Cruciferous Weeds as Sources of Inoculum of *Xanthomonas campestris* in Black Rot of Crucifers

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ABSTRACT

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Cruciferous weeds were studied as a potential source of inoculum of *Xanthomonas campestris*, the causal agent of black rot of crucifers. Four transplant farms in southern Georgia and 19 sites in the seed production areas of California were surveyed, and cruciferous weeds were found to be widespread in both states. In Georgia, black rot was found on *Brassica campestris*, *Lepidium virginicum*, *Coronopus didymus*, and *Raphanus sativus*. In California, black rot was found on *B. campestris*, *B. nigra*, *B. geniculata*, *R. sativus*, and *Cardaria pubescens*. Three of the seven sites in California where black rot was found in weeds were associated with a cultivated crop of crucifers. Field plot data in Georgia showed that *X. campestris* was disseminated up to 12 m from infected weeds to cabbage. These results may explain the unusually high levels of black rot found in transplant and seed fields in the last 10 yr. More attention should be paid to controlling cruciferous weeds in transplant and seed production fields.

Black rot of crucifers, caused by *Xanthomonas campestris*, is considered the most destructive disease of crucifers worldwide (28). Black rot has been a problem for many years but has become progressively more common and therefore more economically important in the last 10 yr. Because *X. campestris* is seedborne (5,10,27), most efforts at controlling the disease have been aimed at eradicating the pathogen from seeds. Soaking seeds in hot water has been recommended for many years (2–4,25). However, such treatments have not been well accepted by industry because they reduce seed viability (8,23) and do not eradicate the pathogen completely (8,18,23). Mercury treatments can eradicate the pathogen from seeds (4), but mercury is currently not allowed by the Environmental Protection Agency. Other chemical treatments that have been tested, including chlortetracycline (Aureomycin) (24), streptomycin (8), streptomycin-sodium hypochlorite (6), and cupric acetate-hot water (18), either adversely affect seeds of some cultivars or fail to eradicate the pathogen. The development of seed assay techniques (9,17,19,22,23) has provided a means for determining if a specific seed lot contains infected seeds.

The role of soilborne inoculum in the epidemiology of black rot has been less certain than the role of seedborne inoculum. Although 3- to 5-yr crop rotations have been recommended to avoid soilborne inoculum in transplant and seed production fields (13,26,28,29), few data are available. *X. campestris* survived in

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plant debris for less than 2 yr in central Georgia (21) and less than 1 yr in the transplant production area of southern Georgia (N. W. Schaad, *unpublished*). In Hawaii, survival of *X. campestris* in soil and/or plant debris is considered the predominant factor in the annual recurrence of black rot (1).

Several cruciferous weeds are hosts of *X. campestris* (26). *Capsella bursa-pastoris* (L.) Medic. and *Raphanus raphanistrum* L. were found naturally infected in New Zealand (31) and Georgia (14), respectively. Furthermore, the pathogen was shown to be seedborne in *R. raphanistrum* (14). Inoculation studies have shown that *Brassica nigra* (L.) Koch, *Lepidium virginicum* L., *C. bursa-pastoris, R. raphanistrum,* and *B. campestris* L. are susceptible (14); however, symptoms vary from a general yellowing of *C. bursa-pastoris* and *L. virginicum* to small, V-shaped, yellow lesions with brown centers on the leaf margins of *B. nigra, R. raphanistrum,* and *B. campestris* (14). Fifteen genera and 31 species of crucifers are reported in Georgia (12) and more than 300 species in California (11). Although cruciferous weeds are abundant in the transplant area of Georgia and seed production areas of California, little attention has been given to weeds as a potential source of inoculum of *X. campestris*. This failure to consider the possible role of weeds in the epidemiology of black rot probably has been the result of the misconception that little care is required to control cruciferous weeds because many are not susceptible (2). We attempted to identify the species of cruciferous weeds around transplant beds and seed production fields, determine which species were infected with *X. campestris*, and measure how far black rot will spread from a single infected weed to a bed of cabbage plants.

