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Black Rot: A Continuing

During the latter half of the 19th century, immigrant farmers from northern Europe brought with them to the midwestern United States the love of brined and fermented cabbage. Over the winter months, sauerkraut, as it was known, was savored along with roasted pork, wursts, and potato dumplings. By the late 1800s, extensive acreages of cabbages were being grown from New York to Wisconsin and sauerkraut production was thriving. In the 1890s, a serious disease devastated the cabbage fields of southeastern Wisconsin, and the resident professor of the new science of bacteriology at the University of Wisconsin, H. L. Russell, was called to examine the fields of Racine and Kenosha counties. Russell concluded that the malady was the black rot disease caused by the bacterium *Bacillus campestris* recently described on rutabaga by Professor Pammel in neighboring Iowa. Since Russell's publication in 1898 (7), there has been a growing recognition of the seriousness of black rot (*Xanthomonas campestris*) on crucifer crops throughout the world.

A Worldwide Problem

Black rot must be considered the most important worldwide disease of crucifers, attacking all cultivated brassicas, radishes, and numerous cruciferous weeds. As with many bacterial diseases, the pathogen thrives in warm, humid climates and is most serious in tropical, subtropical, and humid continental regions. Black rot is known to exist in the cool coastal climates of northern Europe and North America but is seldom a problem there, rarely progressing to the point where the whole plant is destroyed.

After gaining entry through the water pores at the leaf margins or through wounds, *X. campestris* colonizes the vascular system. When temperatures exceed 25 C, the bacteria move rapidly through the vascular system, producing copious quantities of an extracellular polysaccharide known as xanthan (5). (An interesting aside is that xanthan gum produced by *X. campestris* is an important commercial product. Xanthan is used in the food industry as an additive in salad dressings, cake mixes, and many other products. Large quantities are also used in the oil-drilling industry; special properties of the polysaccharide decrease the viscosity of the drilling mud, thereby lubricating the drilling bit.) In the vascular system of crucifers, bacteria and xanthan plug the xylem vessels, restricting water flow and resulting in the characteristic V-shaped chlorotic lesions originating from the margins of crucifer leaves (11) (Fig. 1).

As bacteria move throughout the plant, the vascular tissues darken—the reason for the name black rot. The typical early symptoms are yellowing and drying of affected tissues. Invasion of the fleshy petioles and head leaves by *Xanthomonas* is rapidly followed by a soft-rotting bacterium (*Erwinia carotovora* or *Pseudomonas marginalis*), which is primarily responsible for the rotting phases of the disease. Under ideal conditions, black rot symptoms appear 10–14 days after entry of the bacterium. If temperatures are suboptimal, however, the organism may persist in the vascular system without producing symptoms. Invasion of the flowering stalks may lead to infection of the seed (2).

When Seed Plants Are Infected

Seed of vegetable crucifers is produced primarily in temperate coastal regions of the world where cool, mild winters are ideal for the vernalization needed to induce flowering in the biennial crop forms such as cabbage, Brussels sprouts, cauliflower, turnip, rutabaga, Chinese cabbage, and oriental radishes (Fig. 2). Crops for seed production are densely sown in beds in midsummer and transplanted to production fields after about a month. Plants grow slowly throughout the winter, bolting to flower the following spring. Seed ripens through the summer and is harvested about the time the new seed crop is transplanted. Seed plants may be infected any time during the growing season, but the pathogen is rarely detected because conditions for expression of disease are suboptimal during most of the seed production cycle.

The seed crop is most vulnerable to infection during the late summer in the seedbeds before transplanting and during late flowering and seed maturation. At these times, temperatures are most favorable for bacterial growth, and bacteria on leaves, on plant debris, or in soil can be spread by heavy rain or overhead irrigation to other plants in the seedbed or seedfield.

