Distribution of *Colletotrichum coccodes* in Idaho and Variation in Pathogenicity on Potato

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ABSTRACT

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Tubers and soil in potato-growing areas of Idaho and soil in native vegetation sites were surveyed for the presence of *Colletotrichum coccodes*. Colonization of tubers by *C. coccodes* was highly correlated with colony-forming units found in the soil ($r = 0.69$, $P = 0.001$). The fungus was not detected in native vegetation sites. Isolates of *C. coccodes* from each area were tested for variation in pathogenicity and symptom expression on Russet Burbank potato. All isolates reduced yield in the greenhouse by up to 14%. Some produced leaf lesions and severe wilt. Wilt was negatively correlated with tuber yield ($r = -0.64$, $P = 0.001$) and specific gravity ($r = -0.60$, $P = 0.001$). In the field, one isolate reduced total tuber yield and yield in the >280-g category. Those isolates that produced the most wilt in the greenhouse produced the most in the field.

Colletotrichum coccodes (Wallr.) S. J. Hughes, the causal organism of black dot disease of potato, is a soilborne and foliar pathogen that has been reported worldwide on may different hosts. It has been reported on tomatoes in Canada, the United States, and France (17,21) and on potatoes in the United States, Chile, and Europe (11,15,19,25). It has been reported on several weed and Solanaceous species, including velvetleaf and eastern black nightshade (1,16,27,31), and is also pathogenic on strawberry (23). In Idaho, it occurs in the soil and has been detected in Idaho-certified seed potatoes (8) (J. R. Davis, *unpublished*). It is one of the few species of *Colletotrichum* that forms sclerotia as well as conidia and acervuli (4,20,28), and sclerotia are known to survive for periods of 1 yr or more in soil (5,12,14). *C. destructivum* O'Gara has also been reported to form sclerotia, but further work is required to resolve the relationship between *C. destructivum* and *C. coccodes* (4,20).

C. coccodes is a morphologically diverse fungus with isolates varying in sclerotium size, color, aerial mycelium, and frequency of sector formation (7,18). Variability in virulence of isolates of *C. coccodes* has been established on tomato and strawberry (22,23). The effect of *C. coccodes* on several potato varieties has been examined, but the variability in virulence of the fungus on potato has not been examined thoroughly (29). Andersen and Walker (1) found an isolate of *C. coccodes* that they reported to be nonpathogenic on potato but pathogenic on eastern black nightshade. Komm (18) examined the effects of *C. coccodes* on small potato plants but did not apply the fungus to the foliage, grow them to maturity, or determine yield.

Conidia of *C. coccodes* can cause infection of potato foliage (24), roots, stolons, and tubers. Some conidia are known to survive for up to 52 wk in soil (14), although most fail to survive longer than a few weeks (5). It is not known how long conidia survive on foliage.

The objectives of this research were to determine the occurrence of *C. coccodes* in potato tubers and soil in southeastern Idaho and if differences in pathogenicity on potato occur among isolates from various areas of Idaho. Portions of this work have been published previously (2).

MATERIALS AND METHODS

Survey of potato-growing areas. In 1979 and 1980, Idaho-certified seed lots of Russet Burbank potato from 11 counties were surveyed for the presence of *C. coccodes* (Table 1). Each sample represented a composite from the stem end of 30 tubers that had been randomly selected from a range of seed lots obtained by the Idaho Crop Improvement organization. Periderm and medulla tissues were obtained from a 1-cm-diameter area around the tuber stem end. Tissue sample plugs were taken from the tuber surface to a depth of about 2 mm. The stem ends within each seed lot were pooled, air-dried, ground in a Wiley mill using a 40-mesh (425 μm) screen, and 10 mg of sample was plated five times on NPX medium (6) for each seed lot. A modified Andersen air sampler was used to apply the tissue to the medium (10).