MATERIALS AND METHODS

Field surveys of transplant areas in Georgia. The transplant area of southern Georgia was surveyed monthly from January to July 1980. Four farms were selected. Farm A, located west of Doerun in northwestern Colquitt County, had a fall 1979 crucifer transplant field that contained several sites of plants with black rot and was not disked until early May 1980. Farm B, located near Bridgeboro in southwestern Worth County, had a fall transplant field that contained plants with black rot but was disked during fall 1979 in preparation for spring tomato transplants. Farm C, 16 km west of Tifton, had a field that had had no crucifers for at least 3 yr and that was disked during fall 1979 in preparation for spring crucifer transplant production in 1980. Farm D, 0.8 km east of farm A, had no history of crucifer production and was in fallow before fall 1980 crucifer transplant production.

Previous inoculation studies with cruciferous weed plants in the greenhouse (14) had shown that symptoms on weeds either did not develop or were not typical of black rot symptoms on cultivated crucifers such as cabbage or broccoli. Instead of V-shaped lesions with black veins, lesions were yellow with brown centers and only occasionally V-shaped with black veins. On this basis, leaves of weed plants suspected of being infected with *X. campestris* were collected whenever observed, placed in plastic bags, and returned on ice to the laboratory within 24 hr. For *L. virginicum* and *Coronopus didymus,* which lacked recognizable symptoms in test inoculations, one or two branches from four or five plants were collected and pooled into a single sample. Such samples were collected from random sites on farms A and B on 17 January, 6 March, and 23 April. Bacteria were isolated from surface-sterilized leaves on yeast extract-dextrose-$CaCO_3$ (YDC) agar (30) as described previously (16).

To determine whether *X. campestris* was present on the surface of leaves and roots of *L. virginicum*, eight leaf and root samples were collected on 12 May. Two-plant samples were collected: four from farm A, three from farm B, and one from farm C. The weeds were located on irrigation pipelines between plant beds and along the edge of the field. The roots were detached, washed for 1–2 min in deionized water to remove loose soil, and placed in a sterile petri dish. Leaf or root material (1–2 g) was weighed, placed in 100 ml of cold, sterile 0.85% (w/v) NaCl (saline) containing one drop of Tween 80 (1% w/v), and shaken on a platform shaker for 20 min at 4 C. The suspension was diluted serially in saline, and 0.1-ml samples were plated onto triplicate plates of nutrient-starch-cycloheximide agar (NSCA [19]) and SX agar, a selective medium for *X. campestris* (20). Plates of NSCA and SX agar were examined after incubation at 30 C for 2 and 5 days, respectively. A subsample of each plant sample was dried at 60 C for 24 hr to determine dry weight, used to calculate the numbers of cells per gram of dry weight.

Cultures were identified by immunofluorescence (15) and confirmed by pathogenicity tests (20). Each strain of *X. campestris* was stored on YDC slants and by lyophilization. All weed plants collected in Georgia were identified from Radford et al (12). Immature plants without siliques were transplanted into pots and grown to maturity in a greenhouse for later identification.

Field surveys of seed production areas in California. California seed production areas along the central coast from Lompoc to Gilroy were surveyed during 13–20 March 1980 for black rot in cruciferous weeds. Sites 1, 5–9, and 15–19 were chosen at random. Sites 2–4 near Lompoc were chosen because black rot had been diagnosed in cauliflower seed plants in 1975. Sites 11–13 were chosen because black rot had been diagnosed in 1979. Site 10 was chosen because black rot was found by Monterey County seed inspectors in 1980, and site 14 was chosen because it was near sites 12 and 13.

Isolations were made within 1 day of collections at California State University at San Luis Obispo, Moran Seed Co. in Salinas, and the University of California at Davis. All suspected cultures of *X. campestris* were mailed to Georgia for identification as described above. In addition, leaf samples with black rot symptoms collected from each site were pressed for herbarium storage and were identified later from the descriptions by Munz (11). Immature plants were collected and identified as described above.