Plants infected in the seedbed are unlikely to be detected for several reasons. As seedlings approach transplanting size, seasonal temperatures are

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Threat to World Crucifers

decreasing below the optimum for symptom expression. A second disease, downy mildew (*Peronospora parasitica*), is common in seedbeds and frequently injures the leaves, causing senescence and masking early symptoms of black rot. When transplants are pulled, senescent or injured leaves often fall from the plant unnoticed. Black rot infection is difficult to detect during flowering and seed maturation because of the massive plant growth and heavy senescence of lower leaves. Furthermore, systemic invasion in flower stalks may not result in typical external symptoms, although internal vein darkening of the seed stalks and premature leaf drop may occur.

Seed Production Regions

Of the regions in the world where crucifer seeds are most commonly produced (Fig. 2), the Pacific Northwest Coast of North America, including the Puget Sound region of Washington, the Willamette Valley of Oregon, and valleys of central California, is considered ideal. In these areas, low summer rainfall (normally less than 2 cm per month) combined with abundant subsoil moisture minimizes the potential for spread of *X. campestris* in the seed crop. Seed grown in the Pacific Northwest has the reputation of being free from *X. campestris*, which accounts for this region producing much of the world's vegetable brassica seed.

Such ideal conditions for disease-free seed production do not exist in many other regions where crucifer seed is grown. The potential for crop damage by *X. campestris* is low in northern Europe, Japan, New Zealand, parts of Australia, and Brazil, but relatively frequent summer rains favor spread in the crop and cooler temperatures result in undetected movement of the organism in seed plants. In tropical and subtropical regions where production of numerous leafy forms of *Brassica campestris* and the oriental greens pe-tsai, pakchoi, and choi sum are grown the year round and where the cole crops are grown at higher elevations, *X. campestris* is constantly present. The pathogen cycles from crop to crop or from crop to weeds and back to crop. Seed production in the humid tropics is commonly associated with high levels of seedborne *X. campestris*.

Hot Water Seed Soak

Recognizing that seedborne infection played an important role in the spread of *X. campestris*, J. C. Walker at Wisconsin (12) and E. E. Clayton at Cornell (1) in the 1920s determined that soaking freshly harvested, well-developed seed in water at 50 C for 25–30 minutes virtually eliminated seedborne *X. campestris* without adversely affecting seed vigor. They also noted that seed stored for several years, weak seed, or seed of certain crops, such as cauliflower, was damaged by hot water treatment, and shorter treatment periods were advised for the more delicate seeds (1).

By using only seed produced in the Pacific Northwest and treated with hot water, crucifer growers have, by and large, been able to avoid serious widespread epidemics of black rot over the years. Occasionally, however, black rot has been a problem in cabbage or cauliflower crops grown from disease-free seed. In some instances, disease could be attributed to carry-over of bacteria in residues from previously infected crops, to spread from crucifer weeds, or to infected transplants from contaminated seedbeds.

Risks of Shipping Transplants

Large numbers of cabbages and cauliflowers are grown in seedbeds in Texas, Georgia, Alabama, Florida, and Tennessee and shipped north as transplants for early spring planting. The region around Tifton, GA, is particularly suited for growing and shipping transplanted vegetables and has long been known for producing high-quality transplants of tomatoes, peppers, onions, cauliflowers, and cabbages. Each year millions of transplants are shipped north to Wisconsin, New York, and the New England states. Because plants are also shipped south to Florida for winter cabbage production, the transplant operations around Tifton can be pivotal with respect to wide distribution of diseases.

The state of Georgia has set up inspection and certification procedures to minimize the possibility of diseased plants being shipped out. To obtain state certification of their plants, growers must have their seed assayed and plant beds inspected for freedom from pests and diseases, including black rot. Inspection can be useful in detecting pockets of serious black rot infection (Fig. 3), but the systemic nature of seedborne *X. campestris* plus cool temperatures in the spring often delay symptoms, making detection virtually impossible.

Some Hazardous Practices

A number of practices associated with transplant bed production of crucifers are particularly hazardous with respect to black rot. Some growers traditionally grow rows of radishes, turnips, or mustard among the beds of cauliflower or cabbage seedlings as "indicators" of whether the soil nutrient balance is satisfactory. When the quick-growing indicator rows begin to show deficiencies, side dressings of fertilizer are applied to the seedlings. But these indicator rows

Fig. 1. Characteristic symptoms of black rot on cabbage.

