CP576

Weather Requirements for Infection by Late Leaf Spot in Groundnut[1]

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Abstract

*The literature on effect of weather on infection of groundnut (*Arachis hypogaea *L.) by late leaf spot (*Phaeoisariopsis personata*) is examined. In addition, results from experiments at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Center are used as a basis to propose a simple model to describe the effects of temperature and leaf wetness on infection.*

Sumário

Necessidades Climáticas para a Infecção com Mancha Tardia no Amendoim. *O efeito do clima na infecção do amendoim (*Arachis hypogaea *L.) pela mancha tardia (*Phaeoisariopsis personata*), descrito na literatura, é examinado. Adicionalmente, resultados de experimentos feitos no Instituto Internacional de Investigação de Culturas para os Trópicos Semi-Áridos (ICRISAT) Centro são usados como base para propôr um modelo simples, para descrever os efeitos da temperatura e da humidade das folhas na infecção.*

Introduction

In 1933 Woodroof published a detailed description, distinguishing two pathogens of groundnut (*Arachis hypogaea* L.) that cause early leaf spot (*Cercospora arachidicola* Hori) and late leaf spot [(*Phaeoisariopsis personata* (Berk. & Curt.) v. Arx)]. She noted differences in the seasonal patterns between the two diseases in Georgia, USA, and concluded tentatively "that *C. arachidicola* occurs rather consistently year after year, even when the weather is quite dry." She also stated that "the conditions conducive to the development of *P. personata* are not well enough understood to attempt to explain why it appears only in certain years. Possibly wetter seasons are more favorable to its development than drier seasons."

More than 50 years later there was little improvement in our ability to distinguish between the weather requirements of these two pathogens. Hemingway (1955) observed large differences in the rates of disease increase in eastern Africa, which he attributed to greater spore production of *P. personata*. A similar situation was observed in southern India where the numbers of airborne spores of the two species were compared (Sreeramulu 1970). Effects of temperature and humidity on conidial germination of *C. arachidicola* were reported by Oso in 1972, but equiva-

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lent information on *P. personata* was not available until recently (Sommartya and Beute 1986). Shew et al. (1988) pointed out that long periods of leaf wetness are necessary for late leaf spot lesions to develop on inoculated plants, and demonstrated that infection occurs with intermittent wetness.

The situation at ICRISAT Center, India, is different from that described by Woodroof (1933) for Georgia and it is probable that this is partly caused by differences in climate. At ICRISAT Center, both early and late leaf spot normally infect groundnut in the rainy season, but late leaf spot is usually the dominant disease. Infrequently (less than 1 year in 5), early leaf spot is the more serious disease (P. Subrahmanyam, ICRISAT Center, personal communication). It is still not clear why this happens and, as part of a program to improve our understanding of how weather affects these diseases, we examine in this paper evidence pertaining to infection by *P. personata.*

Weather Variables Affecting Infection

Current knowledge

Jensen and Boyle (1965), Sommartya and Beute (1986), and Shew et al. (1988) made significant contributions to our understanding of how weather affects late leaf spot infection. Findings from these three papers are summarized in this paper with some further analysis of their data.

In 1965, Jensen and Boyle published the results of 2 years' field observations and proposed a scheme for disease prediction (Jensen and Boyle 1966). Advice to growers for fungicide applications in the USA is still based on this scheme, although no distinction was made between early and late leaf spot. The scheme could be used for either disease and since it is so widely used and therefore requires examination in detail.

Jensen and Boyle (1966) recognized the importance of leaf wetness to infection and used a thermohygrograph placed in a screen on the ground between the rows of groundnut in their field experiments. In interpreting their results they made three important assumptions:

1. Adequate inoculum is always present.
2. Free water is necessary for spore germination, and the speed of germination depends on temperature.
3. Periods of relative humidity (RH) greater than 95% indicate periods of leaf wetness (this includes wetness from rain).

On days when RH > 95% occurred in more than one continuous period, they selected the longest continuous period.

