W. R. Slabaugh
University of Arkansas at Monticello

M. D. Grove
Diamond Shamrock Corporation, Miami

Postharvest Diseases of

The banana (*Musa sapientum* L.) is one of the most popular and least expensive fruits available in world markets. Nutritious and wholesome, it forms an important component in the diets of tropical Third World countries, serving, along with plantain fruit, as a major source of starch. In developed countries, bananas are marketed principally as fresh fruit and also as chips and puree commonly used in baby food preparation and pastries. In 1978, per capita consumption of bananas in the United States and Europe was estimated at 20 and 35 lb, respectively.

Most authorities believe the banana was native to the hot, tropical regions of southern Asia and was one of the first cultivated plants. According to Von Loesecke (10), the variety Gros Michel was introduced into the Americas in 1820. Until 1960, Gros Michel was the principal commercial variety because of its good agronomic characteristics, including resistance to scarring and bruising during harvest and transit. These characteristics permitted fruit shipment on stems—the least expensive and most practical method. Gros Michel, however, was highly susceptible to Panama disease caused by *Fusarium oxysporum* Schlecht. f. sp. *cubense* (E. F. Smith) Snyder and Hanson and was replaced in the late 1950s and early 1960s by the variety Valery (Cavendish group). Although Valery has less resistance to scarring and bruising, it has excellent resistance to Panama disease and better agronomic characteristics than Gros Michel. Several dwarf varieties are being utilized commercially, mainly because of their better resistance to high wind velocities and subsequent blowdown.

0191-2917/82/08074605/$03.00/0

Because of Valery's susceptibility to scarring and bruising, conversion from stem to box shipment was necessary to reduce problems occurring in transit to an acceptable level. Cultural practices and handling procedures were vastly improved and are responsible for better-quality fruit reaching the market.

The Diseases and Their Economic Significance

Crown rot. At present, crown rot is the most serious postharvest problem in commercial bananas. It is the most difficult to control because of the physical barriers encountered in reaching infection sites with appropriate chemicals and because of the complex of fungi involved. Crown rot was not a postharvest problem until the conversion from shipment of bananas on stems to shipment in boxes. Shipment in boxes necessitated removing hands from the stems at the crown. These fresh wounds proved susceptible to invasion by various fungi that cause an unsightly rot. A high incidence of crown rot can cause premature ripening during transit and result in direct shipment loss.

Crown rot is generally more serious in European than American shipments because of increased transit time. Controlling the disease is of added importance in fruit destined for Europe because it is displayed on hooks in supermarkets rather than on tables, as in the United States. Severe rot weakens the crown tissue and frequently causes fruit to drop from the hooks. This usually results in claims against the shipper-producer and affects subsequent wholesale prices for the fruit. Hence, considerable losses can be experienced from crown rot. Normally, crown rot only reduces fruit quality in U.S. shipments.

The rot begins at or near the cut surface of the crescent-shaped crown, causing blackening and softening of the tissues (Fig. 1). Grayish-white hyphal growth, commonly referred to as the "crown mold" phase (Fig. 2), may be present on the surface of decaying tissue. Symptoms are first observed during shipment discharge after a transit time of 7 days or longer. Crown rot severity increases with transit time, and the disease spreads rapidly through the crowns during ripening. Occasionally, the decay extends into the pedicels and fingers. Crown rot incidence is not distributed uniformly among cluster crowns in a shipment box, and the same box may contain both healthy and infected crowns. The disease usually is more severe on fruit produced during hot, dry weather than on fruit produced during the wet season (9).

A number of fungi have been isolated from decaying crowns (6), including *Cephalosporium* sp., *Verticillium theobromae* (Turc.) Mason and Hughes, *Fusarium roseum* Lk. ex Fr. emend. Snyder and Hanson 'Gibbosum,' *F. moniliforme* Sheldon, *Botryodiplodia theobromae* Pat., and *Colletotrichum musae* (Berk. and Curt.) Arx (syn. *Gloeosporium musarum* Cooke and Massee). According to Green and Goos (4), *Deightoniella torulosa* (Syd.) M.B. Ellis and *Ceratocystis paradoxa* (Dade) C. Moreau can also cause severe crown rot. *C. paradoxa*, however, is usually not present in crown rot tissues (9). In the last 3 years, *F. roseum* cult. *semitectum* and *Acremonium* sp. have been the principal pathogens responsible for this disease (J. C. Vessey, *personal communication*). The shift to these two fungi is believed to be the result of their tolerance to benzimidazoles. These fungi commonly grow and sporulate on decaying banana flowers and floral bracts as well as on senescent and normal foliage. Spores disseminated by wind and water splash to the crown before harvest and are carried on the crown and floral trash, subsequently contaminating the wash water used in the packing procedure. Wash

ʒananas and Their Control

water contamination has been suspected as the source of crown infection and can lead to infection on the cut surfaces of crowns.

