Distribution of *Puccinia polysora* in Indiana and Absence of a Cool Weather Form as Determined by Comparison with *P. sorghi*

R. A. SCHALL, Plant Pathologist, APHIS, USDA, Lafayette, IN 47901, and J. W. McCAIN, Graduate Research Assistant, and J. F. HENNEN, Professor, Department of Botany and Plant Pathology, Purdue University, West Lafayette, IN 47907

ABSTRACT

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Southern maize (*Zea mays*) rust, caused by *Puccinia polysora*, has now been found widely in Indiana. Weather conditions at the time of disease appearance each year were reviewed. Although southern maize rust was severe in some years, correlations between favorable weather and disease appearance did not indicate that the pathogen had developed new forms that could infect corn during cool weather or overwinter in Indiana. Southern maize rust appeared later in 1978–1981 than common maize rust, caused by *P. sorghi*, and followed periods of southerly winds associated with rainfall and temperatures warmer than those that favored common maize rust. Morphology and taxonomy indicate that *P. sorghi* should be considered the valid name for the common rust pathogen and *P. maydis* is a synonym.

Southern maize (*Zea mays* L.) rust, caused by *Puccinia polysora* Underw., has been known to occur in Indiana for more than 30 yr. Earlier occurrences of southern maize rust cannot be ruled out but could have been recorded as common maize rust, caused by *P. sorghi* Schw. (2,7). The first collection of *P. polysora* in Indiana consisted of uredinia only and was made in 1949 near the Ohio River in Spencer County (10). The first *P. polysora* telia found in Indiana were reported from four counties in the lower Wabash and White river valleys in 1957 (11). Spermogonia and aecia are unknown for *P. polysora* (7). The 1959 collection by A. J. Ullstrup (Arthur Herbarium specimen records, Department of Botany and Plant Pathology, Purdue University, West Lafayette, IN) from Tippecanoe County in north central Indiana was the only other permanently deposited *P. polysora* specimen record for the next 20 yr. Futtrell (3) included southwestern Indiana in a 1974 Mississippi River Valley epidemic but did not cite specific localities or mention that specimens had been kept.

In 1979, southern maize rust was widespread and was often severe on corn in Indiana. Previously, the disease had been mild and localized (11). Melching (7) speculated that new cool temperature forms of *P. polysora* might be found. Such forms would pose a potential threat in the northern Corn Belt (7). The purpose of this study was to determine if *P. polysora* had acquired the ability to infect corn during cool weather periods in Indiana. This paper tests whether occurrence of southern and common maize rust can be correlated with specific weather conditions in Indiana. Comparison of appearance dates of both southern maize rust and common maize rust with weather conditions might permit the detection of cool weather forms.

P. sorghi is favored by cooler temperatures (16–23 C) than *P. polysora* (about 27 C) but both require free moisture for urediniospore germination and penetration (8). Both fungi produced few uredinia at temperatures above 30 C (7). *P. sorghi* probably does not overwinter in the Great Lakes region but is introduced each year as uredinial inoculum from more southern areas (7). Futtrell (3) reported that *P. polysora* inoculum was also carried north by winds. According to Melching (7) and others, latent periods are 5–9 days for *P. sorghi* and 6–12 days for *P. polysora*, depending upon temperature. Thus, our hypothesis is that these maize rusts should appear in Indiana about a week after suitable weather arrives from the southern United States, the presumed overwintering areas (7).

MATERIALS AND METHODS

About 50 of 92 Indiana counties were surveyed during the growing seasons of 1978–1981. One field was sampled per county per visit. If southern maize rust was suspected, samples were collected and preliminary identifications made in the laboratory. Voucher specimens were deposited in the Arthur Herbarium and the identifications confirmed. *P. polysora* has covered telia that encircle the uredinia. The teliospores are more

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angular and have shorter pedicels than *P. sorghi* and the uredinia are rounder and lighter colored (2,5). *P. polysora* reportedly has slightly longer (more ellipsoid) urediniospores (2) but this distinction was not consistently observable in our samples. Disease incidence and severity and corn developmental stages were rated according to the system of James (6).

