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The North American Blue Mold Warning System

Historically, downy mildew of tobacco (blue mold), caused by *Peronospora tabacina* Adam, was mainly a disease of seedbeds in the United States and Canada (1). The first report of blue mold in the United States was in Georgia and Florida in 1921, but little real damage occurred and the disease disappeared for a decade. In 1931 and 1932, a widespread outbreak caused heavy damage in flue-cured seedbeds from Georgia to Maryland and in perique seedbeds in Louisiana. Until the early 1950s, blue mold was an annual threat to seedbeds throughout the commercial production areas of the United States and Canada. The greatest devastation occurred in the Carolinas in 1949, resulting in a serious shortage of transplants.

Generally, the disease was erratic, causing damage in some production areas annually but seldom persisting within a region for more than a few years, except in Georgia and Florida. It always seemed to return about the time growers became complacent, however. Growers came to fear blue mold more than any other tobacco disease because it could strike quickly and devastate seedbeds. Although seldom destroying all the seedlings in a bed, blue mold added transplanting and replanting expenses. Most commercial growers followed a preventive regime using such fungicides as Bordeaux mixture and ferbam as sprays, dusts, or drenches, at an annual cost of over a million dollars. When blue mold ceased to be a major problem in the 1950s, growers again became complacent and stopped using a preventive program.

The 1979 Epidemic

In 1979, the U.S. and Canadian tobacco industries were surprised by an explosive epidemic of tobacco blue mold in the field that cost growers over $250 million (2) and affected world supplies of burley leaf. Generally, the disease spread from south to north, occurring in all production areas except those in southern Wisconsin. The summer of 1979 was unusually cool and wet on the East Coast and in the Ohio River valley. Southern growers were caught without warning at midseason with no chemical or cultural controls in place. Northern growers had more warning but took no action because most believed a change in weather would stop the epidemic. Hot, dry weather did not begin until mid-August. Disease activity slowed then—but damage was already severe.

Even if growers had been alerted, an effective preventive program probably could not have been implemented. Foliar fungicides had never been used in the field in North America on tobacco, so growers were ignorant of foliar spray techniques and did not have adequate spray equipment. Also, the planting arrangement of the crop prevented effective foliar fungicide application with ground equipment. Attempts to use foliar fungicides in rescue roles were fruitless.

Blue mold destroyed 90% of the Cuban tobacco crop during the fall and winter of 1979–1980, disrupting that country's economic and social systems, which are based on tobacco and sugarcane. In addition, sugarcane was plagued by rust in those years, and blue mold caused major damage to tobacco crops in several other Central American and Caribbean countries. Thus, conditions were set for another major epidemic of blue mold in North America during 1980. The chairman of the Tobacco Disease Loss Committee of the Tobacco Disease Council estimated that losses of 30% ($600 million) could be expected if weather favoring blue mold prevailed during 1980 and controls were not implemented (7). Obviously, blue mold demanded attention!

In December 1979, the Tobacco Disease Council (United States and Canada) held an interim meeting—Blue Mold Symposium I (6)—at North Carolina State University in Raleigh. In addition to reviewing available information on blue mold, workers in research, extension, and industry united to develop plans for coping with the disease. Among the plans were a preventive program centered around the use of Ridomil 2E (metalaxyl) and establishment of the North American Blue Mold Warning System.

The Warning System

A valuable tool in blue mold control during the 1940s and 1950s was a warning service established in 1945 and operated by the U.S. Department of Agriculture in cooperation with state experiment stations (3). The system was designed to relay information on blue mold activity from the local community through the state experiment station to the Plant Disease Survey Office of the USDA. The information was shared through timely reports sent to all tobacco production areas. Growers were informed through the state and county extension offices via the mass media. The system functioned well until blue mold became rare. The program declined during the 1960s and was nonoperational when the 1979 epidemic occurred.