Main stalk and stem-end (or neck) rots. Main stalk rot caused by *C. paradoxa* was a serious disease when fruit was shipped on stems, and the fungus also could spread into crown and pedicel tissues, causing stem-end rot. *B. theobromae* and *C. musae* were frequently found in decaying stalk tissue along with *C. paradoxa*. Both *B. theobromae* and *C. paradoxa* are primarily wound pathogens, with the former frequently causing main stalk rot when fruit was not rapidly refrigerated; under proper refrigeration, the latter was the predominant cause of the disease (9). Both main stalk rot and stem-end rot resulted in serious losses in transit in the form of loose fingers. Obviously, not all loose fingers could be salvaged, and the salvaged fruit sold at much lower market prices because of quality loss.

Main stalk rot incidence varied according to geographic location and season. Typically, the disease was more severe in Ecuadorian, Colombian, and Brazilian fruit than in Central American fruit. Stem-end rot losses were most serious during periods of rain and windstorms from June to December, with the most problems occurring during the last 4 months of the year.

Stem-end (neck) rot also occurs by infection of pedicel wounds in boxed bananas. The primary pathogen involved is *C. musae*. Mechanical damage often results from improper handling procedures that flex or otherwise injure the pedicels. Pedicel rot results in loose fingers and unsightly fruit, thus reducing quality and salability.

Main stalk rot occurs as a black soft rot beginning at the proximal end of the stalk and usually progressing to the first one or two hands. Occasionally, the rot begins on other areas of the stalk, including the distal end. Decay can extend into the crown and pedicels of the fruit and initiate the stem-end rot phase. Stalk rot can cause premature ripening of infected and healthy fruit within the same shipping hold. Because bananas are highly perishable and will not maintain quality for long periods after ripening, sizable portions of shipments can be lost under these circumstances. The initial symptom of neck rot is blackening of the pedicel creases resulting from flexing (Fig. 3). Secondary phases of neck rot include a black rot and withering of pedicels. In addition to quality losses, the secondary phase often results in finger drop and handling inconvenience when the fruit is marketed at the retail level.

Finger rots. The most serious finger rot is caused by *B. theobromae*. Less frequent finger rots are caused by *C. paradoxa, C. musae, Nigrospora sphaerica* (Sacc.) Mason, and *Trachysphaera fructigena* Tabor and Bunting. All these organisms except *T. fructigena* cause a watery soft rot of the pulp tissues, rendering the fruit useless, and their spores are commonly airborne in banana plantations. The source of these airborne spores is usually banana refuse and dead vegetation within the plantations. Botryodiplodia finger rot is generally more serious in boxed fruit with in-transit times exceeding 14 days. Transit times are less than 14 days to United States markets, so this disease occurs more often in shipments destined for Europe, where up to 15% of the clusters or hands have shown infection. Infection can occur at the base of decaying flowers on fruit as well as spread from a pedicel infection. *C. paradoxa* usually invades the pulp by spread from the pedicel into the finger but has been of minor importance since shipment was switched from whole stems to boxed fruit. *C. musae* infects bruised or scarred spots and fruit tips and can subsequently invade the pulp and cause a severe decay. However, pulp infection usually does not occur unless temperatures are excessively high during transit and ripening procedures.

N. sphaerica causes squirter disease, which is rare outside of New South Wales and Queensland, Australia. The disease is generally associated with below-optimum temperatures for banana growth and chill-injury temperatures. Infection frequently occurs through the severed petioles of fruit packed as single fingers, and fruit infection occurs only at wounds.

