Effect of *Colletotrichum coccodes* on Potato Yield, Tuber Quality, and Stem Colonization During Spring and Autumn

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ABSTRACT

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The response of five potato cultivars to *Colletotrichum coccodes* was tested in artificially inoculated fields for three consecutive spring and autumn seasons during 1994 to 1996. Significant yield reductions (22 to 30%) were observed in all tested cultivars. Results varied between years, but yield losses were more severe in autumn than in spring. Stem infections of plants were observed 90 days after planting on the surface of the stem and in vascular tissue. *C. coccodes* inoculation also resulted in reduction of the quality of daughter tubers. Cultivars Cara and Nicola were found to be less susceptible to tuber infection than Alpha, Desiree, and Agria. The incidence of diseased daughter tubers was higher when the soil was infested than when the foliage was inoculated. *C. coccodes* contamination of dry stems at harvest (in inoculated plots) was relatively high in all cultivars, with no difference between inoculation methods. Thus, *C. coccodes* infection not only affects potato yield and the quality of potatoes for seed and consumption, but also contaminates soil and serves as an important source of inoculum for future potato crops.

Additional keywords: black dot, early dying of potato, *Solanum tuberosum*

Black dot of potato (*Solanum tuberosum* L.), caused by *Colletotrichum coccodes* (Wallr.) S.J. Hughes, is characterized by the development of small black sclerotia on senescent and dead plant tissue, on decaying roots and stems, and on stolons and daughter tubers (3,16). Until the early 1990s, the disease had been considered of minor importance throughout potato growing areas worldwide (9,11,14,19–22); but its importance has increased, and it now causes economic losses severe enough to necessitate implementation of control measures (1,2,4,17). The fungus, originally thought to be predominantly a tuber-borne pathogen, can be introduced into the soil through contaminated seed tubers. There, it establishes itself and eventually serves as a soilborne inoculum for future crops (7,16,18). However, recent reports on foliar infections indicate that *C. coccodes* might also be classified as an airborne pathogen (8,10,13). The disease might be affected by biotic (13) and abiotic factors (21). In Israel, *C. coccodes* recently caused economic damage in several commercial fields, reducing yields and infesting soil and tubers. Prior to planting, most of these

fields had been fumigated with methyl bromide, vapam, or formalin (23).

The objectives of this study were to evaluate potato yields and quality in infected plots during autumn and spring, and to document the development of disease due to *C. coccodes*.

MATERIALS AND METHODS

Experimental design and cultivars. Six field experiments (one in the spring and one in the autumn of each year) were conducted during 1994 to 1996 at Gilat Experiment Station (located in the northern Negev) in loess soil (organic matter 0.2%, CaCO₃ 13.1%, moisture-holding capacity 24%, pH 7.6). Cultivars used in the experiments and dates of planting and harvest are listed in Table 1. In each experiment, *C. coccodes*-inoculated potato plants were compared with noninoculated control plants in a split plot design (30 m apart). In each split plot, cultivars were arranged in randomized complete blocks with five replicates. The experiment in spring 1994 included an additional control plot, which was adjacent to the inoculated area and

was used for yield evaluation. Plot size for each replicate was four beds wide (bed width 1.85 m) by 6 to 8 m long. The two central beds were used for data collection.

Cultural practices. Certified potato seeds imported from the Netherlands were used for spring planting, and locally produced seeds were used for autumn. The trials were conducted each season on separate plots that had not been cultivated with potatoes for at least 7 to 12 years prior to the experiment; therefore, soil fumigation was deemed unnecessary. All plots were sprinkler irrigated and farmed according to the recommendations for commercial potato production in this region, including preirrigation and broadcast application of composted cow manure.