Their prediction scheme (Fig. 1a) uses periods of wetness and temperature to compute an infection index from 0 to 3, which indicates the extent to which environmental conditions are favorable for spore germination and penetration. This index can be thought of as a measure of the number of lesions (unit area)$^{-1}$ that will subsequently develop. When the infection index is plotted against wetness periods (Fig. 1b) it becomes clear that Jensen and Boyle thought that the period required for maximum infection decreased with increasing temperature between 18°C and 27°C. This implies that the rate of infection increases with temperature, but suggests that, with adequate wetness periods, the final level of infection would not be affected by temperature between 20°C and 27°C.

They observed that favorable conditions must persist for 2–3 days to detect the increase in disease easily; 1 favorable day had little effect on the disease. Although they could not distinguish between the effects of high levels of humidity and rain from their field results, they believed that RH was the best indicator of leaf wetness either from rain or dew.

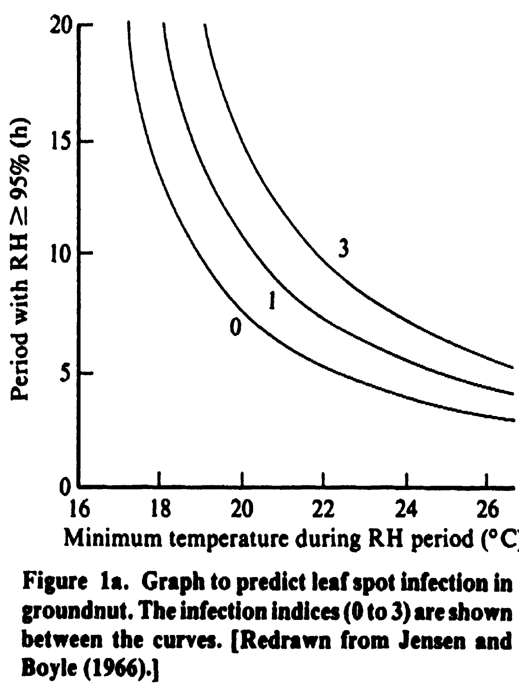

Figure 1a. Graph to predict leaf spot infection in groundnut. The infection indices (0 to 3) are shown between the curves. [Redrawn from Jensen and Boyle (1966).]

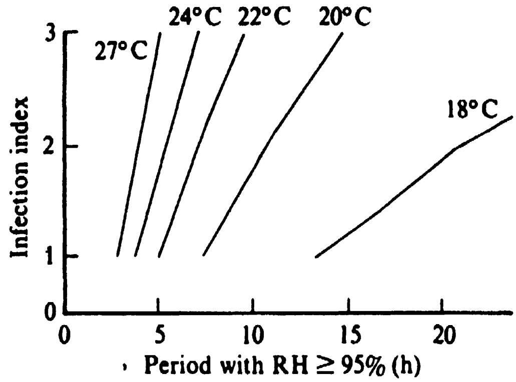

Figure 1b. The implied requirements of leaf wetness (RH≥95%) and temperature for leaf spot infection in Figure 1a.

Sommartya and Beute (1986) studied the germination of different isolates of *P. personata* in vitro and found that the percentage germination of conidia after 48 h decreased with increasing temperatures between 16°C and 32°C (Fig. 2). The steepest reduction was at temperatures greater than 28°C. They also commented on the effect of temperature on the germination rate. In contrast to Jensen and Boyle (1966), Sommartya and Beute (1986) stated that the germination rate was maximum at 20°C, and at this temperature, more than 50% of the conidia had germinated after 12 h. They give no details of germination rates at other temperatures.

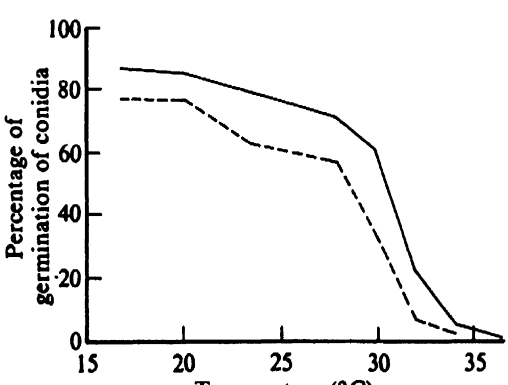

Figure 2. The effect of temperature on the percentage of conidial germination after 48 h in vitro. The two sets of data are for different isolates of *P. personata*. [Redrawn from Sommartya and Beute (1986).]

