# Analysis of Weather and the 1980 Blue Mold Epidemic in the United States and Canada

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**ABSTRACT**

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Tobacco blue mold (*Peronospora tabacina*) occurred in major tobacco production areas in North America during 1980. Blue mold in the field was first reported on 1 January in Cuba and Jamaica, 5 February in Haiti, 25 February in Honduras, 4 March in Nicaragua, 8 April in Florida, 28 April in South Carolina, 11 May in North Carolina, 30 May in Virginia, 10 June in Maryland and Tennessee, 8 July in Kentucky, 11 July in Pennsylvania, 13 July in Connecticut and Massachusetts, 23 July in Indiana, 25 July in Ohio, and 5 August in Canada. Rainfall in the eastern United States was above normal from March through May and below normal for June through August 1980. Temperatures were below normal in March, April, and June, slightly above normal in May, and well above normal in July and August. Compared with 1979, 1980 was generally warmer and drier but was cooler and wetter in March. Weather conditions were less favorable for blue mold development in 1980 than in 1979, therefore resulting in one-third less loss from this weather-sensitive disease.

Tobacco (*Nicotiana tobaccum* L.) is produced in 593 counties in 17 states in the continental United States, largely along the eastern seaboard. Although most of the tobacco hectarage is in North Carolina, Virginia, South Carolina, and Georgia (Fig. 1) certain specialty tobacco types are grown from Florida to Canada and from the Atlantic coast to the inland areas of Kentucky, Ohio, and Wisconsin (12).

Blue mold, caused by *Peronospora tabacina* Adam, attacked major tobacco production areas in North America during 1980. Areas and dates of the first report of blue mold in the field were: Cuba and Jamaica, 1 January; Haiti, 5 February; Honduras, 25 February; Nicaragua, 4 March; Florida, 8 April; South Carolina, 28 April; North Carolina, 11 May; Virginia, 30 May; Maryland and Tennessee, 10 June; Kentucky, 8 July; Pennsylvania, 11 July; Connecticut and Massachusetts, 13 July; Indiana, 23 July; Ohio, 25 July; and Canada, 5 August.

The intracontinental epidemics of blue mold of tobacco in 1979 and 1980 had a serious economic impact on tobacco production in the United States and Canada. Estimates of loss were $250 million in 1979 and more than $84 million in 1980. Latin American countries experienced similar problems in both 1979 and 1980 (8).

Outbreaks of blue mold in the southeastern United States in 1954 and 1963 were largely limited to seedling transplant beds. Field infection and spread were related to local conditions of below normal temperatures and frequent overcast, rainy weather (7,11). In 1979, the first major regional epidemic occurred in the United States and resulted in severe damage and extensive crop losses from Florida to Canada.

Lucas (8) described the general climatic situation during the 1979 epidemic in the United States. The epidemic of 1980 started in Florida and Georgia on 4 February, which was several weeks earlier than in 1979. It spread regionally across the mid-Atlantic states and eventually reached Canada on 5 August. The disease also spread somewhat more slowly in 1980 than in 1979. A late season drought in the southern and mid-Atlantic region, above normal temperatures, and widespread use of fungicides (3) helped prevent a repetition of the serious losses experienced in 1979.

To determine the effects of weather on the epidemiology of blue mold, after the epidemic, an analysis of weather and disease was initiated to collect spatial and temporal disease occurrence data from the United States and Canada for 1980, to compare disease and weather patterns for 1979 and 1980, and to synthesize and interpret regional meteorologic data using factor analytical procedures. Preliminary reports have been made (2,4,5).