Inoculation procedures. In the field trials conducted during 1994, the soil was artificially infested. Dry potato stems heavily infected with *C. coccodes* sclerotia were collected from a commercial field at Kibbutz Nir Yitzhak. Stems were cut into 10- to 15-cm pieces, spread evenly on the plots (50 kg of dry stems per ha), and incorporated into the soil by plowing. Segments from representative stems were surface-sterilized with 1% NaClO for 5 min and plated on potato dextrose agar (PDA) (Difco Laboratories, Detroit, MI). After 5 days of incubation at 27°C, characteristic colonies of *C. coccodes* were detected; stems were free of *Verticillium dahliae*.

In the control plots of both 1994 experiments, disease symptoms developed naturally, probably by foliar infection from adjacent inoculated plots. This indicates that growing conditions in Israel are favorable for spread of the disease by foliar infection. Therefore, in the trials of 1995 to 1996, *C. coccodes* was applied via foliar inoculations (instead of soil infestation), a method that is more accurately quantifiable and repeatable. *C. coccodes* used for foliar inoculation in the experiments of 1995 to 1996 was originally isolated from an infected tuber (cv. Alpha, grown in Kibbutz

Table 1. Cultivars used in the experiments and dates of planting and harvest

Cultivar	Season	Planted	Harvested
Desiree	Spring	25 March 1994	20 July 1994
Alpha, Cara, Nicola, Agria	Autumn	6 October 1994	5 April 1995
Alpha, Cara, Nicola, Desiree	Spring	29 March 1995	23 July 1995
Alpha, Cara, Nicola, Agria	Autumn	18 September 1995	18 March 1996
Alpha, Cara, Nicola, Desiree	Spring	3 March 1996	30 June 1996
Alpha, Cara, Nicola, Agria	Autumn	26 September 1996	28 March 1997

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Nir Yitzhak): segments were taken from the stolon end, surface-sterilized, and placed on PDA. A 10-mm agar disk was removed from a 3-day-old culture of *C. coccodes*, placed in potato dextrose broth (Difco), and grown for 4 to 5 days at 27°C with continuous shaking. The conidial suspension was adjusted with sterile water to a final concentration of 1 to 5 × 10⁶ CFU/ml and sprayed on the foliage at a rate of 400 liters/ha, 50 to 60 days after planting.

Yield evaluation. In all experiments, potato tubers were manually harvested from 4 to 6 m of the two central rows (1.85-m width, total area 7.5 to 11.0 m²) of each plot. Tubers were graded according to standard marketable size (diameter 0 to 35, 35 to 55, or >55 mm), counted, and weighed.

Assessment of disease incidence in tubers. All daughter tubers harvested for yield evaluation were inspected visually for symptoms of *C. coccodes*. Tubers bearing even one grayish spot with black sclerotia were considered infected, and the percentage of these symptomatic tubers was determined.

Assessment of stem infection. At each harvest, 20 to 25 dry stems were collected from each replicate, and the percentage of sclerotia-bearing stems was determined by visual inspection. The sampled dry stems were also examined for the presence of *V. dahliae*.

Ninety days after planting, while foliage was still green, 8 to 10 plants (two to four stems each) were randomly sampled in each inoculated replicate. Colonization of plant tissue with *C. coccodes* was determined for aboveground stems (2 to 3 cm above soil level) and belowground stems (2 to 3 cm below soil level), and from both the surface layer of the stems as well as

their vascular bundles. Stems were surface-sterilized with 1% NaClO for 5 min, and from each stem, 12 segments (6 below and 6 above soil level) were taken from the surface or the vascular bundles and placed on Sorbose Agar (SA) (2% Sorbose, 1.5% agar, and 100 ppm streptomycin sulfate). Plates were incubated for 7 days in the dark at 27°C, segments from which *C. coccodes* grew were counted, and the percentage of infected stems was calculated. In the autumn 1994 experiment, the number of CFU in the sampled stems was determined: 10 to 12 segments (each 20 mm long) of the belowground stem were macerated in an Ultraturrax blender (Janke Kunkel, Staufen, Germany) with 3 ml of sterile water for 60 to 90 s at 40°C. Serial dilutions were prepared in water, and 0.1-ml duplicate aliquots were plated on SA. After 7 days of incubation at 27°C, *C. coccodes* colonies were counted.