In 1988, two seed and two commercial potato production areas were selected in eastern Idaho for soil and tuber assays for *C. coccodes* (Table 2). In each area, at least five growers' fields and one site with native vegetation were selected. In each grower's field, approximately 30 tubers were collected from a 15-m consecutive length of row by lifting the hills with a fork and removing the tubers at random. Twenty-five soil cores were taken to a depth of 15 cm from the same 15-m length of row. The soil cores were pooled and the pooled sample weighed approximately 1,400 g (wet weight). Native vegetation sites were those with sagebrush and grasses and that had never

Table 1. Survey of the incidence of *Colletotrichum coccodes* in samples of tubers from Idaho seed potato production areas

	Lots with *C. coccodes* (no.)		*C. coccodes* cfu/g of air-dried tuber stem ends[y]	
County[x]	1979	1980	1979	1980
Teton	1/10	3/10	0–20	0–160
Butte	0/7	0/10	0	0
Fremont	5/8	9/10	0–1,060	0–2,780
Caribou	2/3	2/8	0–860	0–260
Bonner	0/3	NS[z]	0	···
Lemhi	0/1	0/1	0	0
Clark	NS	1/2	···	0–280
Bonneville	NS	1/2	···	0–20
Jefferson	NS	1/1	···	1,160
Blaine	NS	1/1	···	240
Minnedoka	NS	1/1	···	20
Total	8/32	19/46	···	···

[x]County from which lots of Idaho-certified potato seed of Russet Burbank were obtained.
[y]Values represent the range of colony-forming units found among the seed lots in each county. Cfu values for each seed lot represent the means of values from five plates of NPX medium.
[z]NS = not sampled.

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been cultivated. From these sites, soil samples were taken as described earlier from a 15-m area which encompassed sagebrush and grass rhizospheres and bare areas.

In the lab, 20 tubers were selected from the original 30 tubers from a particular site by first removing tuber pieces and knobs. From the remaining tubers, 20 were randomly selected and stem ends were sampled with a 1-cm-diameter cork borer. The periderm and about 2 mm of cortex, vascular system, and outer medulla was removed, pooled, and air-dried as in 1979–1980. After 3 wk of air drying, the pooled samples were ground with a Wiley mill using a 40-mesh (425 μm) screen and 10 mg of sample was applied to each of five plates of Farley's medium (13) for each site. The tissue was applied to the medium using a modified Andersen air sampler as described by Davis et al (10). The plates were examined after at least 15 days for colonies of *C. coccodes*.

Soil from each site was air-dried, rolled to remove lumps, and randomized in plastic bags. The randomization was done by placing the 25 probes from a site in a plastic bag, filling the bag with air, and tumbling it to mix the soil. Of this soil, 200 g was weighed into beakers for wet sieving through a 355-μm onto a 74-μm sieve (13). The residue on the 74-μm sieve was brought to 100 ml with distilled water and 1-ml aliquots were plated on Farley's medium (five plates per site). The plates were washed and examined for colonies of *C. coccodes* after 3 wk.

Pathogenic variation, greenhouse studies. Isolates of *C. coccodes* were obtained from soil and tubers from various parts of Idaho during the survey of potato-growing areas. Isolations were made as mass transfers from actively growing margins of single colonies onto Farley's medium. Purity was verified with serial transfers from actively growing hyphae onto Farley's medium and by microscopic observation of conidial suspensions. Nine isolates of *C. coccodes* were selected to test for pathogenic variation (Table 3). Two isolates with different morphologies were selected from each growing area; one from soil and one from tubers. The ninth isolate came from an area outside the survey area known to have potato fields and plants heavily infested with *C. coccodes*.

Russet Burbank disease-tested, certified prenuclear mini-tubers from Plant Genetics (Davis, CA) were sprouted and planted in 10 × 10 cm pots in U.C. mix potting soil containing 2:2:1 sand/vermiculite/peat. These were grown in the greenhouse for 1 mo before inoculation. Inoculum was produced by spreading a conidial suspension of the isolates on V8 agar and growing it under continuous fluorescent light for 3 days (3). The conidia were harvested by scraping the plates with a flamed microscope slide and transferring them to sterile distilled water. The concentration of conidia was adjusted after counting with a hemacytometer to 7×10^5 to 1×10^6/ml.

At inoculation, 1 mo after planting, autoclaved sand was blown (40 kph air speed) on plants to induce wounding and simulate wind storm damage. The foliage was then sprayed to near runoff with each of the nine isolates which also contained 1% Sorbo (70% sorbitol, ICI Americas, Wilmington, DE) to aid conidial survival (Table 3). The control contained 1% Sorbo and sterile distilled water. After inoculation, the plants were covered in clear plastic sleeves to avoid cross-contamination and placed in a mist chamber for 88 hr. The amount of mist was adjusted to avoid runoff. Mist was intermittent and did not occur continuously for more than 1.5 min. During this time, the plants received natural daylight through the translucent walls of the mist chamber located in the greenhouse. After 88 hr, the plants were removed from the mist chamber, transplanted into 2-L pots, and kept in the greenhouse until the end of the experiment. This study consisted of four replications, 10 treatments, and three plants per treatment-replication in a randomized complete block design.