Dissemination of *X. campestris*. Circular plots were chosen to measure the approximate distance that black rot inoculum would spread from weeds to cabbage under natural field conditions. Land with no known history of crucifer production was selected for plots at the Georgia Experiment Station in Experiment and the Southwest Branch Station in Plains. Plots were laid out 15.24 m or

TABLE 1. Occurrence of cruciferous weeds on four transplant farms in Georgia

	Farm and month[a]																												
	A							B							C							D						
Weed species	J	F	M	A	M	J	J	J	F	M	A	M	J	J	J	F	M	A	M	J	J	J	F	M	A	M	J	J
Brassica campestris	+	+	+	+	−	−	−	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
B. oleracea var. *acephala*	−	−	−	−	−	−	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
Coronopus didymus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	+	+	+	+	−	−	−	−	−	−	−	−
Lepidium virginicum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	+	+	+	+	−	−	−	+	+	+	+
Raphanus raphanistrum	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−	−
R. sativus	−	−	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−	−

[a] Observations were made monthly on four farms from January to July 1980. Farm A had a fall 1979 crucifer transplant field with black rot and was not disked until May 1980. Farm B had a fall transplant field that contained black rot but was disked after harvest in preparation for spring tomato transplants. Farm C had a field with no crucifers for 3 yr and was disked in fall 1979 in preparation for spring crucifer transplants. Farm D had no history of crucifer production and remained in fallow until fall 1981 in preparation for spring crucifer transplants. + = Cruciferous weeds observed; − = no cruciferous weeds observed.

more apart, with radii of 1.52, 3.05, 6.10, and 12.19 m. Each plot was replicated four times and located by random design. Seed beds 0.5 m wide were prepared around the circumference of each plot with a hand Rotovator. Seeds of cabbage cultivar Market Prize, shown by assay (17) to be free of *X. campestris*, were hand-sown at Plains and Experiment on 18 and 25 April, respectively. Two replicates of 10,000 seeds were sown in a 1 × 5 m bed at each location as controls for natural field contamination. Vegadex (CDEC) herbicide was applied before emergence to control weeds, and Thuricide (*Bacillus thuringiensis*) and Lannate (methomyl) were applied later as needed to control insects.

One week after cabbage seeds were sown, 20 *B. campestris*, 20 *R. raphanistrum*, and four *Chenopodium amaranticolor* plants in the four- to five-leaf stage in 14-cm pots were placed in a dew chamber (Percival model E-54U-DL) set at a water temperature of 30 C and a wall temperature of 10 C. Twenty hours later, plants were removed from the chamber and gently misted with a suspension of *X. campestris* B-24 adjusted to contain approximately 1×10^7 cells per milliliter (20), being careful not to disrupt the guttation droplets. The plants were immediately returned to the dew chamber with water and wall temperatures of 25 C for 24 hr, then removed and placed on a greenhouse bench for 7 days.

One inoculated *B. campestris* or *R. raphanistrum* plant was transplanted into the center of each plot at Experiment or Plains, respectively. One inoculated *C. amaranticolor* plant was transplanted into the center of each of four 1.03-m radius circles containing cabbage plants at the four- to five-leaf stage at Experiment. Plants at Experiment were irrigated with a movable 10.16-cm sprinkler system placed permanently between the plots. Plants at Plains were irrigated with a pivot sprinkler system that moved along a cable at one edge of the field. Irrigation was applied only as needed to supplement rain. Plots were not entered from the time weeds were transplanted until disease incidence was recorded on 10 and 19 June at Experiment and Plains, respectively. Isolations were made from leaves of one or two plants with black rot symptoms from each plot.

Weed seeds. In Georgia, seeds were collected in January from infected *B. campestris* plants in an abandoned fresh-market cabbage field several kilometers from farm C and in July from volunteer *B. oleracea* L. var. *acephala* plants on farm B. In California, seeds were collected in August from *B. campestris* from sites 14 and 16, *B. geniculata* and *R. sativus* from site 16, and *Cardaria pubescens* from near site 17. Black rot symptoms were not evident when seeds were collected. All seed samples were cleaned separately by hand. Approximately 5,000 seeds collected from Georgia were assayed by liquid plating on NSCA (17) and by sowing in soil; approximately 2,000 seeds collected in California were assayed by liquid plating only.