Climatological data were obtained from the National Weather Service for South Bend (north central area of the state), Indianapolis (central), and Evansville (southwest). Weekly precipitation and mean temperatures were recorded and periods when wind direction was southeast to southwest (130–240°) were identified.

RESULTS AND DISCUSSION

More than 50 Indiana collection records of *P. polysora* are now available. During this study, *P. polysora* was collected from the six counties in which Ullstrup (9,10) found the fungus as well as 34 other counties (Fig. 1). These represent all areas of the state, ranging from the southern river valleys to the northern border with Michigan. Most of the collections had both uredinia and telia. *P. polysora* did not appear until late August or early September and was collected most frequently between 7 and 22 September. Two 1979 and three 1981 collections of *P. polysora* were on corn in the dough stage (9.2 on the James [6] assessment index) but the rest were on corn that had either dented or fully matured.

Incidence (percentage of plants infected) of southern maize rust in sampled fields ranged mostly from trace to 10%. Incidence, however, was 95% in some fields surveyed late in the 1979 season. At that time, *P. polysora* was found in 77% of the fields sampled. In the other years, southern maize rust was found in 45% or fewer of the fields. No field was rated higher than trace incidence of *P. polysora* in 1980 or 20% in 1981. Severity (mean percentage of leaf area affected per plant) of southern maize rust was also generally low. Severity ranged mostly from trace to 10%, but individual plants were found with as much as 50% severity in 1979.

P. sorghi was almost ubiquitous in most of the survey years and has been collected from 59 Indiana counties (Arthur Herbarium records). Severity of common maize rust never exceeded 1%, although incidence in fields ranged from trace to 99%. This disease was found much earlier than southern maize rust each year and on younger corn plants (Table 1). From 1978 through 1981, common maize rust appeared in mid-June to late July. Common maize rust was identified in 74–100% of fields surveyed late in the season.

The dates of appearance of these two maize rusts in Indiana from 1978 through 1981 agreed well with published hypotheses (7) about the relationship between weather conditions and development of southern maize rust and common maize rust. The weather graphs for these years (Figs. 2–5) do not suggest that *P. polysora* is adapted to cooler temperatures than it required previously. In 1978, temperature and rainfall conditions and wind directions were suitable for *P. sorghi* to arrive in the northern half of the state in the latter half of June (Fig. 2). No common maize rust was found then, however, because rainfall was limiting in the southern part of the state. At the end of June, the average temperatures were too high (28–30 C) for optimum infection rates. The first period of adequate wind, rain, and temperature occurred statewide about the second week of July and *P. sorghi* was collected on 24 July (Table 1). We suggest that spread of *P. sorghi* to the north was blocked by low moisture in southern areas when northern areas had appropriate weather in June. The July rains provided the necessary humidity to permit infection by the fungus.

A similar pattern can be shown for *P. polysora* in 1978. Mid-August brought favorable weather to the central counties, but the fungus could not move through the dry southern counties. *P. polysora*

Table 1. Initial collection dates compared with stage of corn host plant development for *Puccinia sorghi* and *P. polysora* in Indiana, 1978–1981

	Puccinia sorghi			*Puccinia polysora*		
Year	First collection	Region of state	Corn growth stage	First collection	Region of state	Corn growth stage
1978	24 July	Northwest	Tassel	27 September	Southwest	All dent
1979	11 July	Central	Midwhorl	21 August	Northeast	Dough
1980	18 June	Southwest	Midwhorl	9 September	Central	Mature
1981	29 June	Central	Early whorl	8 September	West Central	Dent