Data were taken from 3 to 31 May for foliar lesions and from 26 May to 28 June for wilt, which was 8–12 and 12–16 wk after planting, respectively. The presence or absence of wilt was recorded in the upper 15 cm of each plant every day. Only the upper 15 cm was checked for wilt to avoid confusion with senescence occurring in the lower leaves. On 29 June, wilt was evaluated on the whole canopy (presence or absence of ≥75% of the plant wilted or yellowing or dead). Leaf lesions were rated on a weekly basis using a modified version of the B.M.S. key for late blight infection (30) where 1 = no symptoms, 2 = up to 10 lesions per plant, 3 = up to 50 lesions per plant, 4 = nearly every leaflet infected in lower 30 cm but normal form retained, and 5 = about 50% of the leaf area in the lower 30 cm destroyed. At harvest on 5 July, tuber yield and specific gravity were determined and one 2.5-cm-long stem base per pot was collected to assay for *C. coccodes*. These were surface-disinfested in 0.525% NaOCl and air-dried. The three stem bases from a treatment-replication combination were pooled and ground in a Wiley mill with a 40-mesh (425 μm) screen. Five 10-mg samples per treatment-replication were plated on NPX medium (6). This medium was used to determine if *Verticillium dahliae* Kleb., as well as *C. coccodes*, was

Table 2. Presence of *Colletotrichum coccodes* in soil and potato tubers in 1988

Source of soil and tubers	Sites with *C. coccodes* (no.)		*C. coccodes* cfu/g of air-dried:[z]	
	Soil	Tubers	Soil	Tubers
Seed areas				
Fremont and Teton County				
Growers' fields	2/5	1/5	0–25	0–2
Native vegetation	0/1	...	0	...
Caribou County				
Growers' fields	5/5	5/5	92–211	540–4,600
Native vegetation	0/1	...	0	...
Production areas				
Bingham County				
Growers' fields	5/5	4/5	0.2–51	0–2,800
Native vegetation	0/1	...	0	...
Cassia County				
Growers' fields	6/6	4/6	2–88	0–8,000
Native vegetation	0/1	...	0	...

[z] The range of colony-forming unit values shown represent the means from five plates of Farley's medium for each field sampled.

Table 3. Isolates of *Colletotrichum coccodes* used in pathogenicity assays

Isolate no.	Origin	Morphological characteristics on NPX medium
AC-1	Tuber, Fremont County	Alternating heavy bands of round, black sclerotia
AC-4	Tuber, Bingham County	Sparse, black sclerotia mixed with conidial patches
AC-14	Tuber, Caribou County	Large, oblong, black sclerotia, conidial masses at colony periphery
AC-18	Tuber, Cassia County	Round, salmon-colored sclerotia, no conidia
AC-28	Soil, Fremont County	Large, oblong, black sclerotia, setae
AC-32	Soil, Bingham County	Large and small black sclerotia, mixed
AC-38[z]	Stem base, Elmore County	Large, round, sparse, black sclerotia
AC-40	Soil, Caribou County	Many large, round, black sclerotia, setae
AC-44	Soil, Cassia County	Small, oblong, black sclerotia, setae

[z] This isolate was obtained from a grower's field in 1988 that had symptoms of *C. coccodes* infection. This field was outside the 1988 survey area.

present. Colony counts were made after 3 wk.

Pathogenic variation, field studies. Three isolates of *C. coccodes* that varied in pathogenicity were selected from the greenhouse study to be used in the field. Russet Burbank single-drop seed potatoes were planted at Kimberly, ID, in April 1989. Inoculum was prepared as previously described. During the day of 27 June, the plants in the field were treated with air-blown, autoclaved sand, as in the greenhouse study, and immediately inoculated with a conidial suspension containing 1% Sorbo and 10^5 conidia per milliliter of isolates AC-14, AC-28, and AC-40 of *C. coccodes* (Table 3). Four liters of the suspension was applied per plot. The control treatment was also treated with air-blown sand and sprayed with 1% Sorbo. This was followed by a 30-min irrigation in the early evening using a solid-set, overhead, sprinkler irrigation system. The field design was a four by four Latin square with plots containing two 10.7-m rows separated by six noninoculated buffer rows with 3 m of buffer between the plot ends.

