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Storage Rot of Sugar Beet

In 1972, a sugar beet industry executive stated that an estimated 9 million tons of sugar beets were stored that year in the United States for an average of 60 days and that the loss of sucrose during the storage period amounted to 540 million pounds. Since that statement was made, a more accurate estimate of sucrose losses caused by rot has been based on root samples taken from a sugar refinery in Minnesota. During a 128-day portion of the 1974–1975 processing season, 1.2% of the 456,820 tons of processed sugar beet were decayed. This small percentage of tissue, however, had a potential yield of 1.1 million pounds of sucrose. The impurities associated with rotted tissue interfere with the crystallization of sucrose, so it was estimated an additional 1.8 million pounds of sucrose were lost to molasses. Therefore, the total sucrose loss at one factory was 2.9 million pounds. Conceivably, similar losses occurred at the five other factories in the Red River Valley of Minnesota and North Dakota, for a grand total of 17.4 million pounds of lost sucrose (2). Losses during the next processing season of 1975–1976 amounted to only 27% of the previous season's losses.

Causes

Causes of the rot also were based on root samples taken from the Minnesota factory. Rotted tissue was excised and weighed, and samples were plated-out on potato-dextrose agar. A total of 2,656 infected tissue pieces were examined and 2,246 roots were sampled. The major causes of decay were four fungal pathogens: *Phoma betae, Penicillium claviforme, Botrytis cinerea*, and *Fusarium* spp. *P. betae* and *P. claviforme* were isolated from more than 70% of the decayed tissue pieces that were plated, whereas *Fusarium* spp. were isolated from 31% and *B. cinerea* from only 2.3% of assayed tissues (2). The low frequency of *B. cinerea* confirmed long-term observations that this notorious rotter of stored vegetables, including sugar beets, was not a major cause of rot in the Red River Valley. The reason is that *P. claviforme* is antagonistic toward *B. cinerea*. *B. cinerea* was completely inhibited when inoculated onto sugar beet roots together with *P. claviforme*. Culture filtrates from *P. claviforme* also inhibited growth of *B. cinerea* (1). When inoculated alone, *B. cinerea* caused more decay than *P. claviforme* did. So this is an unusual case where two pathogens compete for the same host, but the more virulent pathogen loses to the less virulent competitor because of an antagonistic property.

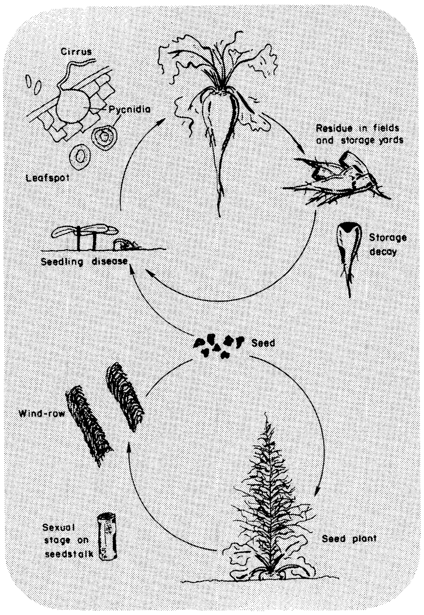

Fig. 1. Disease cycle of *Phoma betae*.

P. betae is the most dangerous storage rot pathogen because it attacks at all phases of the sugar beet's life cycle (Fig. 1). Infected seedlings that survive the seedling disease phase grow into normal, healthy appearing roots, but the latent *P. betae* becomes active to cause rot 80–100 days after the roots have been in storage. Every sugar beet breeder in the world probably has cursed *P. betae* at one time or another for destroying valuable mother roots intended for seed production.

Phoma storage rot usually begins in the crown, is black, and contains pockets lined with mycelia (Fig. 2). Rot caused by *P. claviforme* can be easily identified because of the coremia produced by this fungus (Fig. 3), and *B. cinerea* can be recognized by masses of gray spores and dark sclerotia.

Predisposition to Rot

Sugar beet harvest in northern regions is a race against the onset of frost. Growers delay harvest as long as possible to allow roots to gain sucrose before freezing temperatures arrive. Then they quickly harvest 24 hours a day. Speed contributes toward root damage. There is no time for gentleness. High-speed harvesters and pilers are designed to remove soil from roots mechanically. Terminal portions of the crowns are removed before the roots are lifted. The end product is a greatly injured root. Storage pathogens not already present before harvest find many avenues for entry (Fig. 4).