Shew et al. (1988) examined the effect of periods of leaf wetness on infection at different temperatures. They did this by transferring plants between high and low humidity chambers, so that the period of surface moisture on leaves varied between 3 and 24 h day^{-1}. The humidity treatments were continued for 6 days at temperatures between 20°C and 32°C. For the majority of groundnut genotypes, the maximum number of lesions were obtained at 20°C, but differences between 20°C and 24°C were not large. I have fitted logistic (Gompertz) curves to their data, which relate lesion numbers to wetness periods. For this, the data for 20°C and 24°C were combined and a separate curve was fitted to the data for 28°C. There were no statistical differences between parameters that define the delay and slope of the curves (Fig. 3); they are distinguished only by their asymptotes.

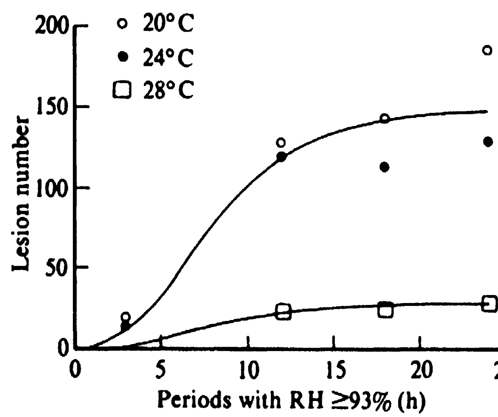

Figure 3. The effect of leaf wetness duration (RH ≥93%) on lesion number at different temperatures. Wetness periods were repeated for 6 days. The Gompertz curves, fitted to the data from Shew et al. (1988), have the same parameters for slope and delay (only the asymptotes are different).

Implications

Several interesting points arise from the work cited above. The relation between percent spore germination and temperature (Sommartya and Beute 1986) is important, since germination is a prerequisite to infection.

It is necessary to reconcile the differences between the conclusions from the field experiments of Jensen and Boyle, and the findings of Shew et al. (1988) and Sommartya and Beute (1986). Jensen and Boyle concluded that the infection rate increased with temperature up to 27°C; therefore, much longer periods of leaf wetness would be required at lower temperatures to achieve a given infection level. However, Sommartya and Beute (1986) found that the germination rate was maximum at 20°C and that the percentage germination decreased with increasing temperature above 20°C. The latter result agrees with the finding of Shew et al. (1988) that the number of lesions decreases with increasing temperature between 20°C and 28°C for all the periods of leaf wetness. Although Jensen and Boyle interpreted their results in terms of infection, they were assessing disease development in the field, which is the result of the whole disease cycle. It is possible that disease progress at low temperatures was limited by inoculum since, for early leaf spot, sporulation is reduced markedly at temperatures below 20°C (Alderman et al. 1987).

Further progress

We carried out a series of experiments at ICRISAT Center in which potted plants were inoculated with conidia of *P. personata*. After inoculation, plants were kept in a greenhouse where the leaves remained dry. At night, selected plants were placed in a dew-chamber for different numbers of nights (each night providing about 16 h of leaf wetness). The air temperature in the dew-chamber was controlled to +0.5 °C and experiments were carried at various temperatures between 13°C and 28°C. The number of lesions that appeared on inoculated leaves was recorded daily until there was no further increase.

With only 1 night of leaf wetness, lesions never developed and with 2 nights, there were usually none or very few lesions. After an initial delay, the number of lesions increased linearly with the number of nights in the dew-chamber until a plateau was reached. Both the initial delay and the time taken to reach the plateau varied with temperature. Infection was most rapid at 23°C when the plateau was reached after 5 nights (Fig. 4a). In contrast, at 13°C infection began after 4 nights and continued to increase in severity even after 11 nights (Fig. 4b).