Wilt data were taken on 15 September by randomly selecting 60 stems per plot and rating the upper 15 cm for presence or absence of wiltlike symptoms. In the field, these symptoms appeared as cupping and pinching of the leaves rather than the wilt characteristic of *V. dahliae* seen in the greenhouse. The percentage of stems with symptoms of black dot was determined on 26 September by visually evaluating 40 stems per plot for the presence or absence of sclerotia of *C. coccodes*. Plots were harvested on 3 October and yield and specific gravity were determined. Tuber stem ends were sampled for *C. coccodes* by randomly selecting 20 tubers per plot and removing stem end cores and processing as described in the section on the survey of potato-growing areas. They were then plated on Farley's medium using the Andersen sampler as previously described.

RESULTS

Survey of potato-growing areas. In 1979 and 1980, *C. coccodes* was detected in Idaho-certified potato seed lots from all counties sampled except Butte, Lemhi, and Bonner (Table 1). *C. coccodes* was found to be widely dispersed throughout potato-growing areas with densities ranging from 0 to 2,780 cfu/g of tuber periderm tissue. In 1988, a wide range of *C. coccodes* inoculum levels (0–8,000 cfu/g of tuber periderm tissue) was detected in growers' fields (Table 2). *C. coccodes* was not detected in native vegetation sites nor in all growers' fields. Colony counts were generally higher from tubers than soil. In production areas, *C. coccodes* was detected in soil in all of the field sites and in 73% of the tuber lots in 1988. In seed areas, *C. coccodes* was detected in 70% of the soil samples and 60% of the tuber lots. Mean tuber counts of *C. coccodes* were highly correlated with mean soil counts ($r = 0.69$, $P = 0.001$).

Pathogenic variation, greenhouse studies. Some isolates of *C. coccodes* formed leaf lesions that were superficially similar to those formed by *Alternaria solani* Sorauer. When isolations were made from these lesions on V8 agar, potato-dextrose agar (PDA), and Farley's media, only *C. coccodes* was recovered. Isolate AC-40 produced the most severe lesions during the 5-wk period (Table 4). During 3 of 5 wk, the salmon-colored isolate AC-18 was not different from the control (Table 4). All other isolates were rated differently from the control except for AC-28 during week one. All treatments inoculated with *C. coccodes* had

Table 4. Effect of *Colletotrichum coccodes* isolates on potato leaf lesions and propagule densities in leaf tissue

Isolate	Leaf lesions[y]					Cfu/g of tissue[z]
	Week 1	Week 2	Week 3	Week 4	Week 5	
Control	1.00 d	1.00 e	1.33 f	1.42 g	1.33 d	0 c
AC-1	1.67 c	2.00 d	2.42 bc	2.25 c–e	2.50 c	1,450 ab
AC-4	1.83 bc	2.33 b	2.58 b	2.58 bc	2.67 bc	1,515 ab
AC-14	1.75 bc	2.00 d	2.08 c–e	2.17 d–f	2.42 c	1,760 ab
AC-18	1.08 d	1.00 e	1.75 e	1.83 f	1.75 d	1,225 b
AC-28	1.17 d	2.00 d	2.00 de	2.08 ef	2.25 c	1,040 ab
AC-32	2.00 ab	2.25 bc	2.67 b	2.83 b	3.00 b	1,180 ab
AC-38	1.75 bc	2.08 cd	2.33 b–d	2.50 b–d	2.50 c	1,705 ab
AC-40	2.25 a	2.83 a	3.17 a	3.50 a	3.92 a	2,740 ab
AC-44	1.75 bc	2.08 cd	2.50 b	2.50 b–d	3.00 b	7,030 a

[y] Within columns, treatments followed by different letters are significantly different ($P = 0.05$) according to the least squares means test. Leaf lesions based on a rating scale of 1 (no symptoms) to 5 (50% of leaf area in lower 30 cm destroyed). Data taken weekly from 3 to 31 May.

[z] Colony-forming units of *C. coccodes* per gram of air-dried stem base tissue. Tissue was collected at harvest and plated five times for each treatment and replication on NPX medium. Treatments followed by different letters are significantly different ($P = 0.05$) according to Duncan's multiple range test from $\log_{10}(x + 1)$ transformation of cfu/g of tissue.