Assessment of root infection. In the experiments of autumn 1994, and spring and autumn 1996, roots from plants sampled for stem colonization were surface-sterilized with 1% NaClO for 5 min, and 8 to 12 segments (each 20 mm long) were placed on SA. Plates were incubated for 7 days in the dark at 27°C, segments from which *C. coccodes* grew were counted, and the percentage of plants with root infection was calculated.

Statistical analyses. Disease incidence and tuber yield were evaluated by one- or two-way analysis of variance (ANOVA). Treatment groups were: inoculation with the fungus and/or potato cultivars. Means were separated by Tukey-Kramer multiple range test. Data taken as percentages were transformed by arcsine before analysis. All analyses were performed with the StatSoft program (Tulsa, OK) at *P* < 0.05.

RESULTS

Effect of *C. coccodes* on yield. The effect of *C. coccodes* inoculation on tuber yield was evaluated, and significant yield reductions were observed (Table 2). Significant yield reductions occurred in each of the five tested cultivars as a result of *C. coccodes* infection in at least one of the experiments. In experiments carried out in three consecutive spring seasons, yield reductions were observed only twice: in 1994 in Desiree (27%) and in 1995 in Alpha (30%). In experiments carried out in three consecutive autumn seasons, significant yield reductions were observed eight times: in 1994, 1995, and 1996 in Agria (19, 26, and 27%, respectively), in 1994 and 1995 in Cara (23 and 26%, respectively) and Nicola (22 and 21%, respectively), and in 1995 in Alpha (28%). Substantial yield losses occurred more frequently in autumn than in spring. This is particularly evident when comparing yield losses in the three cultivars tested in both seasons. In Cara and Nicola, no significant yield reductions were observed in the spring, while in autumn significant yield reductions occurred in two of the three experiments (in 1994 and 1995). With Alpha, there was no difference in yield reductions between spring and autumn seasons. With Desiree, tested only in the spring, a significant yield reduction was obtained in one of the three experiments (1994); in Agria, tested only in autumn, significant yield losses were observed in all three experiments.

In the spring 1994 trial, when only Desiree was tested, yield in the infested plot was significantly less (27.0%) than yield in the standard control plot (at a distance of 30 m from the infested plot) (Table 2) and only slightly less than in the adjacent non-infested plot (29.07 t/ha, which is a reduction of 11.9%).

The effect of *C. coccodes* inoculation on yield in the three autumn seasons varied considerably: a significant yield reduction was observed in three cultivars in autumn 1994 and in all four cultivars in autumn 1995. In contrast, in autumn 1996, the yield of only one cultivar (Agria) was affected.

Disease incidence in daughter tubers.

The percentages of daughter tubers contaminated with *C. coccodes* were evaluated in inoculated and control plots (Table 3). In the spring and autumn of 1994, a considerable portion (21.5 to 33.6%) of the tubers from inoculated plots of all cultivars except Cara (2.9%) were contaminated with *C. coccodes*. In 1995 and 1996, the incidences of contaminated tubers in the inoculated plots were very low (0 to 1%) in Cara and Nicola (tested in both seasons) and higher in Agria (4.1 and 6.8%, tested only in autumn). Variable incidences of contaminated tubers were detected in Alpha (0 to 23%) and Desiree (3 and 16.5%).