RESULTS

Field surveys of transplant areas in Georgia. *L. virginicum* and *Coronopus didymus* were the most common cruciferous weeds observed. Both species were abundant and widespread on farms A and B from January through July (Table 1) in habitats such as sprinkler pipelines, fence lines, farm roads, and field edges. Plants of *Coronopus didymus* began flowering in January and had fully matured by July. Plants of *L. virginicum* began flowering in February, and most were fully mature by July; however, newly flowering plants were found in July on the edge of a forested area next to farm A. A few scattered plants of *L. virginicum* were found on farm D, but not until April (Table 1). Plants of *B. campestris* and *R. sativus* were scattered among cultivated plants on farms A and B and A and C, respectively. Numerous *R. raphanistrum* plants were found along a fence line on farm C. Finally, plants of *B. oleracea* var. *acephala* were scattered along an irrigated pipeline on farm B. Observations at Experiment showed that plants of *L. virginicum* were present during the entire year, and plants of *Barbarea vulgaris* var. *arcuata* (R. Br.) Fries., a species that shows black rot symptoms typical of cabbage when inoculated (N. W. Schaad, *unpublished*), were common from January through April and again beginning in October.

Symptoms of black rot were found in weeds on farms A and B but not on farms C and D (Table 2). Symptoms on leaves of *R. sativus* and *B. campestris* consisted of delimited yellow lesions, whereas no symptoms were evident on leaves of *L. virginicum* and *Coronopus didymus*. The pathogen was also isolated in January from mature *B. campestris* and *L. virginicum* plants in an abandoned fresh-market cabbage field 2–3 miles from farm C. Most of the volunteer *B. oleracea* var. *acephala* plants on farm B had symptoms of black rot, and *X. campestris* was isolated. *L. virginicum* leaf-washing samples II and VI from farm B and III from farm A contained 63, 177, and 116 cells of *X. campestris* per gram of dry weight, respectively. *X. campestris* was not detected in any of the root samples.

Field surveys of seed production areas in California. Of the seven genera and nine species of weeds found (Table 3), *C. bursa-pastoris* and *B. campestris* were most common. Both species were present in 68% (13/19) of the sites surveyed. Plants of all species were flowering except those of *Sisymbrium officinale* (L.) Scop. Symptoms of black rot were found in cruciferous weeds in 37% (7/19) of the sites (Table 3). When both weeds and cultivated crucifers were included, 63% (12/19) of the sites were positive for black rot (Table 3). Four weed species—*B. nigra*, *B. campestris*, *B. geniculata*, and *R. sativus*—were shown to be infected with *X. campestris*. The two weed species most commonly infected were *B. nigra* and *B. campestris*.

Symptoms of black rot (yellow, V-shaped lesions with brown centers on the leaf margin) were most easily recognized on leaves of *B. campestris*. Similar symptoms were evident on *B. geniculata* (Fig. 1), *B. nigra*, and *R. sativus*, but usually the yellowing was less pronounced. Leaves with black veins were rarely observed on any of the weed hosts. All isolations from plants suspected of being infected resulted in the recovery of yellow, mucoid colonies on YDC agar. Such cultures were immunofluorescence-positive and pathogenic.

Dissemination of *X. campestris*. *X. campestris* spread to most plant beds 6.1 m or less from the source of inoculum. However, only one plant bed 12 m from the inoculum source was infected (Table 4). No black rot was observed in cabbage plants in the four plots containing a *Chenopodium* plant nor in cabbage plants in the two uninoculated control plots.

Weed seeds. Seeds of *B. campestris* and *B. oleracea* var. *acephela* collected in Georgia were positive for *X. campestris* by both assays. Seeds of *B. campestris* from site 16 and *Cardaria pubescens* from site 17 in California were positive, while those of *B. geniculata* and *R. sativus* from site 16 and *B. nigra* from site 14 were negative.