## DISEASE DISTRIBUTION

To document the rapid spread of the blue mold pathogen from south to north, a network of reporters was established among the tobacco-producing states along the Eastern Seaboard and Canada. A coordinator, usually the tobacco extension specialist in each state, was designated to work with county agents and others to detect and confirm blue mold. Reports of each initial case of blue mold specified the county, date, location,

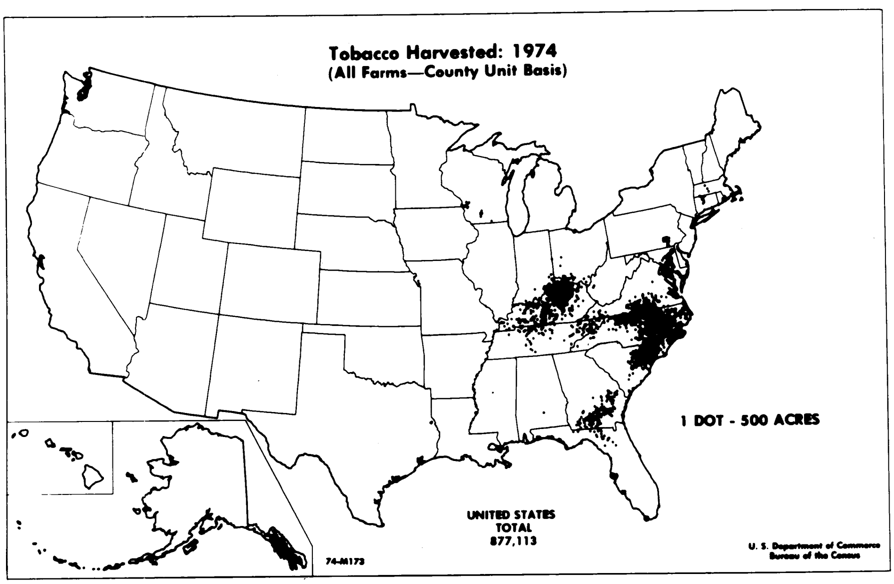


**Fig. 1.** Tobacco acreage in the United States.

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nature of the infection (plant bed vs. field), local meteorologic conditions, and extent of damage. These reports were mailed to North Carolina State University for editing, processing and analyses.

Figure 2 shows first reported occurrences of blue mold by states and counties for 3-mo periods starting in February 1980. Blue mold was reported and confirmed in plant beds in southern Florida on 4 February (Fig. 2A). By 15 March (Fig. 2B), the disease had spread north to all 38 counties in Georgia (3). Blue mold first appeared in plant beds in North Carolina on 2 May and spread to most counties and then into southern Virginia by 1 June. From 1 June through August (Fig. 2C and D), the disease continued to spread north and west until it reached the tobacco fields around Delphi, Ont., Canada, on 5 August.

Of the 593 reporting counties producing tobacco in the United States, only 140 (~ 25%) responded with reports. Lack of response may have been due to the absence of blue mold or failure to submit a report. Incomplete or partial data were received from important tobacco states such as Georgia and Kentucky. However, we consider the data (Fig. 2) sufficient to track the progress and spread of blue mold from Florida to Canada in 1980.

## COMPARISON OF 1980 AND 1979 WEATHER

According to Lucas (8), blue mold can develop at average temperatures of 15–25 C, with the optimum about 20 C. Spores will, however, germinate between 2 and 30 C. Relative humidities in excess of 95% for longer than 3 hr at night, together with intermittent rainy weather, also favor blue mold development.

Weather conditions during the 1980 and 1979 blue mold seasons are shown in Table 1, which shows temperature, precipitation, and sunshine conditions for the eastern United States and is based on data from appropriate weather and

**Table 1.** Regional comparison of temperature, precipitation, and sunshine between the 1980 and 1979 tobacco growing seasons[a]

| Month | Temperature (C) | Precipitation (cm) | Sunshine |
|---|---|---|---|
| March | −2.7 | 9.7 | Less sunny |
| April | −0.1 | −3.3 | Sunnier |
| May | 0.6 | −2.8 | Sunnier |
| June | 0.4 | 1.8 | Sunnier |
| July | 1.9 | −4.1 | Sunnier |
| August | 1.9 | −3.3 | Sunnier |

[a]Average meteorologic conditions for the eastern third of the United States. A positive entry indicates that 1980 was warmer or wetter than 1979. Sunnier indicates that the area of above normal percent of possible sunshine was greater in extent in 1980 than in 1979.