Table 5. Effect of *Colletotrichum coccodes* isolates on wilt of potato plants in the greenhouse

Isolate	Wilt[y]					Severe wilt[z]
	Week 1	Week 2	Week 3	Week 4	Week 5	
Control	0.02 b	0.02 d	0.00 c	0.00 c	0.02 d	0.00 b
AC-1	0.02 b	0.07 cd	0.15 c	0.40 b	0.44 b	0.00 b
AC-4	0.01 b	0.02 d	0.04 c	0.08 c	0.27 c	0.00 b
AC-14	0.02 b	0.01 d	0.20 c	0.42 b	0.31 bc	0.25 b
AC-18	0.04 b	0.19 bc	0.54 b	0.83 a	1.00 a	0.25 b
AC-28	0.11 b	0.46 a	0.98 a	1.00 a	1.00 a	1.50 a
AC-32	0.10 b	0.13 cd	0.19 c	0.30 b	0.44 b	0.00 b
AC-38	0.01 b	0.04 d	0.08 c	0.12 c	0.21 c	0.00 b
AC-40	0.50 a	0.58 a	0.76 ab	0.95 a	1.00 a	1.75 a
AC-44	0.05 b	0.29 b	0.76 ab	0.93 a	1.00 a	1.50 a

[y] Plants rated for presence or absence of wilt in the upper 15 cm. Data represent means of three pots per treatment per replication and were taken daily from 26 May to 29 June. The means of the data for each week were analyzed. Within columns, treatments followed by different letters are significantly different ($P = 0.05$) according to the least squares means test.

[z] Plants rated for presence of absence of severe wilt (75% or greater of the plant was wilted or dead). Data represent means of three pots per treatment per replication and were taken on 29 June. Treatments followed by different letters are significantly different ($P = 0.05$) according to Duncan's multiple range test.

higher colony counts in the stem base than the control at harvest (Table 4). Colony-forming units of *C. coccodes* in the stem bases were positively correlated with leaf lesion data ($r = 0.62$, $P = 0.001$) and with wilt ($r = 0.35$, $P = 0.05$) and were negatively correlated with yield ($r = -0.47$, $P = 0.01$).

About 1.5 mo after inoculation, some isolates began to produce wilt symptoms, including one-sided wilt, similar to those produced by *V. dahliae*. During week one, only isolate AC-40 produced more wilt than the control (Table 5). By week five, all isolates produced significantly more wilt than the control. Plants inoculated with isolates AC-28, AC-40, and AC-44 were the most severely wilted and were almost completely dead at the end of the experiment. The plants were assayed for the presence of *C. coccodes* and *V. dahliae* on NPX medium after harvest. No *V. dahliae* was detected; only *C. coccodes* was detected. Colony characteristics of the recovered isolates were the same as the originals used to inoculate. The salmon-colored isolate (AC-18) produced only salmon-colored sclerotia on the dead stems, although *C. coccodes* typically produces black sclerotia (Table 3). The three isolates (AC-28, AC-40, and AC-44) that produced the most severe wilt and the greatest yield reduction were all obtained from soil (Tables 3, 5, and 6). Plants inoculated with some isolates (AC-18 and AC-28) were almost completely asymptomatic during much of the experiment yet still had significantly reduced yield (Table 6). Symptoms previously seen in the field were also seen in this experiment, including dead stems covered with sclerotia, lesions at the petiole base, and vein necrosis on the abaxial leaf surface.

All isolates of *C. coccodes* reduced yield in the greenhouse and four isolates reduced tuber specific gravity ($P = 0.05$) (Table 6). There was a strong negative correlation between wilt incidence and yield ($r = -0.64$, $P = 0.001$) and tuber specific gravity ($r = -0.60$, $P = 0.001$).

Pathogenic variation, field studies. All three *C. coccodes* isolates produced a significantly greater amount of wiltlike symptoms than the control on 15 September (Table 7). All isolates produced a greater percentage of stems colonized by *C. coccodes* than the control (Table 7). Although the colony-forming units in the tuber stem ends at harvest were not significantly different ($P = 0.05$), there was a five- to sixfold increase in the inoculated plots compared with the control. There was background infection in the controls even though *C. coccodes* was undetectable in field soil assays at the beginning of the experiment. In spite of this background infection in the control plots, isolate AC-14 reduced total tuber yield and the number of tubers in the >280-g size range (Table 8). Isolate AC-14 had no effect on undersized tubers or U.S. No. 1s. Isolates AC-28 and AC-40 produced no effect on yield. No isolates produced significant differences in US No. 1s, those in the <110-g category, malformed tubers, or tuber specific gravity.