TABLE 2. Presence of black rot in common cruciferous weeds associated with transplant farms in Georgia

Weed species	Date	Farm[a]	No. of samples[b] Collected	Positive
Brassica campestris	3/6/80	A	1	1
	4/23/80	A	1	1
Coronopus didymus	1/17/80	B	10	2 (B-95, B-96)[c]
	3/6/80	A	1	1
	4/23/80	A	1	1
Lepidium virginicum	1/17/80	B	1	1 (B-85)[c]
	3/6/80	A	3	0
	4/23/80	A	3	1
Raphanus sativus	3/6/80	A	1	1
	4/23/80	A	1	1

[a] Farms A and B had fall 1979 crucifer transplant fields that contained black rot. Farm A was not disked until May 1980; farm B was disked in late fall 1979.

[b] Samples consisted of leaves with definite yellow lesions except for those of *L. virginicum* and *C. didymus*, which consisted of leaves that were generally yellow. Isolations were made from surface-sterilized leaves onto YDC agar (30) as described. Only cultures pathogenic to cabbage were recorded as positive.

[c] Symbols in parentheses are the designated strain numbers for preserved cultures.

DISCUSSION

Several crucifers, including *C. bursa-pastoris*, *L. virginicum*, *R. raphanistrum*, *B. arvensis*, *B. nigra*, *B. rapa*, and *S. officinale*, are common agricultural weeds in Georgia (7). This is the first detailed report, however, identifying the major species associated specifically with crucifer transplant fields in southern Georgia, and, similarly, the first detailed report identifying the predominant cruciferous weeds associated with seed production fields in California.

Although we expected to find black rot occasionally in cabbage plants in transplant fields in Georgia, we did not expect to find the disease so often in weeds in or near transplant fields. In California, black rot is not considered a serious disease problem in the coastal crucifer production areas, but this could change. The disease occurs occasionally in fresh-market and processed broccoli, Brussels sprouts, and cauliflower, resulting in occasional minor crop loss (Arthur Greathead, *personal communication*). Seed fields generally have been considered free of black rot. In 1975, however, three cauliflower seed fields in Lompoc (our survey sites 2, 3, and 4) were found to be infected with black rot (T. Matsumoto, *personal communication*). We received seed samples collected from plants in the field, and our assays (19) detected *X. campestris* (strain B-44, N. W. Schaad, *unpublished*). Since 1975, black rot has been found in

TABLE 3. Presence of black rot in cruciferous weeds in seed-growing areas of California

Site no.	City	Type of crop or area	Cultivated crop		Major cruciferous weeds present		*Xanthomonas campestris* strain no.
			Identity	Black rot symptoms	Identity	Black rot symptoms	
1	Solvang	Cattle grazing	NA[a]	NA	*Brassica nigra*	yes	B-87
					Raphanus sativus	no	
					B. campestris	no	
2	Lompoc	Fallow	NA	NA	*Capsella bursa-pastoris*	no	
					B. nigra	yes	B-88
					B. campestris	yes	
					Sisymbrium officinale	no	
					R. sativus	no	
3	Lompoc	Seed	Cauliflower	no	*C. bursa-pastoris*	no	
					B. nigra[b]	yes	B-88 A
					S. officinale	no	
					Lepidium lasiocarpum	no	
					B. campestris[b]	yes	
					R. sativus	no	
4	Lompoc	Seed	Broccoli	no	*C. bursa-pastoris*	no	
					Sisymbrium Irio	no	
5	Lompoc	Cover crop	Vetch	NA	*B. nigra*	no	
					C. bursa-pastoris	no	
6	Santa Maria	Roadside	NA	NA	*C. bursa-pastoris*	no	
					B. campestris	no	
					R. sativus	no	
7	King City	Open, weeds	NA	NA	*C. bursa-pastoris*	no	
					B. campestris	no	
8	King City	Roadside	NA	NA	*C. bursa-pastoris*	no	
					B. campestris	no	
					Sisymbrium Irio	no	
9	King City	Roadside	NA	NA	*B. campestris*	no	
					C. bursa-pastoris	no	
10	Gonzales	Seed	Broccoli	yes	*C. bursa-pastoris*	no	
					R. sativus[c]	yes	B-89
11	Gonzales	Fresh market	Cauliflower	yes	*C. bursa-pastoris*	no	
12	Salinas	Fresh market	Cauliflower	yes	*C. bursa-pastoris*	no	
13	Salinas	Fresh market	Broccoli	yes	*C. bursa-pastoris*	no	
14	Salinas	Railroad	NA	NA	*B. nigra*	yes	
					B. campestris	yes	B-90
15	Salinas	Fresh market	Broccoli	yes	*B. campestris*	no	
16	Salinas	Seed	Cauliflower	yes	*B. campestris*[d]	yes	
					B. geniculata[d]	yes	B-92
					B. nigra[d]	yes	
17	San Juan Bautista	Roadside	NA	NA	*B. campestris*	yes	B-94
					Cardaria pubescens	no	
18	Gilroy	Open, weeds	NA	NA	*B. campestris*	no	
19	Gilroy	Seed	Broccoli	yes	*B. campestris*	no	
					R. sativus	no	
					C. bursa-pastoris	no	