A similar warning system is operated by CORESTA (Cooperation Centre for Scientific Research Relative to Tobacco) in Europe and the Mediterranean countries (5). Occurrences of blue mold are reported by cable to the Paris office, which then warns immediately threatened countries by cable and informs all other participants by airmail.

The successful history of warning systems and the obvious pattern of a south-to-north spread of blue mold in 1979 served as the impetus for the Tobacco Disease Council, including Canada, to establish a warning system in December 1979. The system was modeled after that operated in the 1950s but with numerous differences.

A coordinator, usually the person with extension responsibility for tobacco pathology, was appointed for each state or area where tobacco was produced. Each coordinator organized the warning system within the state or area from the local community on up, involving growers, county agents, tobacco commodity specialists, research plant pathologists, and agricultural meteorologists.

Initially, county extension agents obtained reports (written or oral) from community reporters (growers and agribusiness personnel) on Monday and forwarded them to the state coordinators. The reports included information on the status of crop development, recent weather, control action, and blue mold development. The county reports were summarized by the state coordinator and forwarded by phone to the national coordinator by midweek. The national coordinator compiled the information into a warning statement that included the occurrence of blue mold outbreaks, anticipated change in disease status caused by weather, and suggested controls. The report was mailed to state coordinators and interested parties on Friday. State coordinators interpreted the warning statement based on the local situation and used letters and mass media to inform county agents and growers regarding disease status and suggested controls. Urgent information was obtained and disseminated by telephone.

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Fig. 1. Typical local lesion of blue mold on burley tobacco.

Fig. 2. Sporulation of *Peronospora tabacina* on week-old lesions on burley tobacco.

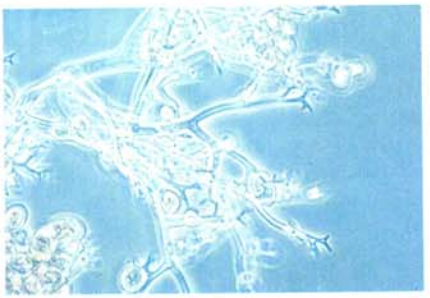

Fig. 3. Sporangia and sporangiophores of *P. tabacina* produced on burley tobacco (×200).

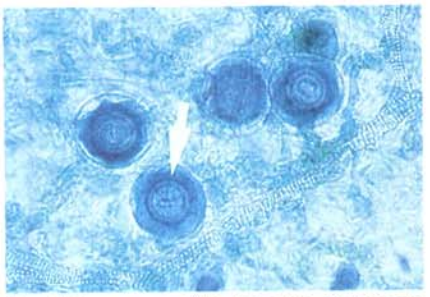

Fig. 4. Oospores of *P. tabacina* produced on burley tobacco (×200).

Cooperation within and between state extension services was at a high level. During 1980, reports were issued in both directions regardless of blue mold activity. The system generated so much information and blue mold activity was reported so frequently, however, that much of the warning value was diminished.

Since 1981, the system has functioned similarly except that reporting is on an "as needed" basis, ie, reports are not made until disease activity is detected; once initiated, reporting continues until disease activity stops. When blue mold is confirmed in a county, the extension agent immediately telephones the state coordinator and the warning system is activated. The state coordinator telephones adjacent counties that might be threatened and informs the national coordinator. The national coordinator alerts adjacent states and threatened areas by telephone and sends a written report to all state coordinators and other interested parties. Once blue mold becomes active in the area, reports are submitted regularly until activity subsides. A national report is prepared by the national coordinator as needed and consists of a summary of the current status of active blue mold (first occurrence, significant change in disease level, etc.). From May through August, weekly reports are usually required because of changing blue mold status. The national report does not include control suggestions; each state develops control strategeies according to tobacco type and local situations. The national coordinator's office also serves as a focal point for the tobacco industry at large for keeping abreast of the blue mold status in North America. Information from blue mold warning systems in Central America is often included, as these systems have a liaison with the North American system.

