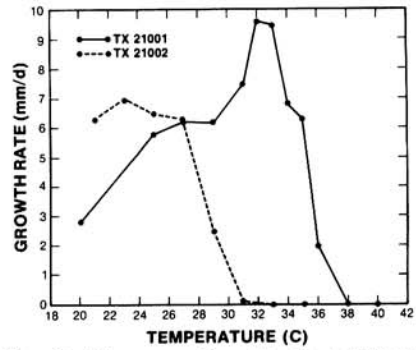

Fig. 2. Mean growth rate *Phytophthora parasitica* (TX 21001) and *P. cryptogea* (TX 21002) on cornmeal agar at 20–40 C.

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