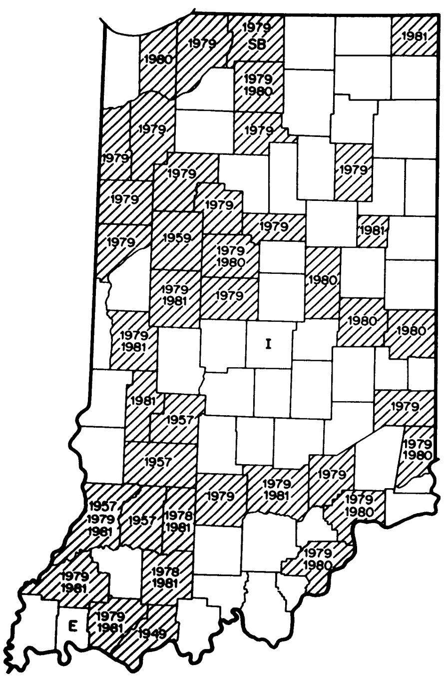

Fig. 1. Distribution and years of collection of specimens of southern maize rust in Indiana. SB = South Bend, I = Indianapolis, E = Evansville, and crosshatching = counties where specimens were collected.

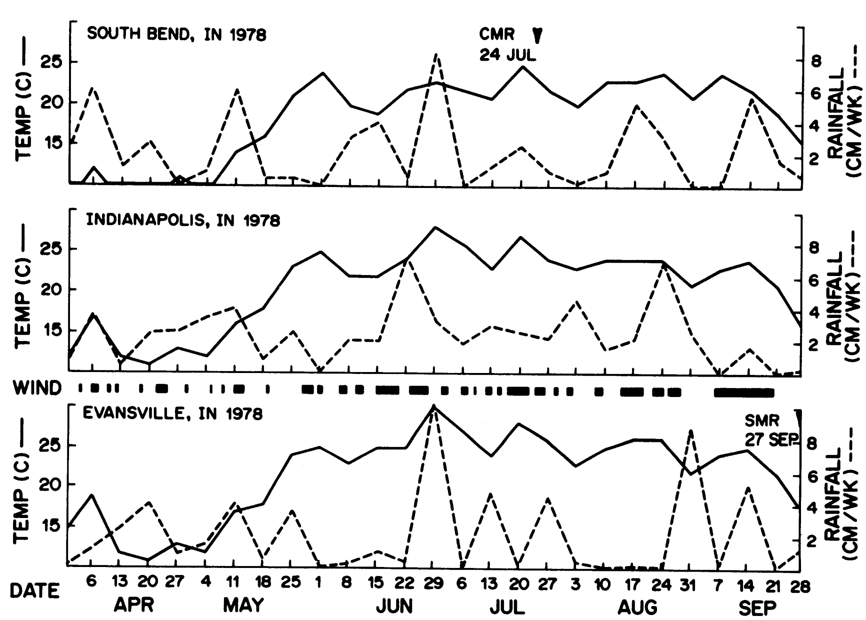

Fig. 2. Weekly mean temperatures (——) and weekly total rainfall (----) for northern (South Bend), central (Indianapolis), and southern Indiana (Evansville), 1978. Points on the graphs indicate the midpoint of each week. Arrows mark dates of first appearance of southern maize rust (SMR) and common maize rust (CMR). Periods of southeast to south-southwest winds (130–240°) are indicated for Indianapolis by horizontal bars.

was first collected in September, after the first episode of favorable weather in southern Indiana but too late for intrastate spread. There were periods of apparently favorable weather in mid- to late July. The fact that *P. polysora* was not collected then indicates there was not a source of primary inoculum nearby in July. The appearance of *P. polysora* 2 mo later than *P. sorghi* further suggests that the southern maize rust fungus overwinters farther south.

In 1979, weather conditions were suitable for *P. sorghi* on about 7 June (Fig. 3) but no infection occurred. Because the host and a favorable environment were present and no disease occurred, we conclude that the pathogen had not yet arrived. The next statewide pattern of favorable wind, temperature, and moisture for common maize rust came in the last week of June and the disease was observed in early July.