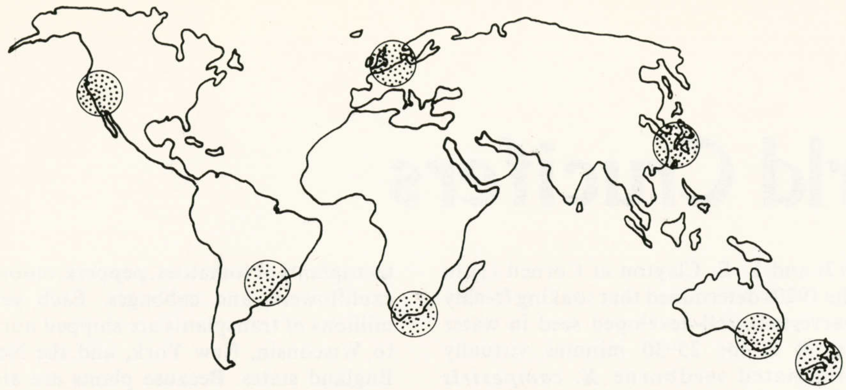


Fig. 2. Regions of major production of vegetable crucifer seed.

Fig. 3. Black rot infestation in a transplant bed. The infection level rose from 0.5% initially to 65% after 3 weeks.

occasionally carry seedborne *X. campestris*!

Excessive fertility, warm temperatures, or a too-low seeding rate frequently results in oversized succulent transplants. In such instances, growers commonly "clip" seedbeds (Fig. 4). Rotary mowers or specially designed flails pass over the plants, removing excess foliage and trimming the plants to fit into shipping crates. If pockets of infection are in the seedbed, clipping virtually ensures uniform and widespread introduction of *X. campestris* among the transplants; the pathogen is not detected until the transplants are growing vigorously in the production fields, several weeks later.

Another hazardous practice is soaking crates or bundles of transplants in tubs of water before transplanting. Such soaking spreads *X. campestris* inoculum from plant to plant through leaf scars and wounded roots.

The practice of locating seedbeds in proximity to production fields greatly increases the chances of black rot spreading from the production fields to the local crop (Fig. 5). Normally, well-drained light soils ensure uniform seedling emergence, provided moisture is adequate. Such light soils are frequently those that can be worked earliest in the season and, in addition to being selected for transplant seedbeds, are occasionally chosen for the earliest planting of "shipped-in" transplants.

Strandberg (10) has shown that *X. campestris* can persist in the soil in crucifer residue at least as long as the residue is not completely decomposed. This may vary from a few months in warm, wet regions to 2 years in cool climates. For this reason, strict rotation of seedbeds should be practiced, avoiding ground cropped to crucifers during the previous two seasons.

Resurgence in the Seventies

For many years, black rot was considered a disease of relatively minor importance to crucifer growers in the major northern production areas of the United States and in the cool coastal valleys of California. Because growers adhered to the recommended practices of planting seed produced in the Pacific Northwest, soaking seed in hot water, rotating seedbeds, and producing and procuring inspected certified plants for the early crop, outbreaks of *X. campestris* were sporadic and limited. In Florida and Texas, however, black rot was a serious threat to production every year, with outbreaks often tied to heavy rainfall and high temperature. Then, during the late 1960s and early 1970s, the frequency and severity of black rot epidemics increased. Particularly serious and widespread outbreaks occurred during 1972 and 1973 in the northeastern and midwestern United States.