Table 2. Effect of *Colletotrichum coccodes* on yield in spring and autumn 1994 to 1996

Season	Cultivar	Treatment ^x	Yield (t/ha) ^y		
			1994	1995	1996
Spring	Alpha	Control	NT ^z	23.6 a	18.9 a
		<i>C. coccodes</i>	NT	16.5 b	16.2 a
	Cara	Control	NT	23.6 a	23.5 a
		<i>C. coccodes</i>	NT	21.1 a	20.8 a
	Nicola	Control	NT	21.9 a	18.9 a
		<i>C. coccodes</i>	NT	19.3 a	18.8 a
Autumn	Desiree	Control	33.0 a	28.2 a	29.5 a
		<i>C. coccodes</i>	24.1 b	24.6 a	28.7 a
		<i>C. coccodes</i>	24.1 b	24.6 a	28.7 a
	Alpha	Control	30.4 a	26.1 a	23.2 a
		<i>C. coccodes</i>	27.2 a	18.8 b	22.1 a
	Cara	Control	22.0 a	21.6 a	29.5 a
		<i>C. coccodes</i>	17.0 b	16.1 b	24.9 a
	Nicola	Control	27.0 a	32.8 a	23.2 a
		<i>C. coccodes</i>	21.0 b	25.8 b	23.0 a
	Agria	Control	21.0 a	23.1 a	27.3 a
		<i>C. coccodes</i>	17.0 b	17.1 b	20.0 b

^x In 1994, soil was infested by incorporation of dry potato stems infected with *C. coccodes* into the soil. In 1995 and 1996, conidial suspension of *C. coccodes* at a concentration of 1 to 5 × 10⁶ CFU/ml was sprayed on the foliage.

^y Tubers were harvested from each replicate, total area of 7.5 to 11.0 m². ANOVA was carried out for each season separately, and means were separated by Tukey-Kramer multiple range test (*P* < 0.05). Different letters within columns indicate significant difference between treatments in each cultivar.

^z NT = not tested.

In some of the experiments, the incidences of infected tubers in the control plots were relatively high (especially in Alpha), and no significant differences were observed between inoculated and control plots (e.g., Alpha in autumn 1994 and spring 1995, Agria in autumn 1996).

Incidence of *C. coccodes* sclerotia on dry stems. At the end of the season, the percentages of dry stems bearing *C. coccodes* sclerotia were determined (Table 3). Dry stem infection was detected in inoculated and control plots, with almost no significant difference between the cultivars (Table 3). In general, however, incidence of contaminated dry stems was high in the autumn of 1994 and 1995 and in spring 1996, and lower in spring 1995 and autumn 1996.

***C. coccodes* colonization in stems.** Stems of plants from inoculated plots, sampled 90 days after planting, were assessed for *C. coccodes* colonization. The

incidence of below- and aboveground infected stems, on the stem surface (Table 4) or in the vascular tissue (Table 5), was determined. *C. coccodes* was detected on the surface and in the vascular tissue of all cultivars.

CFU of *C. coccodes* in belowground stems was determined only in autumn 1994. Colonization in Agria (1×10^5 CFU/g of stem) was significantly higher ($P < 0.05$) than in Nicola, Cara, and Alpha (3.2×10^4 , 6.1×10^4 , and 6.6×10^4 CFU/g, respectively). Vascular colonization of *C. coccodes* in Agria in this experiment was also higher than in the other cultivars in all years (Table 5).

Root infection by *C. coccodes*. Fungal colonization of roots was determined in plants from inoculated plots 90 days after planting in the autumn of 1994 and in autumn and spring of 1996. Root infection was detected in plants from all cultivars. In autumn 1994, the incidences of root-in-

fected plants were 26.2 to 55.5%, with no significant difference among cultivars. In the spring of 1996, the incidence of root infection was significantly lower ($P < 0.05$) in Nicola (23.1%) than in the other cultivars (82.5 to 87.8%). In the autumn of 1996, the percentage of root infected plants was significantly higher in Agria (38.6%) than in the other cultivars (6.6 to 8.9%).