Table 6. Effect of *Colletotrichum coccodes* isolates on potato tuber yield and tuber specific gravity in the greenhouse[y]

Isolate	Tuber weight (g)[z]	Tuber specific gravity
Control	598.1 a	1.080 a
AC-1	554.3 b–d	1.086 a
AC-4	559.9 bc	1.081 a
AC-14	556.4 bc	1.082 a
AC-18	544.7 b–d	1.074 b
AC-28	523.1 cd	1.074 b
AC-32	544.1 b–d	1.081 a
AC-38	562.7 b	1.082 a
AC-40	517.6 d	1.072 b
AC-44	537.1 b–d	1.070 b

[y] Within columns, treatments followed by different letters are significantly different ($P = 0.05$) according to Duncan's multiple range test.
[z] Mean tuber weight per pot of three pots per treatment per replication.

Table 7. Effect of *Colletotrichum coccodes* isolates on potato wilt, stem colonization, and populations in tuber stem ends in the field after artificial inoculations

Isolate	Stems with wilt[x] (%)	Stems colonized[y] (%)	Cfu/g of tissue[z]
Control	26.7 c	26.7 b	1,150 a
AC-14	53.3 b	58.5 a	5,840 a
AC-28	67.9 a	56.7 a	6,330 a
AC-40	68.8 a	61.0 a	5,445 a

[x] Values taken 15 September. Values within the column followed by different letters are significantly different ($P = 0.05$). Duncan's multiple range test is based on the arcsine-square root transformation of percent stems with wilt.
[y] Values taken 26 September. Values within the column followed by different letters are significantly different ($P = 0.05$). Duncan's multiple range test is based on the arcsine-square root transformation of percent stems colonized by *C. coccodes*. Colonization was determined visually by the presence of sclerotia.
[z] Colony-forming units of *C. coccodes* per gram of air-dried stem end tissue. The values shown represent the means from five plates of Farley's medium for each treatment and replication. Duncan's multiple range test from $\log_{10}(x + 1)$ transformation of cfu/g of tissue ($P = 0.05$).

Table 8. Effect of *Colletotrichum coccodes* isolates on potato tuber yield in the field

Isolate	Yield (t/ha) <110 g	U.S. No. 1's	110–280 g malformed	>280 g smooth	Total yield	Tuber specific gravity
Control	5.2 a[z]	17.3 a	8.30 a	31.0 a	61.9 a	1.079 a
AC-14	5.9 a	16.0 a	11.10 a	24.4 b	57.4 b	1.078 a
AC-28	5.4 a	13.8 a	9.22 a	30.6 a	59.0 ab	1.080 a
AC-40	4.8 a	14.7 a	10.71 a	31.6 a	61.9 a	1.078 a

[z] Values within a column followed by different letters are significantly different ($P = 0.05$) according to Duncan's multiple range test.

DISCUSSION

The results of the soil and tuber survey in Idaho indicate that even though *C. coccodes* is not present in all growers' fields, it is widespread even in seed-producing areas. It was also widespread in Indiana (18). Although *C. coccodes* was detected in 100% of the production fields included in the 1988 survey, it could not be detected in certain production fields sampled subsequently and was not detected in all seed-area fields. The fact that *C. coccodes* was not detected in native vegetation areas and some of the fields in seed areas suggests that seed potatoes may be an important method of introducing the disease into soils where it has not been found previously. This has been shown to be possible in a study by Barkdoll and Davis (*unpublished*) in which Russet Burbank seed potatoes naturally infested with *C. coccodes* were grown in the greenhouse. After 3.5 mo, *C. coccodes* was detected in the soil. The high correlation found between soil and tuber counts of *C. coccodes* also supports this idea. Similar correlations between soil and stem tissue counts of *C. coccodes* have been reported by Davis and Everson (8).

An alternative explanation may be that the fungus exists in undetectable levels until production of a host crop, such as potato, allows it to multiply to detectable levels. This may have been

occurring during field studies on pathogenic variation because initial soil assays before planting did not detect *C. coccodes*, yet some infection of tubers occurred in the control plots. It also may be introduced to new areas during dust storms, which are common in southern Idaho and eastern Oregon.