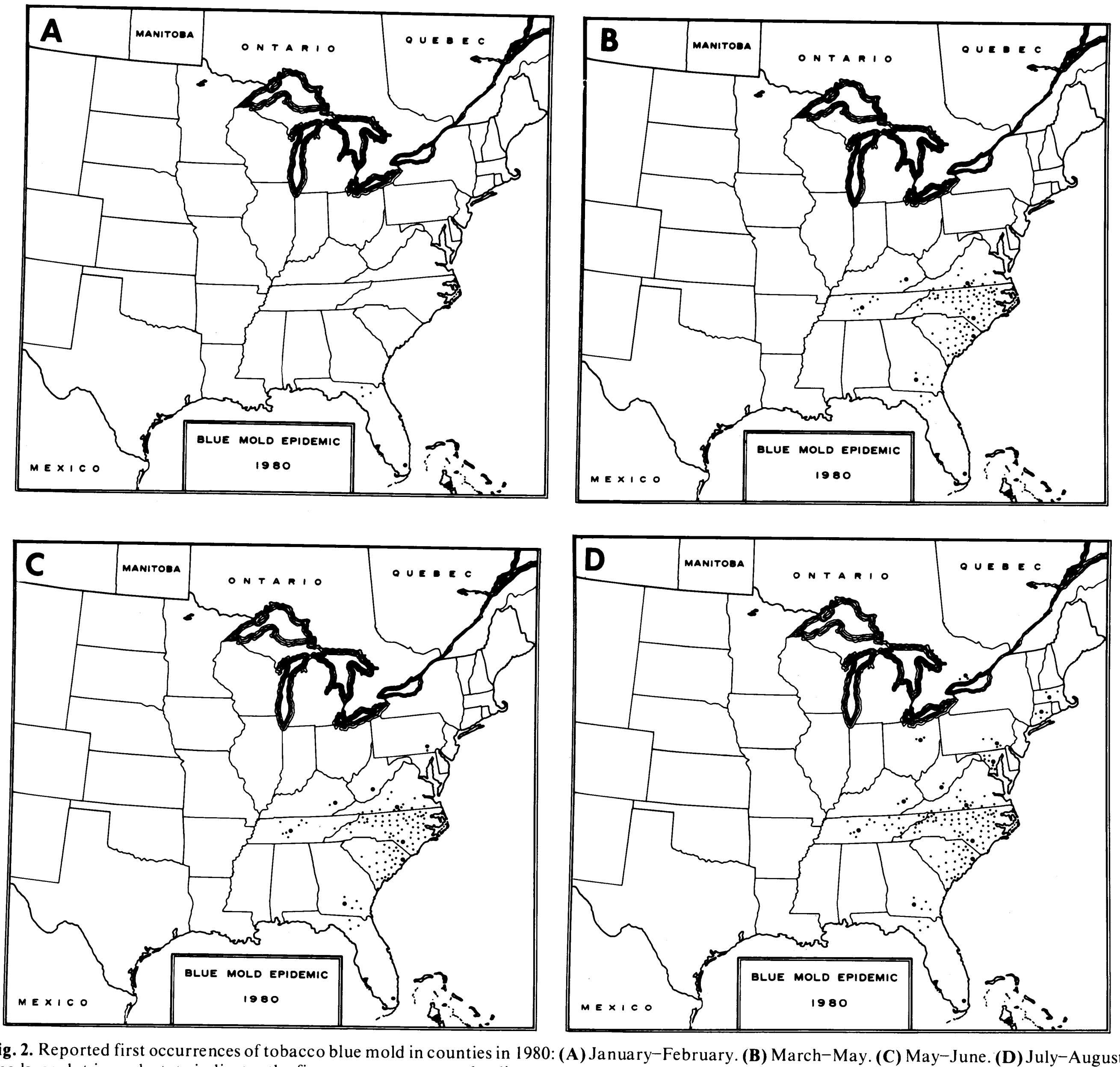


**Fig. 2.** Reported first occurrences of tobacco blue mold in counties in 1980: **(A)** January–February. **(B)** March–May. **(C)** May–June. **(D)** July–August. The large dot in each state indicates the first county to report the disease.

crop bulletins (9,10). Compared with 1979, 1980 was generally warmer and drier, except for March, which was cooler and wetter in 1980. "Sunnier" indicates that the area of above normal percent of possible sunshine was greater in extent in 1980 than in 1979. Except for March, 1980 was characterized by larger land areas exposed to more sunshine than normal each month compared with the 1979 season.