Trachysphaera finger rot, caused by *T. fructigena*, is a rare disease and has been reported only on Gros Michel fruit from the Cameroons and on Lacatan fruit ripened in rooms previously used for Cameroon fruit. Infection of the fruit is usually limited to the blossom end and causes dry, fibrous decay of the pulp. The organism can invade fruit wounds in the ripening room (7) and cause severe crown rot in boxed Cameroon fruit. The fungus also is a contributing cause of cigar-end disease on green fruit in West African plantations.

Fruit spots. Two major postharvest fruit spots can cause serious quality losses during transit, storage, and ripening. The pathogens responsible for these diseases are *Pyricularia grisea* Sacc. and *C. musae*. The latter is also the organism responsible for a third postharvest fruit spot of minor importance under current shipping practices.

Pitting disease caused by *P. grisea* is serious after as well as before harvest because of the latent nature of some infections. The disease is a peel blemish that makes the fruit unsightly (Fig. 4). Infection occurs in the field. Some spotting is evident at harvest but most occurs during transit and ripening. Although spotted hands are removed during packing procedures to reduce the chance of latent disease development, up to 60% of the clusters may be affected after ripening. If severe spotting occurs on the fruit pedicels, finger drop can

Fig. 1. Degree of crown rot on ripened fruit ranges from little disease (bottom right) to severe rot extending into pedicels and fingers (bottom left).

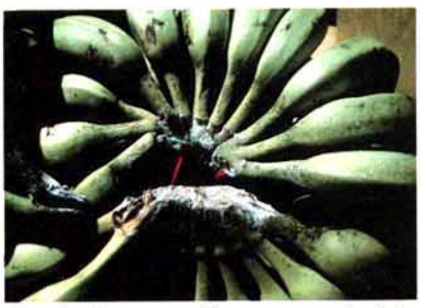

Fig. 2. Crown mold on green fruit is characterized by grayish-white hyphal growth on cut surface.

Fig. 3. Neck rot at creases caused by severe flexing of pedicels during harvest operations.

Fig. 4. Sunken, brown, round lesion of pitting disease caused by *Pyricularia grisea*.

Fig. 5. The lenticular or diamond-shaped spot commonly observed on ripened fruit is caused by *Colletotrichum musae* infection of a wound in the peel. The wound results from point scarring during harvest operations when the hard points of the fingers on an adjacent hand puncture or severely bruise the peel.

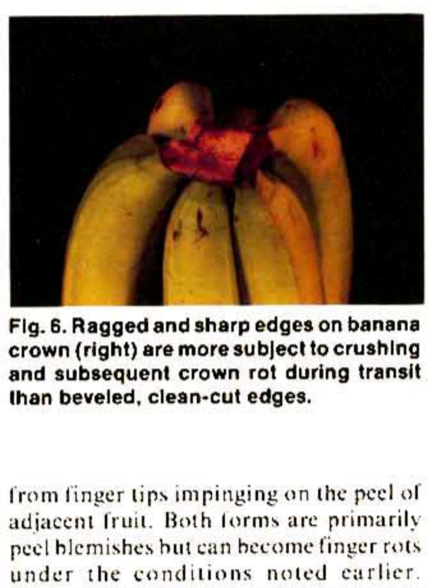

Fig. 6. Ragged and sharp edges on banana crown (right) are more subject to crushing and subsequent crown rot during transit than beveled, clean-cut edges.

occur, causing a handling problem in the supermarket. Fortunately, pitting disease incidence is high only after prolonged rainfall periods and where control procedures are inadequate. Latent spot incidence varies greatly from one area to another and from one season to the next. Spores are wind-disseminated and are produced primarily on hanging trash leaves, transition leaves, and bracts (5). Infection normally begins 6 weeks after the start of the rainy season and ends with the start of the dry season.

Anthracnose caused by *C. musae* occurs in two distinct forms. One originates from a latent infection of green fruit in the field, and latency remains until ripening begins; lesions are not produced on green fruit before harvest (8). The second occurs as a nonlatent infection on green fruit in transit, and the wound source is generally point scarring arising from finger tips impinging on the peel of adjacent fruit. Both forms are primarily peel blemishes but can become finger rots under the conditions noted earlier. Because this disease is primarily a peel defect, losses are usually in the form of quality. On latent-disease fruit, brown blotches develop, enlarge, and sometimes coalesce as ripening progresses. Infections occurring through fruit scars develop into lenticular or diamond-shaped spots that are generally smaller and less numerous (Fig. 5). Inoculum becomes airborne during rainy weather via splash dispersal of conidia from acervuli. In the field, conidia germinate within 72 hours and hyphae, after the cuticle is penetrated, remain dormant until the fruit reaches maturity (2). Lesions from wound infection can develop within 6–8 days at 14 C, the temperature commonly used during fruit transit. In addition to a cosmetic quality loss, infected fruit ripen faster and shelf life is reduced. Anthracnose was a more serious problem when fruit was shipped on stems and scarring was more likely. Modern packing methods have reduced scarring and bruising even though currently grown commercial varieties are more susceptible.