In 1979, southern maize rust appeared earlier and became more severe than in the other years of the study. From late July through early August, Indiana weather stations reported high temperatures, copious rainfall, high relative humidity, minimal drying, and unusually persistent cloud cover. Southern maize rust was found in mid-August (Fig. 3). Disease incidence was as high as 95% and severity 10% in southeastern Indiana in early September, when the host plants were in the all dent stage.

In 1980, common maize rust was found 3 wk earlier than in 1979 and southern maize rust was 2 wk later. The first occurrence of favorable weather for *P. sorghi* was on 5–7 June at Evansville (Fig. 4), and the fungus was collected 11 days later in southwestern Indiana. *P. sorghi* had not been observed in northern counties during the suitable weather of the last week in May, supporting our expectation that the fungus should arrive in Indiana from the south. Southern maize rust apparently was delayed in southern Indiana by spotty rain and extreme heat in July and early August (14+ days with maximum temperatures greater than 32 C). Some mid-August weather was within the range presumably favorable for *P. polysora* but the rust was not discovered until 9 September. *P. polysora* requires specific weather conditions for infection but is not always present when these conditions occur.

The 1981 season began with heavy May rains (Fig. 5), which caused Indiana corn planting to lag up to 3 wk behind normal. Thus, the southwest winds of 2–5 June probably came too early in the crop season, and the first effective urediniospore showers of *P. sorghi* in the state probably occurred on 12–21 June. Common maize rust appeared in the southern tier of counties in late June, before the corn had emerged in parts of northeastern Indiana.

In 1981, southern maize rust appeared late in the season as in the other years. Favorable wind directions, temperatures, and moisture were recorded in at least part of the state the first and third weeks of July and in early August, well before the appearance of southern maize rust in any surveys. The first period statewide when 25 C temperatures were matched with rainfall greater than 10 mm and with southwest winds did not occur until 22 August–2 September. *P. polysora* was collected 1 wk later in southern and central Indiana. Southern maize rust severity was not greater than in other years. This may have been because of late establishment of the rust and slightly below normal temperatures statewide in August and September.

In summary, the late-season arrival of *P. polysora* in Indiana indicates this fungus does not overwinter here. If inoculum could survive in this state, we would expect southern rust to appear early in the season, but this did not happen (Table 1). *P. polysora* should also occur in the same area during successive years if it has overwintered, but repeat collections were made in only a few