The 45 weather stations used in constructing this table covered a region bounded by the East Coast, Orlando (FL), Mobile (AL), Memphis (TN), Indianapolis (IN), and Concord (NH). Major temperature differences between years occurred in March, when 1980 was nearly 3 C cooler than 1979, and in July and August, when 1980 was about 2 C warmer in each month than 1979. In other months, differences were less than 1 C. Rainfall in March 1980 was about 10 cm more than in 1979. Differences in other months were generally less than 4 cm. In local areas, conditions often varied considerably from these monthly regional averages.

With the exception of New England, portions of Florida, and the mid-Atlantic East Coast, temperatures in 1980 were several degrees below the 30-yr normal from March through May (Fig. 3A). Except for portions of New England and the Midwest, rainfall amounts in all regions were normal or above during this period (Fig. 3B).

Although June through August temperatures in 1980 averaged above normal (Fig. 3C), temperatures were below normal in June over much of the eastern United States. Much of this same region, with the exception of portions of the Midwest, had below normal rainfall amounts from June through August (Fig. 3D). August rainfall in many areas along the East Coast and in the southeastern and south central United States was less than 50% of normal.

## WEATHER ANALYSIS OF 1980 EPIDEMIC

Although Fig. 3 provides summary information, it does not allow detailed analysis of the individual months that were combined to produce the seasonal data. The method of principal components analysis provides great flexibility in this regard because it provides an economical way of describing the spatial and temporal features of the meteorologic data. In our study the relationships between 12 interconnected meteorologic variables were summarized in terms of three components. The variables considered were monthly deviations from normal of temperature and precipitation data for March through August 1980 for the 45 eastern U.S. weather stations.

Three main components were identified: precipitation and early and late season temperatures. Principal components analysis is a relatively straightforward method of transforming a given set of variables into a new set of composite variables, or principal components, that are orthogonal (uncorrelated) to each other (1,6). The first principal component is extracted based on the best linear combination of the original variables to account for more of the variance in the data than any other combination of variables. Subsequent principal components are extracted in a similar manner until the variance in the data is exhausted. The relationship between the original observations and the components is expressed as a positive or negative value, referred to as a component score.

Figure 4 shows the spatial distribution of the scores from the first three principal components. In Fig. 4A the larger positive numbers refer to geographic areas that had rainfall amounts well above normal during March through May and well below normal during June through August. Other locations with smaller positive values exhibited the same above normal-below normal rainfall time sequence but to a lesser quantitative degree. Areas with negative scores tended to have below average rainfall in the early months and above average rainfall later.

The first component also reflects the June temperature pattern to a greater degree than the third component does. Where the scores were positive, June temperatures were above normal, and