A number of reasons are associated with the resurgence of black rot. During the 1960s, the advantage of F_1 hybrid brassicas, particularly cabbage, Brussels sprouts, and broccoli, became apparent to crucifer growers throughout the world. Several Japanese seed firms produced F_1 hybrids of superior uniformity and market quality that were in demand by growers and processors. Because many of these hybrids were produced in regions of Japan where *X. campestris* was endemic, a proportion of the seed lots entering the United States from Japan was infested with the organism. Much of this relatively expensive and frequently delicate seed was not treated with hot water, and infested seeds were commonly sown in seedbeds along with disease-free seeds produced in the Pacific Northwest. In southern seedbeds, seedborne infection frequently went unnoticed and was occasionally intensified by heavy rains, overhead irrigation, and clipping.

In the 1973 epidemic, approximately 70% of several million early transplants originating from a single seedbed were systemically infected, but disease was not detected at transplanting time. In Wisconsin and other midwestern states, the infected transplants were planted in April on the earliest tillable fields. Portions of several of these fields were selected for early sowing of the local or main crop of transplants. Infection remained undetected during the cool spring, and not until mid-June did the first signs of black rot appear in the transplants. Then it was too late to prevent the spread of *X. campestris* from the early transplanted crop to the adjacent main crop seedbeds. The epidemic was widespread. Cabbage growers, processors, transplant operators, and seedsmen all suffered!

Blackleg, a Fellow Traveler

The epidemiology of blackleg, caused by the fungus *Phoma lingam*, is remarkably similar to that of black rot except that *Phoma* is more active than *Xanthomonas* on crucifer tissues at lower temperatures. *P. lingam* is also seedborne and spreads most rapidly in seedbeds through water-splashed pycnidiospores.

Phoma is frequently found on seed crops produced in cool, humid regions and causes spreading lesions on the leaves and stem cankers. Lesions have light brown centers with darkened margins and contain the characteristic pycnidia of *Phoma* (Fig. 6). The name blackleg derives from cankers on the lower stem and at the ground level that frequently girdle the stem, causing wilting and death of the plant (13). *Phoma* causes a dark dry rot on root crops and cabbage in storage.

Although blackleg can spread rapidly under optimal conditions, spread is seldom as explosive as that of black rot. Numerous strains of *P. lingam* exist, some having more restricted host ranges and more limited virulence than others. The perfect stage of *P. lingam*, *Leptosphaeria maculans*, permits genetic recombination among isolates. In Australia, France, and England, airborne ascospores produced on crop residues are a major source of inoculum in epidemics of blackleg on oilseed rape.

NCR-100 Takes Action

Because of the growing threat of black rot and blackleg to crucifer production in the United States, a committee was formed of researchers representing 18 states in which crucifer seeds, transplants, or crops are grown. The committee, sponsored by the Cooperative State Research Service and designated NCR-100, met first in 1975 and annually thereafter to plan cooperative research on control of seedborne diseases of crucifers. A component of NCR-100 that has contributed significantly to its success is the inclusion, on an unofficial basis, of representatives of U.S. and international seed industries, transplant growers, crucifer growers, shippers, processors, and members of state and federal regulatory agencies.

Each year, the 30–40 attendees have met in a different state representing a particular phase in the chain of crucifer production. At each location, problems associated with crucifer production were observed and research initiated to address specific needs. The committee met first in Washington State in production areas of the Pacific Northwest, then at Tifton, GA, where transplant operations are extensive, and next in Wisconsin, where sauerkraut and market cabbages are important. Winter production in central Florida and production in the Salinas Valley of California were viewed in subsequent meetings.

NCR-100's activities are resulting in a growing list of reports and publications representing collaborative research among members (3,4,8). Research has focused primarily on identifying gaps in understanding the epidemiology of black rot and blackleg and in developing improved procedures to detect and control seedborne infection. The development and implementation of crucifer seed lot assays were among the first activities of the committee (6,8). Through assays of seed lots produced or purchased for sale in the United States, a

Fig. 4. Tractor-driven mower "clipping" tomato transplants in a seedbed. Such a practice before crucifer plants are lifted is particularly hazardous in spreading such bacterial diseases as *Xanthomonas campestris*.

Fig. 5. Of this transplanted early crop of cabbage (left) growing adjacent to a large seedbed, 70% were systemically infected with *X. campestris*. Subsequent heavy rains spread infection into the seedbed.