Kentucky's Warning System

Although the states are connected through a strong cooperative effort with the Tobacco Disease Council, each state coordinator is free to establish a locally effective system. The system developed for Kentucky typifies those in major tobacco-producing states, although some differences exist from state to state.

Agriculture in Kentucky is very diverse—mainly tobacco, cattle, horses, forages, and grains—and most growers are involved with multiple ventures. Tobacco is produced on about 240,000 acres by about 150,000 growers in 118 of 120 counties. About half the total crop is produced by growers with less than 2 acres of tobacco and the other half by growers with 2–100 acres. Small growers make up about 87% of the total growers. Tobacco is the leading source of agricultural income in Kentucky and is important financially, politically, and socially. In 1982, the crop sold for about $1 billion and accounted for 35% of the net farm income. Tobacco-related articles often have front-page priority in most newspapers in the state, from the metropolitan dailies to the county weeklies.

The Kentucky warning system is coordinated by Extension Plant Pathology, College of Agriculture, University of Kentucky. The philosophy is to keep growers informed of the status of blue mold as it progresses toward and through the state and to alert them when the disease threatens the crop in their area. Control strategies are delivered to growers in advance through established extension programs, but control options appropriate for the situation are included in advisory statements. County agents, extension tobacco specialists, and plant disease diagnostic laboratories provide most of the input on blue mold activity and crop status. Extension agricultural meteorology provides weather data. These inputs, along with the national information, are summarized by the state blue mold coordinator and the extension plant pathologist with tobacco responsibility. No acceptable predictive model for determining the direction or intensity of the epidemic exists, so the state coordinator makes a judgment based on inoculum production, wind

direction, leaf wetness (dew, rain, fog), stage of crop development, temperature, general weather patterns, and grower reaction. The coordinator's suggestions are submitted to the National Weather Service, Extension Public Information, and county agents for delivery to growers.

Several special projects have been implemented to support the warning system in Kentucky. To aid in collecting information on blue mold status, in-depth training on blue mold diagnosis and scouting procedures is conducted regularly for growers and agents. A slide-tape set is available in each county extension office to assist in this task. During winter meetings, infected live specimens are used to familiarize growers and agribusiness personnel with the various symptoms and signs associated with blue mold (Figs. 1 and 2). These two training programs have greatly reduced the number of false reports of blue mold and have led to early detection of uncommon phases of the disease during the past 4 years.

Scouting patrols of trained pathologists travel throughout the state when needed to gather details on early outbreaks. This program has been most helpful in establishing the distribution and direction of movement of the initial outbreaks and in verifying that the source of inoculum is windborne sporangia (Figs. 3 and 4). Once a single confirmed report has been obtained, these scouts have been able to quickly establish the extent of the epidemic, often detecting blue mold in other communities weeks before growers and agents find the disease. In 1981, for example, these investigators found that blue mold was active in an area 125 miles wide before growers detected the disease.

Scouting information has been valuable to the state coordinator for estimating where outbreaks will occur in Kentucky and where control programs should be intensified. A 24-hour telephone answering service with radio quality was established so the agricultural mass media (only) could obtain the latest information on blue mold status and controls. The state coordinator places advisories on the line daily (as needed) and provides a special in-depth update every Tuesday. Before this system was functional, the state coordinator was granting over 20 interviews (telephone and personal) daily. The agricultural press has accepted this information delivery system and has used it in a wide variety of daily and weekly programs.

Blue mold status, along with pertinent weather information, is also transmitted daily through the National Weather Service, Agricultural Advisory. This is the most rapid means of getting blue mold advisory information to the Kentucky grower. Special bulletins can be available to the grower within 20 minutes of their release by the state coordinator, and routine information is available four times a day as part of the regular agricultural weather advisory.