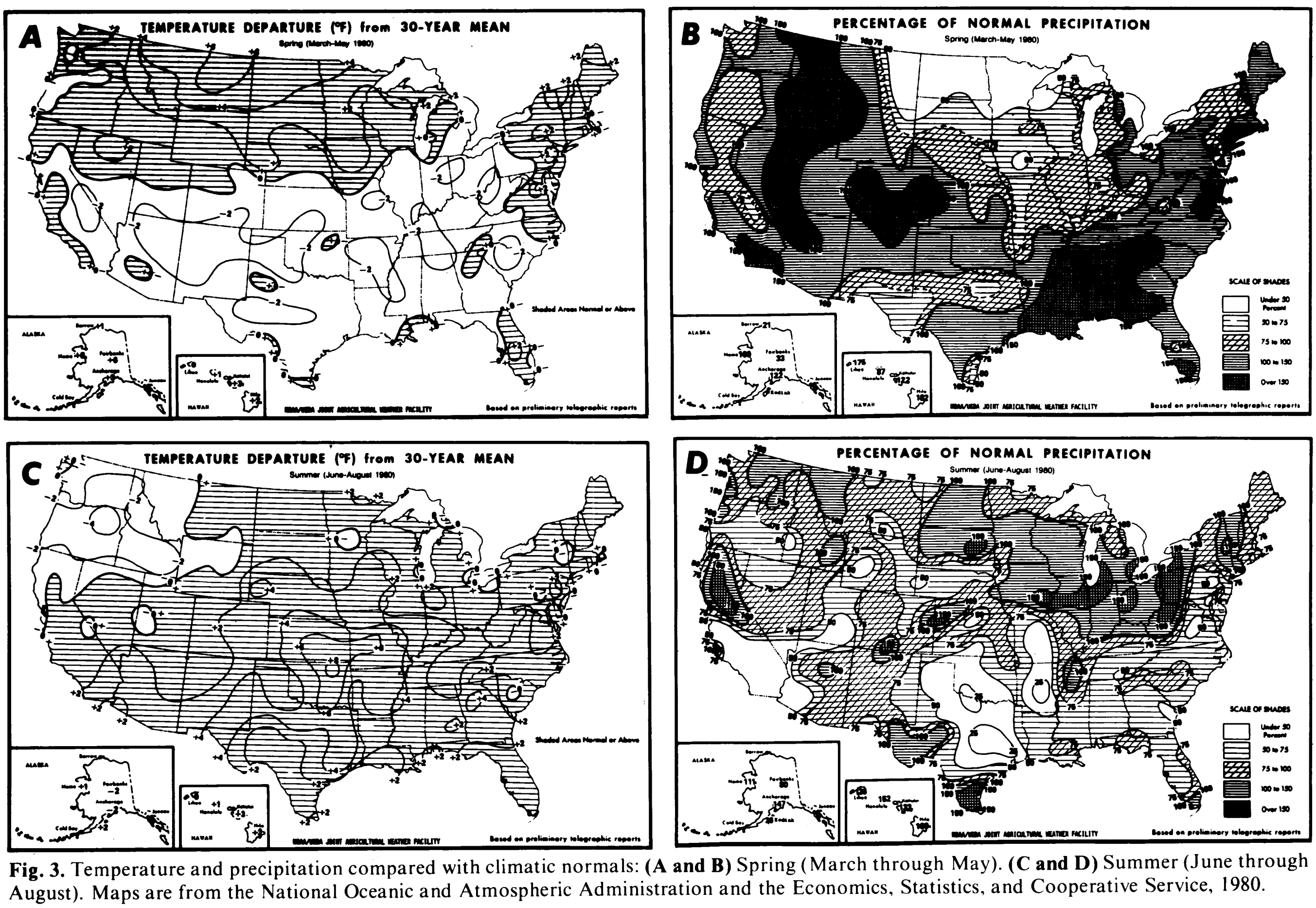


**Fig. 3.** Temperature and precipitation compared with climatic normals: **(A and B)** Spring (March through May). **(C and D)** Summer (June through August). Maps are from the National Oceanic and Atmospheric Administration and the Economics, Statistics, and Cooperative Service, 1980.

where the scores were negative, the temperatures were below normal. Above normal temperatures were greatest where the scores were the most positive.

Positive scores for component two (Fig. 4B) indicated geographic areas that had above normal temperatures from March through May. Regions where the component scores were negative were marked by below normal temperatures during March through May.

The third component (Fig. 4C) represents departures of July, August, and, to a lesser extent, June temperatures from normal. Areas with high positive numbers had temperatures well above normal during the period. Stations with scores near zero had temperatures moderately above normal, and a negative score indicated near normal conditions for the period.

Typically, a thermal band or wave of potentially favorable weather for blue mold (15–25 C) migrates north as the growing season progresses. The temperatures are too cool north of the band and have become too warm south of the band for blue mold development.

Table 2 shows 30-yr normal temperatures at 10 of the 45 East Coast weather stations during March through August. In a normal March, the only area exhibiting favorable conditions is Florida, but by June the area of favorable temperatures generally extends into the mid-Atlantic states.