We found that under experimental conditions, we can cause previously unreported leaf lesions in potato by foliar inoculations with conidia of *C. coccodes*. Pantidou and Schroeder (26) showed that infected tomato foliage provided inoculum for fruit infection. Conidia can survive for at least 1 wk on potato foliage under dry conditions (A. W. Barkdoll and J. R. Davis, *unpublished*). We can cause disease in the greenhouse or field via foliar inoculation with conidia in the presence of mist or irrigation and with or without wounding. Under experimental conditions, conidia can cause foliar infection. This suggests the potential for foliar infection and disease spread via conidia under the arid conditions of southern Idaho when aided by the use of sprinkler irrigation and wind storms, which are both common in southern Idaho. Fields with overhead irrigation in the Egin Bench area of Idaho had a greater incidence of *C. coccodes* than fields with gravity flow irrigation (J. R. Davis, *unpublished*).

Symptom expression was quite severe in the greenhouse pathogenicity tests. In the field, nutrient and growth conditions were optimum for potato and symptoms were mild. Some researchers have suggested that *C. coccodes* is more severe under stress conditions (18). Field control plots also had a background level of infection, whereas greenhouse controls did not. These factors may explain why fewer effects of inoculation with *C. coccodes* were seen in the field.

The results of the pathogenicity studies suggest several reasons why this disease may often be overlooked. Symptom expression occurs late in the growing season when it could be confused with natural senescence. Wilt symptoms have been mentioned by other researchers, but they have not reported wilt data (16). The wilt symptoms may appear similar to those produced by *V. dahliae*, and *C. coccodes* has been shown to have additive effects with *V. dahliae* in reducing tuber yield (S. K. Mohan and J. R. Davis, *unpublished*). This may further add to *C. coccodes* being overlooked as a primary disease-causing organism. Lesions of *C. coccodes* do not have concentric rings of raised and depressed necrotic tissue which give the "bull's-eye" appearance to *A. solani* lesions. Although leaf lesions are distinguishable from those produced by *A. solani*, they might be overlooked if one is not looking specifically for them. Also, yield loss can occur with very little symptom expression. Some isolates do not produce the typical black sclerotia and there may be isolates that do not produce sclerotia at all. Growers may not only suffer a yield loss but a loss in specific gravity, which is a loss of quality. The yield losses from field-grown potatoes in this study correspond in quantity to yield losses observed earlier by Davis et al (9).

Although infection in the field may result from foliar inoculations, symptoms were not as severe as naturally occurring symptom development. When we understand the factors needed to create these symptoms, we may also understand ways in which to control the disease. Research into factors related to plant stress may be fruitful for better understanding the black dot disease of potato.