The roots are then stored in unprotected piles 17–22 ft high by 180–220 ft wide. Piles may be several hundred yards to a quarter mile long. Weeds, sugar beet petioles and leaves, and soil accumulate in the storage piles, restricting ventilation and reducing the oxygen supply. Anaerobic conditions allow "hot spots" or fermentation sites to develop in the

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pile. Sugar beet roots contain an endogenous microbial population, and the bacteria and yeast cause fermentation and sucrose depletion. Temperatures in a hot spot commonly reach 110 F, even if the ambient temperature is −20 F. Storage piles in the Red River Valley are routinely monitored for hot spots with remote infrared sensors. Beets from hot spots are processed first.

Soil fertility affects storability of the sugar beet. Roots grown in soil low in phosphate were more susceptible to *P. betae* than roots grown in soil with

Fig. 2. Phoma storage rot in the crown of sugar beets that had been stored for about 100 days at 4–6 C.

Fig. 3. Rot caused by *Penicillium claviforme* showing distinctive coremia.

adequate amounts of phosphate. Phosphate fertilization also seemed to reduce the loss of sucrose by respiration (8). Sugar beets grown under low nitrogen fertility were more susceptible to *P. betae* than those grown under adequate nitrogen fertility (5). Results from the Soviet Union have shown that roots grown in adequately fertilized soil are more resistant to *B. cinerea* than roots grown under low fertility (7). A standard practice in the United States is to make available only enough nitrogen to provide adequate top growth during most of the growing season. The intent is to have the available nitrogen supply depleted from the soil a few weeks before harvest. This reduces top growth and causes more sucrose to accumulate in the root instead of being used as an energy source for growth. The production of roots with a low amino nitrogen content is highly desirable because these

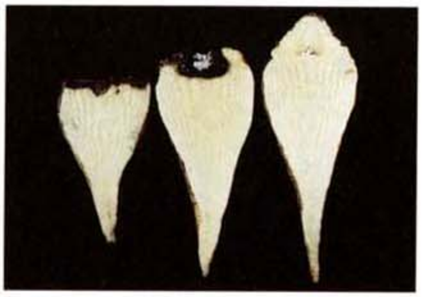

Fig. 4. Phoma storage rot in roots topped at the lowest leaf scar (left) and part way up the crown (center), compared with untopped root (right). The traditional practice of removing tops from roots intended for storage is losing acceptance. Topping aggravates the storage rot problem and increases sucrose loss through wound respiration.

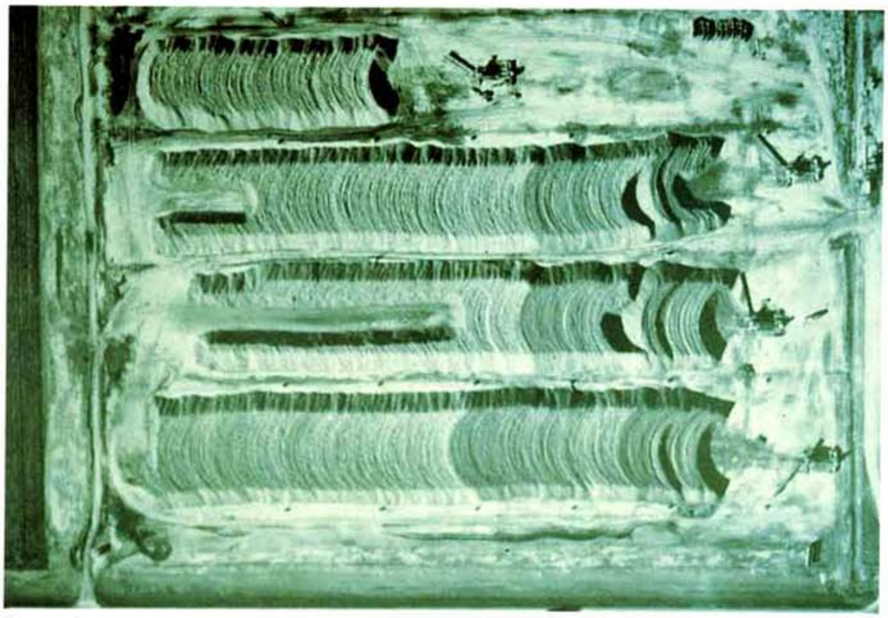

Fig. 5. Aerial view of four storage piles at Min-Dak Sugar Cooperative, Wahpeton, North Dakota. The two middle piles are being loaded into the factory by removing the center portions, leaving two small piles. The small piles freeze solid and the roots store well. This procedure is called pile-splitting and has gained acceptance in the Red River Valley.

compounds interfere with the extraction of sucrose during processing.