Table 3 provides a similar interpretation of temperature conditions for the blue mold epidemics of 1979 and 1980 based on mean monthly temperatures for those years. For 1980 at least, this interpretation agrees closely with actual occurrences of blue mold (Fig. 2B) based on disease distribution and tobacco phenology. The generally lower than normal temperatures in this region (Figs. 3A and 4B) during the early 1980 growing season were within the optimal temperature range (7,8) for spore germination and infection, and the greater than normal amount of rainfall was also conducive to the increase and spread of the disease.

The lower than normal temperatures in many areas in June 1980 were favorable for disease, because temperatures remained within the optimal range later in the year than usual. The June temperature pattern is depicted by the first principal component (Fig. 4A). In much of the tobacco-growing region, disease increase was limited by below normal rainfall in June.

Temperatures in July and August were above normal and well above the optimal temperature band in most areas; in many cases temperatures were above the upper limit of 30 C (7,8). Rainfall amounts in July and August were well below normal in most of the tobacco-producing areas, but rainfall amounts were normal or above normal in many parts of Kentucky in July and August.

## DISCUSSION

The broad-scale meteorologic approach we used allows synthesis and interpretation of the general effects of weather on blue mold development and spread. However, the technique tends to filter out the smaller scale meteorologic events that could influence localized disease

**Table 2.** Normal temperatures (1941–1970) for 10 of 45 weather stations[a]

| Location | March | April | May | June | July | August |
|---|---|---|---|---|---|---|
| Tallahassee, FL | *15.7* | *19.9* | *23.8* | 26.7 | 27.3 | 27.3 |
| Savannah, GA | 14.4 | *18.9* | *22.9* | 26.2 | 27.3 | 27.0 |
| Columbia, SC | 12.3 | *17.8* | *22.3* | 26.0 | 27.3 | 26.8 |
| Knoxville, TN | 9.9 | *15.7* | *20.2* | *24.2* | 25.7 | 25.2 |
| Raleigh, NC | 9.6 | *15.3* | *19.7* | *23.6* | 25.3 | *24.7* |
| Lexington, KY | 6.4 | 12.9 | *18.2* | *22.8* | *24.6* | *23.9* |
| Washington, DC | 5.4 | 11.7 | *17.0* | *21.7* | *24.1* | *23.1* |
| Scranton, PA | 2.5 | 9.3 | *15.1* | *20.1* | *22.5* | *21.3* |
| Albany, NY | 0.8 | 8.3 | 14.3 | *19.7* | *22.2* | *20.9* |
| Buffalo, NY | 0.1 | 7.2 | 12.8 | *18.7* | *21.1* | *20.2* |

[a]Temperatures set in italic type fall within the optimal range (15–25 C) for blue mold development.

**Table 3.** Mean monthly temperatures for 10 of 45 weather stations[a]

| | 1979 | | | | | | 1980 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | March | April | May | June | July | August | March | April | May | June | July | August |
| Tallahassee, FL | 14.4 | *19.4* | *22.2* | *25.0* | 27.2 | 27.2 | *16.1* | *17.8* | *23.3* | 26.7 | 28.3 | 28.3 |
| Savannah, GA | *15.6* | *20.0* | *23.3* | *25.0* | 27.8 | 27.2 | 13.9 | *18.9* | *22.8* | 26.7 | 28.9 | 28.3 |
| Columbia, SC | 13.3 | *16.7* | *20.6* | *22.8* | 26.1 | 26.7 | 10.0 | *16.7* | *20.6* | *24.4* | 27.8 | 27.2 |
| Knoxville, TN | 11.7 | 25.6 | 29.4 | *22.8* | *23.9* | 25.6 | 8.9 | *15.0* | *20.0* | *23.9* | 27.8 | 27.8 |
| Raleigh, NC | 11.1 | *15.6* | *19.4* | *21.1* | *23.9* | *25.0* | 8.3 | *16.7* | *21.1* | *23.9* | 26.1 | 26.7 |
| Lexington, KY | 8.9 | 12.2 | *17.2* | *21.7* | *23.3* | *23.3* | 5.6 | 11.7 | *18.3* | *21.7* | 26.1 | 25.6 |
| Washington, DC | 11.1 | 13.3 | *20.0* | *22.2* | 26.1 | 26.1 | 7.8 | *15.6* | *21.1* | *23.9* | 27.8 | 28.3 |
| Scranton, PA | 5.0 | 7.8 | *15.0* | *18.3* | *21.7* | *21.7* | 2.2 | 10.6 | *16.7* | *18.3* | *22.8* | *23.9* |
| Albany, NY | 3.9 | 7.2 | *15.6* | *18.9* | *22.8* | *20.6* | 0.6 | 8.9 | *15.6* | *17.2* | *22.2* | *21.7* |
| Buffalo, NY | 3.3 | 6.7 | 13.9 | *19.4* | *21.7* | *20.0* | 0.0 | 7.8 | 14.4 | *16.7* | *22.2* | *22.8* |