DISCUSSION

Artificial inoculation of five potato cultivars with *C. coccodes* resulted in significant yield losses. These results indicate that under the growth conditions in Israel (semiarid climate and use of sprinkler irrigation), considerable yield losses may occur due to *C. coccodes* infection. Most reports on the economic damage of *C. coccodes* to potato refer mainly to its effect on the quality of the tubers. Only a limited number of reports indicate a significant reduction in total yield under controlled

Table 3. Infection of tubers and stems by *Colletotrichum coccodes* at harvest

Season	Cultivar	Treatment ^v	% infected tubers ^w			% infected dry stems ^x		
			1994	1995	1996	1994	1995	1996
Spring	Alpha	Control	NT ^y	17.0	3.6	NT	58.6	33.3
		<i>C. coccodes</i>	NT	23.0 a ^z	4.0 b	NT	47.6 a	67.7* a
	Cara	Control	NT	1.0	0.0	NT	36.1	68.3
		<i>C. coccodes</i>	NT	0.0 b	1.1 b	NT	27.3 a	89.2 a
	Nicola	Control	NT	0.0	0.0	NT	35.2	43.1
		<i>C. coccodes</i>	NT	1.0 b	1.9 b	NT	43.8 a	63.8* a
Autumn	Desiree	Control	6.3	4.0	5.7	38.5	16.9	64.7
		<i>C. coccodes</i>	33.6*	3.0 b	16.5* a	62.4*	19.7 a	87.9 a
	Alpha	Control	26.6	0.0	2.9	43.1	NT	14.0
		<i>C. coccodes</i>	38.1 a	0.5 b	15.6* a	67.6* a	79.2 b	38.4* a
	Cara	Control	0.1	0.0	0.0	64.8	NT	8.0
		<i>C. coccodes</i>	2.9 c	0.2 b	0.0 b	82.6 a	77.3 b	37.6* a
	Nicola	Control	5.3	0.0	0.0	58.2	NT	13.9
		<i>C. coccodes</i>	21.5* b	0.0 b	0.0 b	61.1 a	73.4 b	30.2* a
	Agria	Control	9.9	0.4	6.9	62.0	NT	14.5
		<i>C. coccodes</i>	27.6* ab	4.1* a	6.8 a	70.2 a	92.5 a	34.0* a

^v In 1994, soil was infested by incorporation of dry potato stems infected with *C. coccodes* into the soil. In 1995 and 1996, conidial suspension of *C. coccodes* at a concentration of 1 to 5×10^6 CFU/ml was sprayed on the foliage.

^w All harvested tubers were visually evaluated for *C. coccodes* surface infection.

^x Twenty to 25 dry stems collected after foliage destruction from each replicate were visually evaluated for *C. coccodes* sclerotia.

^y NT = not tested.

^z Two-way ANOVA was carried out for each season separately, and means were separated by Tukey-Kramer multiple range test ($P < 0.05$). Different letters within columns within a season indicate significant difference among cultivars grown in the inoculated plots only. * indicates significant difference between control and inoculated plots in each cultivar.

Table 4. Surface colonization of the above- and belowground stems of inoculated plants by *Colletotrichum coccodes* 90 days after planting^w

Season	Cultivar	1994		1995		1996	
		Above ^x	Below	Above	Below	Above	Below
Spring	Alpha	NT ^y	NT	27.8 a ^z	NT	88.5 a	95.9 a
	Cara	NT	NT	25.0 a	NT	84.4 a	92.3 a
	Nicola	NT	NT	16.7 a	NT	27.1 b	52.0 b
	Desiree	NT	NT	27.8 a	NT	79.4 a	93.0 a
Autumn	Alpha	79.2 a	75.0 a	20.4 a	20.3 a	25.8 b	22.9 b
	Cara	41.7 b	63.9 a	17.6 a	6.9 b	23.2 b	27.9 b
	Nicola	80.9 a	95.2 a	10.0 b	9.2 b	17.7 b	31.4 b
	Agria	81.3 a	81.3 a	23.3 a	24.1 a	56.2 a	64.5 a

^w Eight to 10 plants (with two to four stems on average per plant) from each inoculated replicate were collected, and from each plant 12 segments were cut from the stem surface and placed on potato dextrose agar supplemented with 100 ppm streptomycin. The percentage of infected stems is presented.