Fungal scald is associated with controlled-atmosphere packs and is also caused by *C. musae*. The disease occurs where the fruit comes in contact with a polyethylene liner and a film of water, usually the finger tips and bottom clusters, where moisture is most likely to accumulate. Scald incidence is generally greater on high caliper grade fruit (fully mature), fruit with a tendency to ripen in transit, and fruit in transit longer than 14 days. Up to 40% of the clusters can be affected when transit time exceeds 14 days.

Control Measures

Crown rot. Field sanitation by removal of trash leaves, bracts, and transition leaves at the time of fruit bagging is the starting point for postharvest disease control. These materials are a good source of crown rot inoculum, and their removal from the immediate vicinity of the fruit helps to reduce inoculum pressure and subsequent disease development. The length of time harvested fruit is held at ambient temperatures and the rapidity with which field heat is removed from the fruit are also important factors in crown rot control. Crown rot incidence and severity are likely to increase as fruit exposure time to temperatures above 16 C increases. Crown rot control is aided by harvest-to-refrigeration intervals of less than 48 hours and by proper crown trimming procedures that leave clean-cut, uncrushed crowns free from ragged and sharp edges, which are most susceptible to bruising and subsequent infection (Fig. 6). A clean, abundant flow of water in the dehanding and delatexing tanks as well as other packing station sanitation procedures help reduce exposure to infection.

Chlorination of fruit wash water has been used in Central American packing stations in an attempt to reduce viable inoculum levels of the crown rot fungi. The chlorine concentration necessary for good activity, however, proved difficult to maintain because of trash and latex accumulation in the wash water. A chlorine concentration of 1 ppm is sufficient to kill most of the hyaline, thin-walled conidia of *Cephalosporium* sp., *F. roseum*, *C. musae*, and *V. theobromae* after 1-minute exposures but not the brown, thick-walled conidia of *B. theobromae* and *D. torulosa* (1).

According to Greene (3), hypochlorous acid killed the conidia of *C. musae* readily but not the appressoria, indicating the limited effect of chlorination even under desirable concentration maintenance. Recent work with chlorine maintained at desirable concentrations in wash water has shown that crown rot incidence was not significantly reduced by chlorination and raised the question of field infection before harvest (J. C. Vessey, *personal communication*).

The systemic fungicide thiabendazole has supplanted the use of chlorination for control of crown rot and has been effective in most cases. Benomyl and thiophanate-methyl provide similar levels of control. Control of crown rot declined dramatically during 1977–1979 in areas receiving benomyl sprays for leaf spot control because of benzimidazole tolerance in the crown rot fungi. This tolerance apparently developed from benomyl applications for banana leaf spot control, since these fungi commonly colonize and reproduce on banana debris within the plantation. In areas with highly tolerant populations and a severe crown rot problem in European shipments, imazalil has provided effective control.

Various means of applying these systemic fungicides are in use, ranging from a dip (Fig. 7A) to an automated spray chamber (Fig. 7B). Most Central American and Philippine commercial producers use booths equipped with up to five overhead nozzles or cascade systems to provide a curtain drench (Fig. 7C). Most employ a recirculating system that reduces fungicide waste by capturing excess spray or drench. Difficulties have been encountered with the recirculating systems, however, because latex accumulates and entraps the fungicide active ingredient.

Controlled-atmosphere packs with oxygen and carbon dioxide levels of 2–3 and 5–7%, respectively, can be used to control crown rot. Although this method of packaging eliminates the need for fungicides, fungal scald occurring where the wet polyethylene liner comes in contact with the fruit can become a severe postharvest problem. Controlled-atmosphere packaging is not in use currently because of cost and fungal scald.