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LITERATURE CITED

1. Andersen, H. N., and Walker, H. L. 1985. *Colletotrichum coccodes*: A pathogen of eastern black nightshade (*Solanum ptycanthum*). Weed Sci. 33:902-905.
2. Barkdoll, A. W., and Davis, J. R. 1989. The relationship of *Colletotrichum coccodes* to potato tubers and soil in Idaho. Am. Potato J. 66:506.
3. Barksdale, T. H. 1967. Light induced in vitro sporulation of *Colletotrichum coccodes* causing tomato anthracnose. Phytopathology 57:1173-1175.
4. Baxter, A. P., Van Der Westhuizen, G. C. A., and Eicker, A. 1983. A review of literature of the taxonomy, morphology and biology of the fungal genus *Colletotrichum*. Phytophylactica 17:15-18.
5. Blakeman, J. P., and Hornby, D. 1966. The persistence of *Colletotrichum coccodes* and *Mycosphaerella ligulicola* in soil with special reference to sclerotia and conidia. Trans. Br. Mycol. Soc. 49:227-240.
6. Butterfield, E. J., and DeVay, J. E. 1977. Reassessment of soil assays for *Verticillium dahliae*. Phytopathology 67:1073-1078.
7. Chesters, C. G. C., and Hornby, D. 1965. Studies on *Colletotrichum coccodes* I. The taxonomic significance of variation in isolates from tomato roots. Trans. Br. Mycol. Soc. 48:573-581.
8. Davis, J. R., and Everson, D. O. 1986. Relation of *Verticillium dahliae* in soil and potato tissue, irrigation method, and N-fertility to Verticillium wilt of potato. Phytopathology 76:730-736.
9. Davis, J. R., Mohan, S. K., Sorensen, L. H., and Schneider, A. T. 1988. *Colletotrichum coccodes* on potato foliage, the association with metribuzin, yield losses, and colonization of tubers. Am. Potato J. 65:475-476.
10. Davis, J. R., Pavek, J. J., and Corsini, D. L. 1983. A sensitive method for quantifying *Verticillium dahliae* colonization in plant tissue and evaluating resistance among potato genotypes. Phytopathology 73:1009-1014.
11. Dickson, B. T. 1926. The "black dot" disease of potato. Phytopathology 16:23-41.
12. Esser, W. A. II 1978. Survival and control of *Colletotrichum coccodes* in field soil. M. S. thesis. Purdue University, West Lafayette, IN. 81 pp.
13. Farley, J. D. 1972. A selective medium for assay of *Colletotrichum coccodes* in soil. Phytopathology 62:1288-1293.
14. Farley, J. D. 1976. Survival of *Colletotrichum coccodes* in soil. Phytopathology 66:640-641.
15. Fernandez, M. C. 1987. Identificacion de *Colletotrichum atramentarium* (Berk et Br.) Tamb. (syn. *C. coccodes* (Wallr.) Hughes) en papa. Agric. Tec. Santiago 47:184-186.
16. Harrison, D. E. 1963. Black dot disease of potato. J. Agric. Victoria Aust. Dec.:573-576.
17. Illman, W. I., Ludwig, R. A., and Farmer, J. 1959. Anthracnose of canning tomatoes in Ontario. Can. J. Bot. 37:1237-1246.
18. Komm, D. A. 1979. Biology, etiology and epidemiology of *Colletotrichum coccodes* on *Solanum tuberosum*. Ph.D. dissertation. Purdue University, West Lafayette, IN. 152 pp.
19. Komm, D. A., and Stevenson, W. R. 1978. Tuber-borne infection of *Solanum tuberosum* 'Superior' by *Colletotrichum coccodes*. Plant Dis. Rep. 62:682-687.
20. Lenne, J. M. 1978. Studies on the biology and taxonomy of *Colletotrichum* species. Ph.D. dissertation. University of Melbourne, Melbourne, Australia. 454 pp.
21. Loprieno, N. 1961. Investigations on tomato anthracnose on the growth of *Colletotrichum coccodes* (Wallr.) Hughes. I. The influence of carbohydrates. Caryologia 14:219-229.
22. Loprieno, N., and Guglielminetti, R. 1962. Investigations on tomato anthracnose III. The influence of amino acids on the growth of *Colletotrichum coccodes* (Wallr.) Hughes. Phytopathol. Z. 45:312-320.
23. Maas, J. L., and Howard, C. M. 1985. Variation of several anthracnose fungi in virulence to strawberry and apple. Plant Dis. 69:164-166.
24. Mohan, S. K., and Davis, J. R. 1986. Pathogenicity of *Colletotrichum coccodes* to the aerial parts of potato plant. (Abstr.) Phytopathology 76:845.
25. Otazu, V., Gudmestad, N. C., and Zink, R. T. 1978. The role of *Colletotrichum atramentarium* in the potato wilt complex in North Dakota. Plant Dis. Rep. 62:847-851.
26. Pantidou, M. E., and Schroeder, W. T. 1955. Foliage as a source of secondary inoculum for tomato anthracnose. Phytopathology 45:338-345.
27. Raid, R. N., and Pennypacker, S. P. 1987. Weeds as hosts for *Colletotrichum coccodes*. Plant Dis. 71:643-646.
28. Sutton, B. 1980. The Coelomycetes. Commonw. Mycol. Inst./Assoc. Appl. Biol., Kew, England. 696 pp.
29. Thirumalachar, M. J. 1967. Pathogenicity of *Colletotrichum atramentarium* on some potato varieties. Am. Potato J. 44:241-244.
30. Umaerus, V. 1987. Disease assessment of late blight (*Phytophthora infestans*) in the foliage. Pages 21-27 in: Potato Disease Assessment Keys. European Association for Potato Research.
31. Wymore, L. A., Poirier, C., Watson, A. K., and Gotlieb, A. R. 1988. *Colletotrichum coccodes*, a potential bioherbicide for control of velvetleaf (*Abutilon theophrasti*). Plant Dis. 72:534-538.