Blue mold advisories are sent to the grower under three levels of urgency modeled after the severe-storm forecast system of the National Weather Service. A "report" carries the lowest level of urgency and is designed to maintain grower awareness. Generally, a report is used to inform growers of the progress of the disease outside their area. A "watch" is issued when weather and crop status favor disease development and inoculum arrival is suspected. Growers are advised to increase control intensity, remain watchful for the disease, and report any suspected disease activity to the county agent. A "warning" is issued when disease activity has been sighted and remains in effect as long as weather remains favorable for blue mold and the disease is active. A watch or a warning is issued for a specific area (county, geographic region, etc.) of the state.

An example of a typical blue mold advisory follows. On 27 May 1982 a report was issued stating "blue mold was active on native wild (weedy) tobacco in Texas and Georgia flue-cured plantings. Southerly winds could bring spores into Kentucky, especially western Kentucky. Present weather is not favorable for widespread disease development, but plant bed irrigation should be done early enough that plants dry before dark. Preventive fungicide programs are advisable." On 6 June a watch was issued for southern and western counties following a week of rainy weather: "Growers are advised to remove plant bed covers, intensify fungicide sprays in the beds, and remain watchful for the disease, because plants are highly susceptible, weather conditions are ideal for blue mold development and UK plant pathologists assume spores are landing in Kentucky from activity to the south or southwest." On 15 June a warning was issued for the Mammoth Cave area: "Blue mold was found in three beds in two counties (Hart and Edmonson). The disease appeared to have been present for at least two weeks and sporulation is heavy. Blue mold activity is expected to intensify in the Mammoth Cave area. Winds during the past 10 days have been principally from the south and southwest, so spread east and north is likely. Also a blue mold watch is issued for areas east and north of the Mammoth Cave area. The watch issued on June 6 for southern counties remains in effect."

The Warning System's Role in Control of Blue Mold

Measures used to reduce blue mold activity include chemical applications, smaller plant populations, good site selection, and early destruction of infected seedbeds and crops. A major weakness of the warning system is that most controls must be implemented before blue mold appears. In North America, the systemic fungicide Ridomil 2E is the principal tool and is highly effective against current strains of the pathogen (4). In the United States, however, Ridomil 2E is labeled only for preplant use in seedbeds and fields and for supplemental soil-directed applications in fields. These supplemental applications are designed to extend the protection period and cannot be used legally unless preplant applications have been made. Ridomil 2E is highly effective in soil or foliar postplant applications in response to a warning, but the manufacturer has

Table 1. First occurrence and crop loss estimates from the 1979 epidemic of tobacco blue mold in the United States and Canada

State or region	Tobacco type	First occurrence	Reduction in crop value	
			%	$
Northern Florida	Flue-cured	May 16	3.50	1,065,668
Georgia Coastal Plain	Flue-cured	May 14	1.50	2,130,000
South Carolina Coastal Plain	Flue-cured	May 11	3.97	6,764,880
North Carolina Coastal Plain	Flue-cured	May 24	4.02	38,437,005
Maryland	Maryland	June 5	15.00	5,700,000
Southern Virginia	Flue-cured	June 15	3.00	4,984,200
Western North Carolina	Burley	June 18	39.59	8,480,178
Western Virginia	Burley	June 20	20.00	5,576,000
Western Tennessee	Burley	July 5	10.00	12,350,000
Pennsylvania	Cigar filler	July 11	30.00	4,400,000
Southern Ontario	Flue-cured	July 12	30.00	90,000,000
West Virginia	Burley	July 15	20.00	502,740
Western Tennessee	Dark	July 16	1.00	321,569
Southern Kentucky	Burley	July 26	10.00	56,000,000
Connecticut	Shade wrapper	July 30	15.00	4,860,000
Massachusetts	Shade wrapper	August 3	10.00	1,020,000
Southern Ohio	Burley	August 3	30.00	9,000,000
			Av. 14.50	Total 251,592,240

Table 2. First occurrence and crop loss estimates from the 1981 epidemic of tobacco blue mold in the United States and Canada