[a]Temperatures set in italic type fall within the optimal range (15–25 C) for blue mold development.

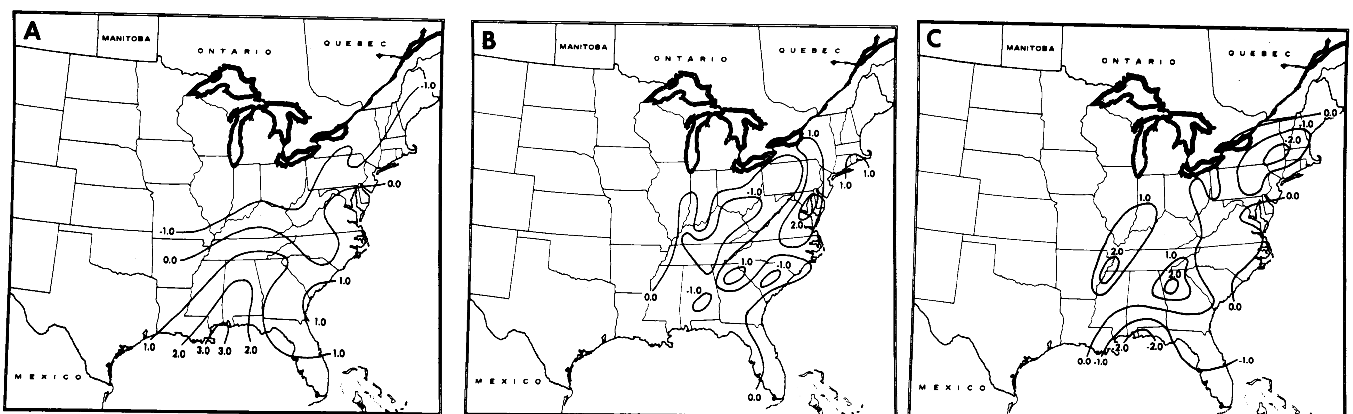


**Fig. 4.** Spatial distributions of the component scores relating the original observations to the first three principal components: **(A)** Precipitation. **(B)** Early season temperature. **(C)** Late season temperature.

situations.

Continuation of the 1980 blue mold epidemic into July and August in North Carolina and other southern states despite generally unfavorable temperature and moisture conditions is cause for concern and should receive additional attention. We cannot rule out the possibility that a strain of *P. tabacina* tolerant to high temperatures has developed in the natural population.

The possibility of conidial transport to the southeastern United States from infested fields in Cuba and Jamaica should also be considered. The direction of prevailing winds at low levels is generally favorable for transport during late spring and early summer (8). Considering the abundant inoculum this pathogen produces, it is reasonable to assume that viable conidia are transported by wind from Cuba and Jamaica to the southernmost states of the continental United States.

In our reporting network, one to two latent periods (8–12 days) probably elapsed after initial infection before blue mold was detected and confirmed. This, together with turnaround time for preparing and mailing reports, presents serious problems with using this approach in any timely forecasting system for implementing preventive control actions. Our analyses of the 1980 epidemic should provide tobacco pathologists, meteorologists, and others with an additional data base and approach from which to design new and improved forecasting systems.


## ACKNOWLEDGMENTS

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