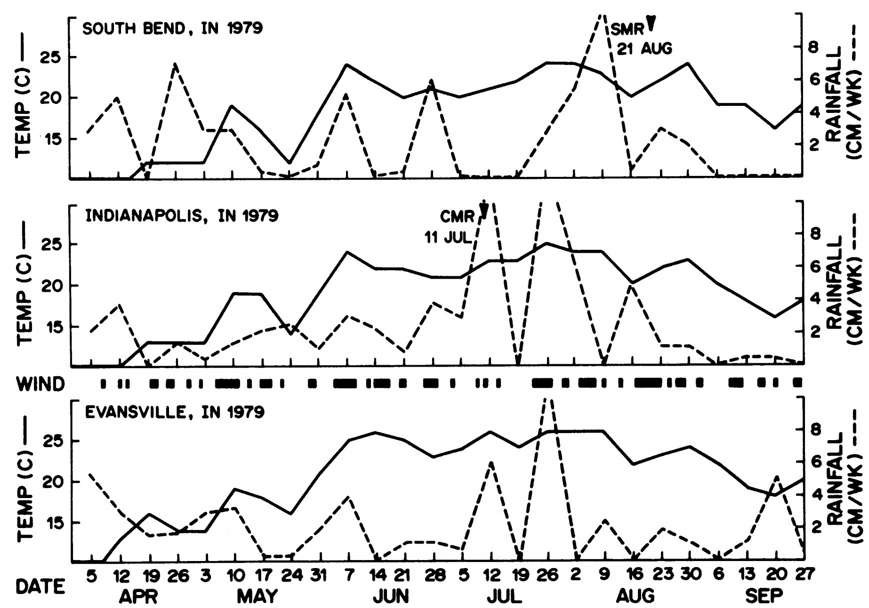

Fig. 3. Weekly mean temperatures (——) and weekly total rainfall (----) for northern (South Bend), central (Indianapolis), and southern Indiana (Evansville), 1979. Points on the graphs indicate the midpoint of each week. Arrows mark dates of first appearance of southern maize rust (SMR) and common maize rust (CMR). Periods of southeast to south-southwest winds (130–240°) are indicated for Indianapolis by horizontal bars.

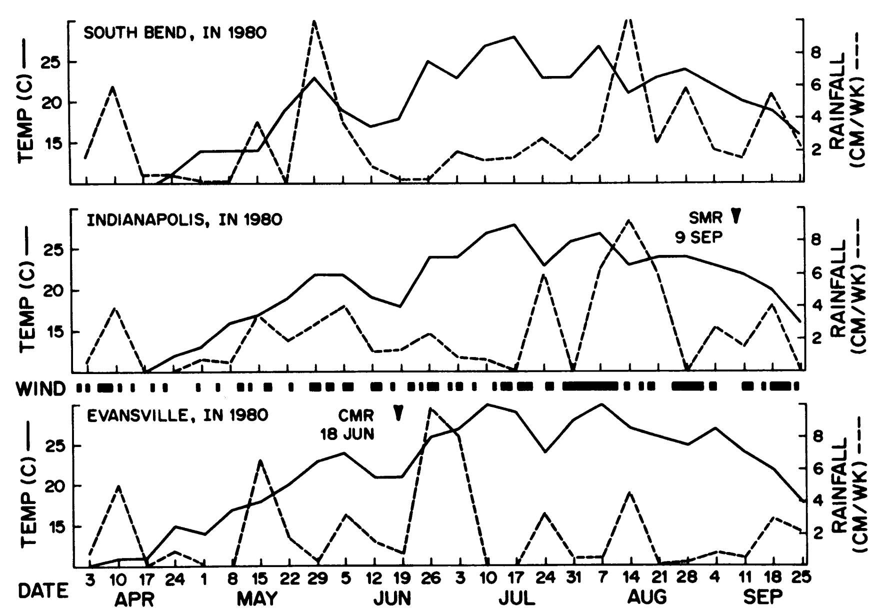

Fig. 4. Weekly mean temperatures (——) and weekly total rainfall (----) for northern (South Bend), central (Indianapolis), and southern Indiana (Evansville), 1980. Points on the graphs indicate the midpoint of each week. Arrows mark dates of first appearance of southern maize rust (SMR) and common maize rust (CMR). Periods of southeast to south-southwest winds (130–240°) are indicated for Indianapolis by horizontal bars.