Fig. 6. Leaf lesion of *Phoma lingam*, the cause of blackleg, showing characteristic pycnidia.

Guidelines for Minimizing the Threat of Blackleg and Black Rot of Crucifers

I. Guidelines for Crucifer Seed Production

1. All stock seed being planted in seedbeds prior to transplanting or direct seeded in seed production fields should be determined to be free of *Xanthomonas campestris* and *Phoma lingam*.
2. Fields selected for seedbeds should not have had crucifer crops on or near them for at least four years, should be located as far as possible from existing fields of crucifer crops and should not receive surface run-off water likely to contain contaminants from fields with crucifers.
3. Inbreds used in the production of major seedlots of F_1 hybrids should be separated within the seedbed areas from other open-pollinated seedlots, and where possible, large seedbeds should be divided into smaller separated units.
4. Seedbeds should be kept weed free, especially from mustards, wild radish and other cruciferous weeds. Radish or other leafy crucifers should not be used in seedbeds as soil nutrient markers unless determined to be free from *X. campestris* or *P. lingam*.
5. Seedbeds should be thoroughly inspected by a qualified person for the presence of any obvious foliar symptoms of disease caused by *P. lingam* and *X. campestris*. Infected plants should be removed and destroyed and remaining plants observed frequently throughout the reproductive cycle to see if the eradication has been successful. *Removal of diseased plants from the seedbed does not insure eradication of the problem.*
6. Plants in the seedbeds should be treated with recommended pesticides in order to prevent the entry or buildup of any potential disease or insect in the seed crop and to prevent the occurrence of pest damage that would mask disease symptoms. Careful observation of local rainfall patterns and coordination of pesticide spray schedules should be followed to provide effective protection.
7. Equipment used in the cultivation and management of the seedbeds should be isolated from that used on other crucifer crops or if used in crucifer crops, should be thoroughly cleaned and disinfested with steam or germicidal sprays before being brought into the seedbed.
8. Upon lifting, transplants should *not* be sprayed or dipped in water prior to transplanting. Plants remaining in the seedbed after the transplanting operation should be destroyed as soon as possible. Seed production fields should not have had a previous crucifer crop for at least three years.
9. For issuance of a phytosanitary certificate, a seed crop must be inspected while actively growing and during each growing season.
10. Recommended pesticides should be applied to the production fields.
11. After the seed is harvested and cleaned, representative seed samples from each production lot, taken according to International Seed Testing Association procedures, should be assayed for *P. lingam* and *X. campestris*. The assay must show that neither pathogen is present in viable condition in a sample of 10,000 seeds for *P. lingam* and 30,000 seeds for *X. campestris*. If either pathogen is detected, appropriate eradicant treatment should be applied to the whole seedlot. Reassay of the seedlot should follow treatment. Retreatments may be necessary until tests show the pathogens are eradicated.
12. Seed producers should be prepared to provide well-documented reports of seedbed protection, inspections, seed treatments, and seed assays if requested to do so by customers.