State or region	Tobacco type	First occurrence	Reduction in crop value %	Reduction in crop value $
Northern Florida	Flue-cured	March 20	0.01	300
Pennsylvania	Cigar filler	June 8	1.5	310,000
Southern Virginia	Flue-cured	June 15	0	0
Maryland	Flue-cured	June 22	0	0
Connecticut	Cigar types	June 23	0	0
Western Kentucky	Burley and dark	July 1	1.5	13,120,000
Southern Indiana	Burley	July 2	0	0
Middle Tennessee	Burley	July 4	2.0	4,600,000
Western North Carolina	Burley	July 13	1.9	1,160,000
Southern Ohio	Burley	July 14	0.01	220,000
West Virginia	Burley	July 20	7.0	330,000
Central and western Virginia	Burley and sun-cured	July 20	4.0	2,050,000
Southern Ontario	Flue-cured	August 14	0	0
Western Missouri	Burley	August 16	5.0	250,00
			Av. 1.64	Total 22,040,300

not supported such requests at the state or national level. Foliar applications of standard protectant-type fungicides (maneb, zineb, metiram, mancozeb, and ferbam) are also labeled, but few growers use them. In southern flue-cured tobacco areas, 90% or more of the growers have been using Ridomil 2E preplant in seedbeds and fields since it became available. In this area, blue mold usually occurs early in the season, at or shortly after transplanting. Also, much of the use of Ridomil 2E is aimed at controlling black shank (*Phytophthora parasitica* Dast. var. *nicotianae* (Breda de Haan) Tucker), which is widespread. Acceptance in burley areas has been much slower because most blue mold activity occurs in midseason and later. Use of Ridomil 2E is increasing, and in 1983 an estimated 70% of the growers applied the chemical preplant. In Canada, use in seedbeds is common but preplant application in the field is rare.

Despite a program that has little legal room for decisions based on a warning system, growers are using the system's information in their decision making. In all areas, supplemental foliar sprays in seedbeds are based on disease pressure, and few growers use supplemental sprays unless advised to by the warning system. In the field, supplemental application is more popular in the burley areas, where blue mold is a threat until harvest. Growers are basing their decisions to use supplemental applications on the status of blue mold. An increasingly popular approach is to apply a small amount (one-half or less) of the chemical preplant in the field, regardless of blue mold status, then "wait to see" what the status becomes in Kentucky before making the supplemental application at cultivation.

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If labeling permitted, most Kentucky growers would not use Ridomil 2E preplant in the field unless advised to by the warning system and unless the chemical was needed to control black shank or damping-off caused by *Pythium* spp. Canadian growers have adopted a similar policy of using Ridomil 2E in seedbeds preplant but not applying the chemical in the field unless blue mold is active in a northern production area of the United States, ie, Ohio, Pennsylvania, or Connecticut.

The warning system is very active in monitoring for pathogen strains tolerant to Ridomil 2E. Research plant pathologists regularly monitor the pathogen population and pass their reports along through the system. All instances of active blue mold in sites where Ridomil 2E has been used are reported promptly, along with reasons for the failure.

Accomplishments and Needs

The North American Blue Mold Warning System operated by the Tobacco Disease Council in cooperation with the Cooperative Extension Service and its equivalent in Canada is serving the tobacco industry well. The system is keeping the industry aware of blue mold activity in the Western Hemisphere through timely reports from reliable sources. Growers are being helped to some extent in timing controls, but much greater flexibility in fungicide usage and labeling is needed before this aspect can be expanded. A predictive model is also needed. The system keeps the industry abreast of the effectiveness of Ridomil 2E by reporting all instances of blue mold activity in fields where the chemical has been used.

Since 1979, blue mold activity has declined steadily in the United States and Canada because of less favorable weather and the implementation of preventive programs. This reduction is apparent when crop loss estimates from the 1979 epidemic (Table 1) are compared with those from the 1981 epidemic (Table 2).

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