[a] NA = not applicable.
[b] Infected *B. nigra* and *B. campestris* plants were growing in an uncultivated open area next to the cauliflower seed field.
[c] Infected *R. sativus* plants were growing along a roadside and mixed among the broccoli seed plants.
[d] *B. campestris*, *B. geniculata*, and *B. nigra* plants were growing on a gravel pit bank next to the cauliflower seed field.

TABLE 4. Dissemination of *Xanthomonas campestris* from weeds to cabbage in Georgia

Plot location	No. of plots with black rot[a]			
	Plot radius (m)			
	1.52	3.05	6.10	12.19
Experiment	3	3	4	0
Plains	2	3	3	1
Total	5	6	7	1

[a] Each plot consisted of a single infected *Brassica campestris* (Experiment) or *Raphanus raphanistrum* (Plains) plant growing in the center of a circular, 0.5-m wide bed of cabbage seedlings. Each plot was replicated four times, and incidence of black rot was recorded after 8 wk. The presence of *X. campestris* was confirmed by isolations and pathogenicity tests.

an increasing number of seed fields in the Salinas area by county and state regulatory inspectors (B. Oliver and T. Matsumoto, *personal communication*). Furthermore, several seed lots originating in California have been shown to contain *X. campestris*-infected seeds by our routine Georgia seed certification assays (N. W. Schaad, 1978 and 1979 annual reports to NCR-100).

Finding black rot in cruciferous weeds in or next to infected crucifer crops was not too surprising. However, the ease with which we found black rot in cruciferous weeds along a railroad right-of-way near Salinas, a roadside in San Juan Bautista, and uncultivated grazing area in Solvang (32 km from the nearest cultivated crucifer crop in Lompoc) was unexpected. We did not survey the area around Solvang to see if nearby garden crucifers were also infected; however, the weed site was about 0.8 km from the nearest house.

C. bursa-pastoris was the most common cruciferous weed throughout the seed-growing areas of California. However, as expected from inoculation studies (14), we did not observe any plants with recognizable lesions. No attempts were made to isolate *X. campestris*.

We have established that black rot is present in cruciferous weeds in the important transplant production area of Georgia and seed production areas of California, and that *X. campestris* is readily disseminated under field conditions from infected weeds to cabbage. Our plot data suggest that the probability of *X. campestris* spreading 12 m is low (one of eight plots positive); however, our plots contained only one infected weed, and the situation we observed in nature was much different. In nature, when black rot was present, the number of infected weed plants was very high. Thus, the distance of dissemination in nature could be greater than 12 m with a higher inoculum potential than in our plots. Our observations of a high ratio of infected to healthy plants when black rot was found in a large population of weeds, together with the successful transmission of *X. campestris* from seeds collected from naturally infected weeds, suggest that black rot has become endemic in cruciferous weeds in both Georgia and California. This is further supported by our finding black rot in weeds in California in an uncultivated area over 30 km from the nearest cultivated crucifer crop. Still, we have no data proving that infected weeds have resulted from inoculum originating from weeds. The inoculum may have originated from nearby infected cultivated plants.