^x Aboveground stems = 2 to 3 cm from soil level, and belowground = 2 to 3 cm below.

^y NT = not tested.

^z ANOVA was carried out for each season separately, and means were separated by Tukey-Kramer multiple range test ($P < 0.05$). Different letters within columns indicate significant difference among cultivars.

greenhouse conditions (2,8,13,21), and even fewer indicate a yield loss under field conditions. In England, Read and Hide (17) did not observe a significant reduction in total yield in the field. In the United States, Barkdoll and Davis (2), Mohan et al. (13), and Johnson (8) reported significant reduction in yield in several of their experiments. However, yield reductions in these experiments were observed only in the late maturing cultivars (Russet Burbank and/or clone A68113-4) and were not observed in the early maturing cultivar (Norgold Russet). Moreover, the maximum loss reported by these researchers was only 7 to 12%. In the present study, we observed more severe yield reductions (up to 30%) in all cultivars, including early maturing cultivars (Agria and Nicola).

Since potatoes are grown in Israel in both spring and autumn, it was important to test the effect of *C. coccodes* on yield in both seasons. The results of the present study indicate that yield losses are more severe in autumn. However, even in a particular season, results were variable from year to year. Variations obtained in different years are not unusual in field experiments and may even be the rule rather than the exception in *C. coccodes* infection. Mohan et al. (13) also reported such variations in their experiments. The observed yield differences cannot be attributed to the inoculation method and may be due to differences in environmental factors. Several reports indicate that environmental conditions have an extremely strong effect on black dot expression (16,21). The difference in yield reduction between autumn and spring may be indicative of factors such as temperature and day length affecting disease expression in the field. However, the effect of each factor needs to be examined separately under controlled growth conditions. *V. dahliae* similarly causes more severe symptoms in autumn than in spring (12). It has also been shown that disease symptoms and fungal colonization were enhanced under short day growth conditions of 8:16 L:D (24). It is

possible that light duration also plays an important role in *C. coccodes* infection and may be one of the factors responsible for the severe yield losses observed in autumn. Therefore, evaluation of new clones or cultivars for tolerance or resistance to the disease should be tested in the most severe conditions (in autumn).

All the experiments were carried out in plots where potatoes had not been grown for 7 to 12 years prior to the experiment. Therefore, soilborne inoculum of *C. coccodes* was considered to be negligible. However, by the end of the season, *C. coccodes* was detected on dry stems in both control and inoculated plots in all the experiments. The infection in the control plots may be attributed to secondary foliar infection by fungal conidia, which are dispersed by wind and irrigation water drops from inoculated plots. Dispersal to adjacent plots may occur after the fungus penetrates and colonizes the upper parts of the potato plants (8). An additional source of infection in the control plots may be the seed tubers, which were checked only visually before planting and may have been latently infected with the pathogen. However, since we used tubers from the same lot in the inoculated and control plots, any significant difference in the results can only be attributed to *C. coccodes* inoculation.

At the end of the season, *V. dahliae* was detected on dry stems in both *C. coccodes*-inoculated and control plots in all experiments. In most of the experiments, the incidence of dry stems contaminated with *V. dahliae* was low (1 to 6%), with no difference between inoculated and control plots. Only in spring of 1995 was the incidence relatively high (30%) in both. Since *V. dahliae* does not usually cause yield reduction in spring potatoes in Israel (12), and in the 1995 spring, a significant yield reduction was observed only in one of the tested cultivars (Alpha), it was assumed that *V. dahliae* infection did not cause yield loss. However, a possible effect of *V. dahliae* on yield reduction, observed in the

cultivar Alpha in spring 1995, cannot be ruled out.