Main stalk and stem-end (or neck) rots. Main stalk rot is not economically significant because bananas are no longer shipped as bunches to world markets. Before the era of boxed bananas, this disease was controlled by retrimming and covering the fresh wound with a fungicidal paint. As with other in-transit rots, rapid cooling and preventing wounds on the bunch were essential preventive measures. Stem-end rot in boxed bananas results from fungal invasion of wounded tissue, so any measures that reduce pedicel wounds caused by flexing and creasing will reduce rot incidence. Pedicel rot in single-finger packs is reduced by making clean cuts during finger removal from the crown and preventing bruises. When these preventive measures are not adequate, thiabendazole application will provide adequate control.

Finger rots. Botryodiplodia finger rot is more common on high caliper grade fruit, fruit with a tendency to ripen in transit, scarred or bruised fruit, and fruit subjected to a delay in reaching shipping temperature. Reducing the caliper grade shipped and avoiding fruit scarring and bruising and refrigeration delays are effective methods of reducing disease incidence. Control is enhanced by thiabendazole treatment. Squirter disease and other finger rots are readily

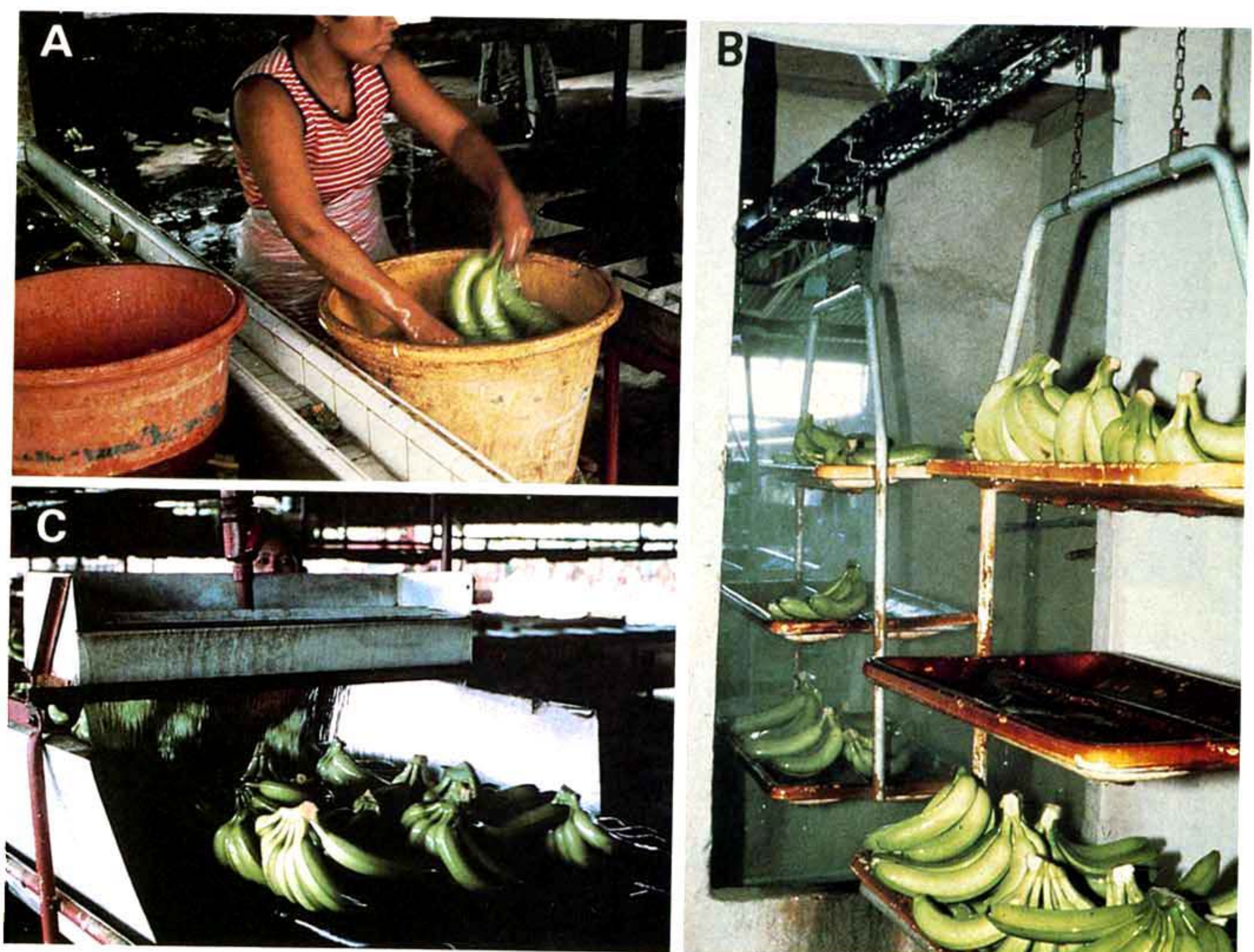

Fig. 7. To prevent crown rot, systemic fungicides are applied to fruit immediately before packing in boxes for shipment. Methods include (A) dipping by hand, (B) an automated spray chamber, and (C) a recirculating cascade system to reduce fungicide waste.

controlled with thiabendazole spray or dips.

Fruit spots. Pitting disease is controlled with a combination of cultural practices and protective sprays. A good sanitation program is essential, since the principal source of inoculum is banana trash leaves. All collapsed and dying leaves, including the transition leaves and bracts, should be removed at regular intervals during the rainy season. In most Central American production areas, two mancozeb sprays are applied at weekly intervals before bagging. These sprays are effective when applied uniformly and adequately over the bunch. Recently, the use of mancozeb-dusted bags has provided control similar to that of the protective sprays and has eliminated the frequent "misses" associated with sprays applied via knapsack sprayers.

Anthracnose fruit spot control also is aided by good sanitation practices in the field. Since *C. musae* is primarily a wound pathogen, any cultural practices that reduce scarring and bruising reduce disease incidence. In practice, leaves close to the fruit are removed and the fruit is bagged to reduce scarring. During harvest, shoulder pads are used to reduce scarring and bruising between the plant and the packing station. Polyethylene liners and paper pads used between layers of fruit during packing also help reduce scarring during transit. Because overmature fruit is more susceptible to anthracnose, good harvest caliper grade control helps to reduce disease incidence. Prompt refrigeration after harvest and packing also aids control. Postharvest thiabendazole sprays used for crown rot control also protect against anthracnose. A combination of all these practices generally provides good control. *C. musae* also causes fungal scald in controlled-atmosphere packs; this disease is easily controlled with thiabendazole sprays before packing.