II. Guidelines for Plant Bed and Container-Grown Operation and Planting

1. Fields selected for seedbeds should not have had crucifer crops or debris on or near them for at least one growing season beyond the time taken to fully decompose heavy stem tissue residues. (This time may vary from less than one year in warm humid climates to more than two years in cool dry regions.) Seedbeds should be located as far as possible from existing fields of crucifer crops and should not receive surface run-off water likely to contain contaminants from fields with crucifers.
   1a. Container-grown operations should follow the guidelines in this section where applicable and particular attention should be given to overall sanitation.
2. Only seed assayed and shown to be free of *P. lingam* and *X. campestris* should be sown in seedbeds. Unassayed trial samples should not be grown in or near transplant beds. Large seedbeds should be divided into smaller separated units.
3. Seedbeds should be kept weed free, especially from mustards, wild radish and other cruciferous weeds. Radish or other leafy crucifers should not be used in seedbeds as soil nutrient markers unless determined to be free from *X. campestris* or *P. lingam*.
4. Seedbeds should be thoroughly inspected by a qualified person for the presence of any obvious foliar symptoms of disease caused by *P. lingam* and *X. campestris*. If positive identification of *P. lingam* or *X. campestris* is made in a seedbed, infected plants should be removed and destroyed. The remaining plants of the seedlot and in the bed should be kept under close surveillance. If other plants are found to be infected, the infested lot or whole seedbed unit should be destroyed. Equipment used in a seedbed in which infection is found should be considered to be contaminated and should be decontaminated using suitable disinfectants.
5. Plants in seedbeds should be treated with recommended pesticides in order to prevent the entry or buildup of any potential disease and to prevent the occurrence of pest damage that would mask disease symptoms. Careful observation of local rainfall patterns and coordination of pesticide spray schedules should be followed to provide effective protection.
6. Equipment used in the cultivation and management of the seedbeds should be different from that used on other crucifer crops or if used in crucifer crops, it should be thoroughly cleaned and disinfested with steam or germicidal sprays before being brought into the seedbed.
7. Transplants should not be mechanically "topped," "clipped" or "chopped" to toughen them or to reduce their size in order to fit the plants into shipment crates.
8. Upon lifting, transplants should not be sprayed or dipped in water prior to transplanting.
9. Only new crates which have never been used for shipping cabbage, broccoli, cauliflower, mustard, turnip greens, collards or radishes should be used for shipping transplants. Reusable plastic or wooden plant containers brought to the field should be cleaned and disinfested before returning them to the seedbed area for reuse.
10. Plants remaining in the seedbed after pulling the transplants should be destroyed as soon as possible.

III. Guidelines for the Purchase or Receipt of Crucifer Transplants

1. Crucifer growers, shippers, and sauerkraut packers should contract acreage only from growers agreeing to adhere to the guidelines herein.
2. Crucifer growers, shippers or kraut packers should purchase transplants from plant bed growers who can verify that their plants have been grown in accordance with the guidelines herein.
3. For transplants moving across state lines, only plants certified by local state inspectors should be acceptable for sale or purchase provided certification is in compliance with the guidelines herein.
4. Purchasers of transplants may request additional specific information relative to "certification" of their particular lots of transplants: a) seedlot numbers; b) seeding and pulling dates; c) verification that plants have *not* been topped or clipped; d) seedbed spray schedules; e) seedbed inspection schedules. Such additional information may be appropriately obtained by persons other than the plant bed operator or state certification officials.

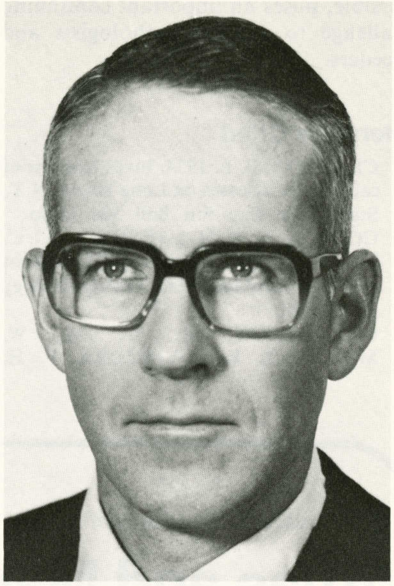
IV. Guidelines for the Production of the Crucifer Crop

1. Follow the practices for the production of healthy, vigorous crops according to the recommendations of the region or state with particular attention being given to the following guidelines.
2. Direct seed or transplant the crop in weed-free and crucifer-residue-free ground which has not had an immediately preceding crop of crucifers. Crucifers should not be grown on ground that has had *P. lingam* or *X. campestris* infected crucifers for at least three preceding crops. The land should be so located as not to receive surface water from soil or debris from plants likely to contain *X. campestris* or *P. lingam* from adjacent fields or previous crops.
3. Water for irrigation should not be drawn from sources which could receive surface run-off containing *P. lingam* or *X. campestris*. Overhead sprinkler irrigation should be avoided if possible.
4. Good pest management should be practiced. *X. campestris* can be readily spread via insects. Weeds, particularly crucifers (mustard, wild radish, cress, shepherds purse, etc.) should be removed from the crop and surrounding areas.
5. When working in the crop with cultivation or spray equipment, wait until the crop is dry from dew or precipitation. Boom sprayers are less likely to spread *X. campestris* as rapidly through a field than are airblast sprayers.