The incidence of infected tubers was higher in autumn 1994, when the soil was infested, than in autumn 1995, when the foliage was inoculated; although yield reductions and the incidence of contaminated dry stem were similar, indicating the importance of the inoculum source. The effect of the inoculum source on tuber infection is further supported by our observations in commercial fields, where low incidences of infected tubers were observed when natural foliar infection occurred. Tuber infection, observed in few of the controls, might also be due to secondary foliar infection. Results of the four experiments of 1995 and 1996, when foliage was deliberately inoculated, indicated that Cara and Nicola are less susceptible to tuber infection, while Alpha, Desiree, and Agria appear to be more susceptible. Read (15) also reported that Cara was less susceptible, while Desiree was the most susceptible. No difference in tuber susceptibility was observed between spring and autumn.

The high incidence of infected dry stems in all cultivars points to another deleterious effect of *C. coccodes*; even in seasons in which yield reduction and/or tuber infection were negligible, it can be expected that the soil will be contaminated with *C. coccodes* sclerotia. It was recently reported that *C. coccodes* sclerotia survive in soil for at least 8 years (6). Spraying the foliage during growth with a specific fungicide (such as prochloraze, imazalil, etc.), may reduce disease levels (5), prevent secondary foliar infection of adjacent fields, and consequently minimize soil infestation. Thus in the short term, it may prevent yield losses, and in the long term, it may minimize soil infestation and the need for fumigation.

LITERATURE CITED

1. Andrivon, D., Ramage, K., Guerin, C., Lucas, J. M., and Jouan, B. 1997. Distribution and fungicide sensitivity of *Colletotrichum coccodes* in French potato-producing areas. Plant

Table 5. Colonization of the vascular tissues of inoculated plants by *Colletotrichum coccodes* 90 days after planting^w

Season	Cultivar	1994		1995		1996	
		Above ^x	Below	Above	Below	Above	Below
Spring	Alpha	NT ^y	NT	11.1 a ^z	NT	85.5 a	85.5 a
	Cara	NT	NT	5.6 a	NT	67.3 a	67.3 a
	Nicola	NT	NT	8.3 a	NT	18.8 b	18.8 b
	Desiree	NT	NT	5.6 a	NT	68.1 a	68.1 a
Autumn	Alpha	6.3 b	6.3 b	20.4 ab	16.9 ab	13.3 b	13.4 b
	Cara	27.7 b	41.7 ab	22.8 ab	6.4 b	10.4 b	24.7 ab
	Nicola	21.4 b	26.2 b	14.1 b	12.2 b	7.2 b	12.0 b
	Agria	64.6 a	72.9 a	30.4 a	26.9 a	51.5 a	57.7 a

^w Eight to 10 plants (with two to four stems on average per plant) from each inoculated replicate were collected, and from each plant 12 segments were cut from the vascular bundles and placed on potato dextrose agar supplemented with 100 ppm streptomycin after surface sterilization. The percentage of infected stems is presented.

^x Aboveground stems = 2 to 3 cm from soil level, and belowground = 2 to 3 cm below.

^y NT = not tested.

^z ANOVA was carried out for each season separately, and means were separated by Tukey-Kramer multiple range test ($P < 0.05$). Different letters within columns indicate significant difference among cultivars.