The presence of *X. campestris* in seeds of *Cardaria pubescens*, a noxious perennial weed, implies the existence of *X. campestris* in seeds of other symptomless hosts. Seed transmission may play a role in the possible endemic survival of black rot in weeds but probably is not necessary for endemic survival of inoculum in weeds. Because cruciferous weed species are present all year in Georgia and California, the pathogen could spread from one generation to the next throughout the year. In Georgia, different weed species are not needed for continuous survival, because plants of *L. virginicum* are present all year. Furthermore, infection of perennial species such as *B. geniculata* and *Cardaria pubescens* in California would provide a continuous source of primary inoculum. Weeds could serve as a primary source of inoculum for systemic infection of commercial seed plants and also for direct

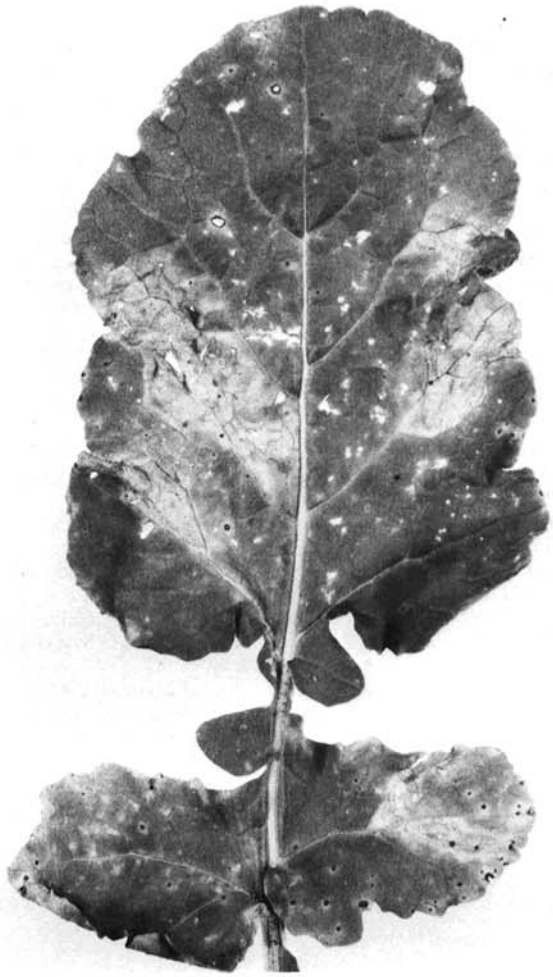

Fig. 1. Black rot lesions on a leaf of *Brassica geniculata* (Desf.) J. Ball. collected on 19 March 1980 from plants next to a cauliflower seed field (site 16) near Salinas, CA. (Photograph by J. Hall)

infection of siliques. Therefore, long-term rotations, commonly recommended to eliminate soilborne inoculum (13,26,28,29), would not be expected to control black rot.

Results of this investigation, together with the loss of mercury as a seed treatment, may explain the unusually high levels of black rot experienced during the last 10 yr. Plants in transplant and seed fields probably are becoming infected by increasing inoculum potential from diseased weeds. We recommend that transplants and seed plants not be grown in areas where cruciferous weeds abound. If plants must be grown in such areas, a major effort must be made to eliminate cruciferous weeds, including such symptomless species as *L. virginicum*, *Coronopus didymus*, and *Cardaria pubescens*. When planting in a new area with no history of crucifer crops, all possible efforts must be made to avoid introducing black rot into the native cruciferous weeds, including assaying seeds for *X. campestris* and inspecting fields thoroughly for black rot-diseased plants. Finally, fresh-market cruciferous crops should not be grown near transplant and seed crop fields (28).

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