profile of the primary sources of seedborne infection has been obtained. The development of assays together with improved fungicidal eradicants for *P. lingam* has significantly reduced seedborne inoculum as a threat to the transplant industry (3). Research on methods to eradicate *X. campestris* from seed is under way (4). When fully developed and cleared for use, the techniques should provide acceptable alternatives to the hot water soak. At present, however, the hot water soak is the recommended treatment even though application to old or weak seed can affect seedling vigor. Research on survival of *X. campestris* in residues (10) and on weeds in seed production and transplant areas has clarified the need for rotation and sanitation in disease control.

A major contribution from NCR-100 is a set of guidelines designed to minimize the threat of black rot and blackleg. The guidelines cover all aspects of crucifer production—seed, transplants, and crop—and are the result of several years of deliberation among those directly involved with each phase of production. The emphasis is on sanitation, particularly in seed production and transplant bed operations. The procedures can be reasonably followed and should reduce the probability of continuing widespread epidemics of black rot and blackleg. The guidelines were unanimously approved 18 March 1980 by the 44 members of NCR-100 attending the annual meeting in Monterey, CA.

An aspect of production that, in conjunction with the guidelines, would help minimize disease outbreaks is direct sowing of assayed seed free from *X. campestris* and *P. lingam* into residue-free soil. Transplants are necessary, however, for early crop production and for seed production of F_1 hybrids from limited quantities of hand-pollinated inbred seed.



Paul H. Williams

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Fig. 7. Row of cabbage on the right is a resistant Badger Inbred derived from the Japanese cultivar Early Fuji.

Resistance, a Long Sought Goal

Despite many early attempts to identify and utilize resistance to *X. campestris*, it was not until 1973 that stabilized resistance derived from the Japanese cabbage cultivar Early Fuji was released from the Wisconsin Agricultural Experiment Station as Badger Inbreds 14 to 20 (Fig. 7) (14). These inbreds are now used worldwide, and a number of hybrid cultivars bearing *X. campestris* resistance have reached the market during the past 2 years.

Reports from India, Australia, Japan, South America, and various regions of the United States indicate that the Early Fuji source has resisted a variety of indigenous strains of *X. campestris*. The durability of this source of resistance remains to be seen. At present, *X. campestris* resistance has been identified in cabbages and Indian cauliflowers (9).

The need to find new sources of resistant *X. campestris*, while incorporating existing forms into other brassica crops, is pressing. Resistance is particularly needed for crops grown in the humid tropics and subtropics. Indeed, the new sources of resistance for breeding programs must be seeded in such regions, where black rot is endemic.

That partial resistance to *X. campestris* exists in many Japanese cultivars and that strong resistance was found in the old, open-pollinated Early Fuji cannot be attributed to chance. Japan and China represent the greatest diversity of crucifer crops in the world, and *X. campestris* is endemic in these regions. The success of the Japanese in hybrid crucifer production has undoubtedly narrowed the genetic base on which varietal selection will be made. The Chinese also are pursuing the production of F_1 hybrids at the communal and provincial levels.

Hybrid breeding strategies, combined with eradication of black rot as an endemic disease in the breeding and producing regions, may have profound effects in eliminating important sources of variation and resistance to diseases such as black rot. Resolution of the divergent objectives of maintaining high levels of sanitation in the actual production of crucifer crops, together with the long-term need for evolution and selection of the pathogen among as diverse a range of crucifer germ plasm as possible, poses an important continuing challenge to crucifer pathologists and breeders.

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