Continuing Problems and Needs

Banana is a labor-intensive crop and will remain so in the foreseeable future. As inflationary pressures of labor, machinery, materials, and transportation costs increase, there will be a corresponding need to increase marketable fruit production or banana cannot remain the low-cost fruit it is today. This can be accomplished by reducing fruit waste from postharvest diseases during packing and reducing losses from diseases during transit and ripening. The quality losses experienced in world commerce during transit and from diseases are difficult to measure because quality values concerning consumer acceptance vary from one country to another. Nonacceptance of unsightly or costly fruit leads to substitution with other fruits in population diets and subsequent reduction in the world market demand. Although the latter is not necessarily undesirable from the consumer point of view, the banana-producing countries are developing nations that rely on banana exports for employment of their work force and for a large portion of the foreign exchange monies that keep their economies viable.

Crown rot undoubtedly will remain the most serious postharvest disease problem. New approaches to control are needed if the problem is to be rectified at a reduced cost. These approaches should certainly include new protective chemicals to broaden the fungicide arsenal beyond the benzimidazoles, improved methods of fungicide application, and improved packing practices. Unquestionably, more effective systemic fungicides are needed to control anthracnose and pitting disease, since both exhibit latency and can seriously affect quality in the marketplace.

W. R. Slabaugh

Dr. Slabaugh received his Ph.D. in plant pathology at West Virginia University in 1973. He began studies on tropical plant diseases in 1976 with the United Fruit Company's Division of Tropical Research and concentrated his efforts on leaf spot and bacterial wilt control. He later became head of the company's Department of Plant Pathology. Currently, he is doing research on soybean diseases for the University of Arkansas at the Southeast Research and Extension Center located at Monticello. He also has extension responsibilities for southeast Arkansas.

M. D. Grove

Dr. Grove is the manager of technical commercial development of agricultural chemicals in Latin America for the Diamond Shamrock Corporation. After receiving his Ph.D. in 1976 from Washington State University, he was an associate pathologist for the Division of Tropical Research, United Fruit Company, La Lima, Honduras. He joined Diamond Shamrock in 1979.

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