- Pathol. 46:722-728.
2. Barkdoll, A. W., and Davis, J. R. 1992. Distribution of *Colletotrichum coccodes* in Idaho and variation in pathogenicity on potato. Plant Dis. 76:131-135.
 3. 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.
 4. Denner, F. D. N., Millard, C., Geldenhuys, A., and Wehner, F. C. 1997. Treatment of seed potatoes with prochloras for simultaneous control of silver scurf and black dot on daughter tubers. Potato Res. 40:221-227.
 5. Dillard, H. R., and Cobb, A. C. 1997. Disease progress of black dot on tomato roots and reduction in incidence with foliar applied fungicides. Plant Dis. 81:1439-1442.
 6. Dillard, H. R., and Cobb, A. C. 1998. Survival of *Colletotrichum coccodes* in infected tomato tissue and in soil. Plant Dis. 82:235-238.
 7. Jeger, M. J., Hide, G. A., van den Boogert, P. H. J. F., Termorshuizen, A. J., and van Baaren, P. 1996. Pathology and control of soil-borne fungal pathogens of potato. Potato Res. 39:437-469.
 8. Johnson, D. A. 1994. Effect of foliar infection caused by *Colletotrichum coccodes* on yield of Russet Burbank potato. Plant Dis. 78:1075-1078.
 9. Johnson, D. A., and Miliczky, E. R. 1993. Distribution and development of black dot, Verticillium wilt, and powdery scab on Russet Burbank potatoes in Washington State. Plant Dis. 77:74-79.
 10. Johnson, D. A., and Miliczky, E. R. 1993. Effects of wounding and wetting duration on infection of potato foliage by *Colletotrichum coccodes*. Plant Dis. 77:13-17.
 11. Komm, D. A., and Stevenson, W. R. 1978. Tuber-borne infection of *Solanum tuberosum* 'Superior' by *Colletotrichum coccodes*. Plant Dis. Rep. 62:682-687.
 12. Krikun, J., and Orion, D. 1979. Verticillium wilt of potato: Importance and control. Phytoparasitica 7:107-116.
 13. Mohan, S. K., Davis, J. R., Sorensen, L. H., and Schneider, A. T. 1992. Infection of aerial parts of potato plants by *Colletotrichum coccodes* and its effects on premature vine death and yield. Am. Potato J. 69:547-559.
 14. Otazu, V., Gudmestad, N. C., and Zink, R. T. 1978. The role of *Colletotrichum atramentarium* in potato wilt complex in North Dakota. Plant Dis. Rep. 62:847-851.
 15. Read, P. J. 1991. The susceptibility of tubers of potato cultivars to black dot (*Colletotrichum coccodes* (Wallr.) Hughes). Ann. Appl. Biol. 119:475-482.
 16. Read, P. J., and Hide, G. A. 1988. Effects of inoculum sources and irrigation on black dot (*Colletotrichum coccodes* (Wallr.) Hughes) and its development during storage. Potato Res. 31:493-500.
 17. Read, P. J., and Hide, G. A. 1995. Development of black dot disease (*Colletotrichum coccodes* (Wallr.) Hughes) and its effect on the growth and yield of potato plants. Ann. Appl. Biol. 127:57-72.
 18. Read, P. J., and Hide, G. A. 1995. Effects of fungicides on the growth and conidial germination of *Colletotrichum coccodes* and on the development of black dot disease of potatoes. Ann. Appl. Biol. 126:437-447.
 19. Read, P. J., Storey, R. M., and Hudson, D. R. 1995. A survey of black dot and other fungal tuber blemishing diseases in British potato crops at harvest. Ann. Appl. Biol. 126:249-258.
 20. Rowe, R. C., Davis, J. R., Powelson, M. L., and Rouse, D. I. 1987. Potato early dying: Causal agents and management strategies. Plant Dis. 71:482-489.
 21. Stevenson, W. R., Green, R. J., and Bergesen, G. B. 1976. Occurrence and control of black dot root rot in Indiana. Plant Dis. Rep. 60:248-251.
 22. Thirumalachar, M. S. 1967. Pathogenicity of *Colletotrichum atramentarium* on some potato varieties. Am. Potato J. 44:241-244.
 23. Tsrer, L., Erlich, O., Hazanovsky, M., and Peretz, I. 1994. Black dot of potato in Israel. Phytoparasitica 22:88.
 24. Tsrer (Lahkim), L., Livescu, L., and Nachmias, A. 1990. Effect of light duration and season on Verticillium wilt in potato. Phytoparasitica 18:331-339.