The above research suggests that the high-quality roots desired by the processor are more susceptible to storage rot than roots of lower quality. This interaction was recognized in the Soviet Union, where it was suggested that selection for resistance to storage rot pathogens proceed simultaneously with selection of sugar beet lines with low levels of impurities. Because of the impact on the sugar beet industry, more corroborating data are needed before acceptance of the conclusion that roots with low impurity levels are more susceptible to storage rot than roots with high impurity levels.

Control

The primary control measures for storage rot consist of forced-air ventilation and fungicide application, with genetic resistance a future measure. Forced-air ventilation helps to cool the roots, thereby lowering their respiration rate and reducing the activity of storage rot pathogens. Air movement also helps to heal the numerous wounds made during the harvest procedure. Wound periderm will develop within 10–14 days at 10 C, with relative humidity not below 95% and an air velocity of 0.08–0.25 m/sec (6). Durable ventilation ducts have been difficult to fabricate, but the American Crystal Sugar Company located in the Red River Valley has designed a ventilation duct system made from metal culverts cut longitudinally and braced. They use their ventilation system not only to cool the huge piles of sugar beets early in the fall but also to freeze the piles near mid-December. The Red River Valley is the only sugar beet growing area in the United States where temperatures are low enough to freeze sugar beet piles solidly (Fig. 5). They will stay frozen until March or April during very long processing campaigns. The frozen beets store well, and the industry has been able to process frozen roots.

In the Soviet Union, milk of lime, a by-product of the factory process, is used routinely early in the storage season. This material is sprayed on the outside of sugar beet piles and renders the treated roots unsuitable for growth or establishment of a pathogen. The white surface also reflects the sunlight and helps to cool the roots. In the United States, the only fungicide that has approval for storage rot control in sugar beet piles is Mertect (thiabendazole). The fungicide is applied with a sprayer fastened to the end of the piler. Mertect does an excellent job of controlling storage rot caused by *Botrytis* and *Penicillium* but cannot do an acceptable job of controlling rot caused by *Phoma*, because this fungus usually is embedded in root tissue and cannot be reached by the fungicide.

Since *P. betae* is a seedborne pathogen and remains within sugar beet tissue until the root reaches storage (4; H. M. El-Nashaar and W. M. Bugbee, *unpublished*), the assumption was that if seed treatments were used to reduce *Phoma* in the seed, subsequent storage rot in the pile would be reduced. This was not the case. The most effective fungicides as seed treatments did not improve stand counts but did reduce the number of surviving seedlings that were infected with the fungus (3). Fewer infected seedlings did not result in less storage rot caused by *Phoma*. Apparently, infection of roots by *Phoma* in the storage piles was coming from sources other than just the seed. Therefore, fungicidal seed treatment gave a healthier crop in the field but did not necessarily reduce *Phoma* storage rot.

Resistance is the most economical method of controlling plant diseases. A breeding program by USDA scientists to develop storage-rot-resistant germ plasm and experimental hybrids has been under way at the North Dakota Agricultural Experiment Station for several years. Rot development in resistant experimental breeding lines is comparable to that obtained when Mertect is used. Cultivars resistant to storage rot are grown on several hundred thousand hectares in the Soviet Union where their storage rot breeding program began over 40 years ago.

A complete list of control measures that could be used to reduce storage rot is quite long. Instructions to the grower include: 1) reduce harvest injuries by not removing crown tissue, 2) ventilate storage piles to lower root temperatures, respiration rates, and microbial activity and provide adequate oxygen concentrations to enhance repair of harvest wounds, 3) reduce the trash content of long-term storage piles by storing only the cleanest loads, 4) in regions where roots cannot be frozen solid, store the roots under protective cover and ventilate them to reduce damage from freeze-thaw cycles and dehydration, 5) grow roots in soil with adequate fertility, 6) use *Phoma*-free seed and practice a 4-year rotation to avoid planting in *Phoma*-infected soil, and 7) grow storage-rot-resistant cultivars when they become available.

Implementation of these controls is expensive and may partially explain the reluctance of the sugar beet industry in the United States to fully practice the procedures. The economic status of the industry governs whether investments will be made to alleviate the storage rot problem.

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