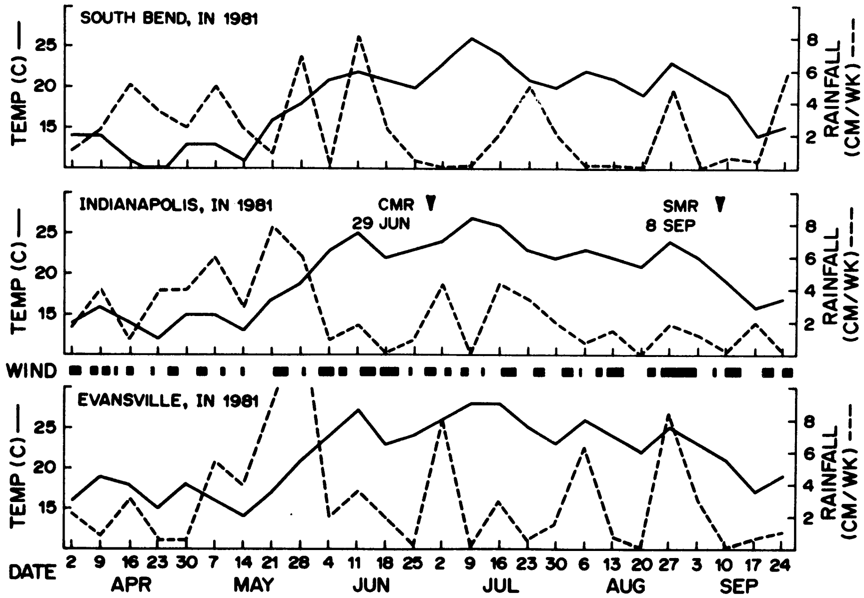

Fig. 5. Weekly mean temperatures (——) and weekly total rainfall (----) for northern (South Bend), central (Indianapolis) and southern Indiana (Evansville), 1981. Points on the graphs indicate the midpoint of each week. Arrows mark dates of first appearance of southern maize rust (SMR) and common maize rust (CMR). Periods of southeast to south-southwest winds (130–240°) are indicated for Indianapolis by horizontal bars.

counties (Fig. 1). Wild reservoir or alternate hosts for overwintering of *P. polysora* were not found by Cummins and Ullstrup (A. J. Ullstrup, *personal communication*) during searches of Indiana in the late 1950s.

Because periods of favorable weather occurred before the appearance of *P. polysora* in 1978–1981, we suspect the fungus did not overwinter in states near enough for it to spread into Indiana during these periods. Disease development and weather conditions in adjacent states, however, were not reviewed. All commercial hybrid corn seedlings tested by Melching (7) were susceptible to *P. polysora* so infection should occur each season as soon as inoculum and favorable conditions are present.

Our data show that southern maize rust is being detected more widely in this state than before 1978 but that the disease still occurs late in the growing season. If *P. polysora* inoculum had been present when weather conditions were favorable earlier in the season, as in 1981, the disease could have been very damaging. Southern maize rust usually remained a less damaging problem than common maize rust, however, because of its late appearance. Common maize rust is a common but relatively minor disease in Indiana. We believe we can account for the date of appearance of both *P. sorghi* and *P. polysora* in the field each year in Indiana according to their known climatic requirements. We have no evidence of new cool temperature forms of *P. polysora* in Indiana, as predicted by Melching (7). We find that *P. sorghi*, the cooler weather pathogen, always precedes *P. polysora*, which appears initially only after periods of high (about 25 C) temperatures.

Taxonomic note. A recent review of corn rusts (5) has caused some confusion by resurrecting *P. maydis* Bereng. as the cause of "tropical corn rust," the name usually reserved for the disease caused by *Physopella zeae* (Mains) Cumm. & Ramach. *P. maydis* reportedly differed from *P. sorghi* only by slightly different but overlapping sizes of urediniospores and slightly thicker urediniospore cell walls. Urediniospores from *P. sorghi* specimens in the Arthur Herbarium bridge the size and wall thickness ranges reported by Hou et al (5) for both *P. maydis* and *P. sorghi* so we find no real difference between these species. Schweinitz (1) published *P. sorghi* as a new rust of both sorghum (*Sorghum bicolor* (L.) Moench) and corn. Arthur and Bisby (1), however, examined the Schweinitz type specimen and found leaves of corn but none of sorghum. Thus, the epithet "sorghi" has lost its etymological basis. The Sydows (9) insisted on discarding this "little suited" name in favor of *P. maydis*, a later name, but the International Code of Botanical Nomenclature (4) does not allow that. Therefore, on the basis of morphology, host range, and taxonomy, *P. maydis* is not the valid rust species name but is a synonym for *P. sorghi*.

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