Our results confirm the finding of Shew et al. (1988) that infection occurs with intermittent periods

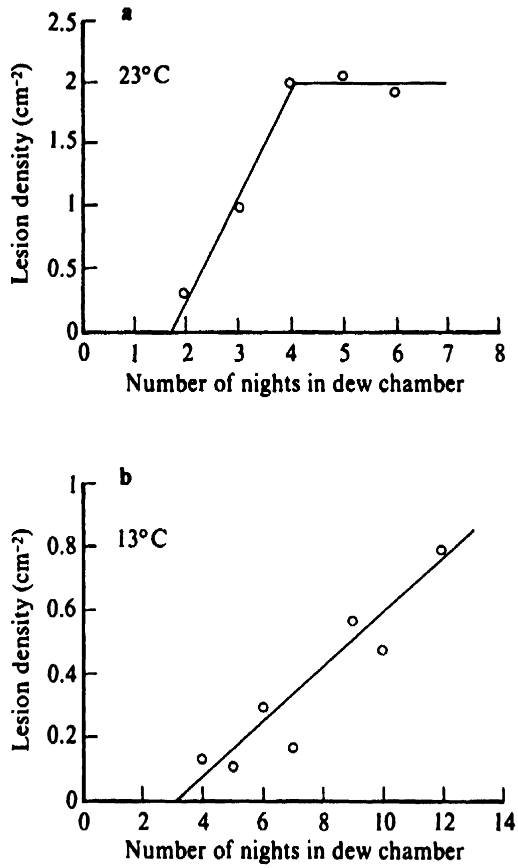

Figure 4. Lesion numbers on inoculated groundnut plants in relation to numbers of nights in a dew-chamber (each night providing 16 h of leaf wetness). Dew-chamber temperatures: (a) 23°C; (b) 13°C.

of surface moisture. It appears that the dominant variable affecting infection at a particular temperature is the total number of hours of leaf wetness. When our results at 23°C and those of Shew et al. (1988) at 20°C and 24°C are shown with that time scale, the agreement is remarkable (Fig. 5).

Compared with these results, the findings of Sommartya and Beute (1986) are surprising in that such long periods of leaf wetness are necessary for infection when more than 50% of conidia germinate in 12 h. Initial observations of conidia on leaf surfaces indicate that germ-tube growth is slow and leaf penetration is rare within the first 32 h of wetness.

We now have sufficient evidence to propose a simple model to describe late leaf spot infection in terms

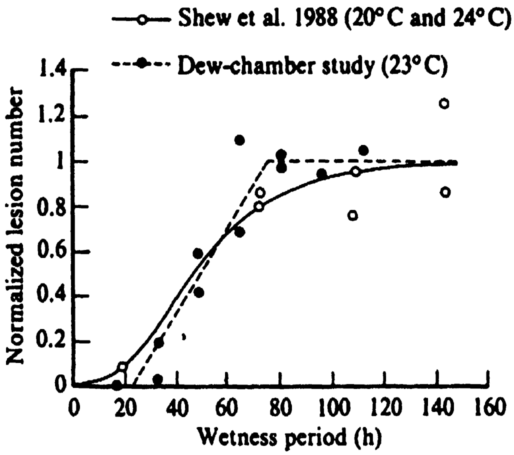

Figure 5. Lesion numbers in relation to the total number of hours of leaf wetness on inoculated groundnut plants.

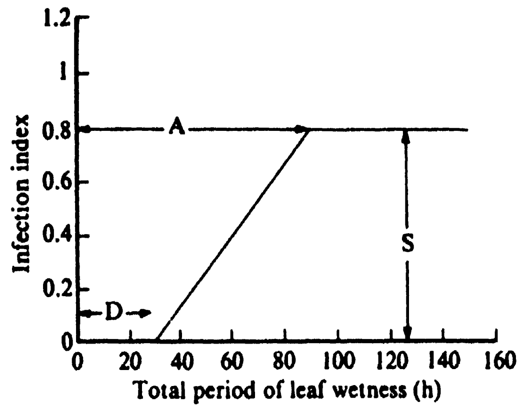

Figure 6. Temperature sensitive parameters for a model of late leaf spot infection. D is the initial delay; A is the period beyond which there is no further increase in disease; S is the maximum disease severity.

of leaf wetness periods and temperature. Temperature affects the process in two ways: (a) it determines the percentage germination of conidia and (b) it determines the rate of infection (this includes germination, germ-tube growth, and leaf penetration). It seems reasonable to assume that infection does not proceed if the leaves are dry, but that the process starts again where it left off, when leaves are re-wetted. With this assumption, the total period of leaf wetness after spore deposition and the mean temperature during that period are required to calculate the amount of infection. If the rate of infection is rapid, the time required to reach maximum infection would be short, and a shorter period of accumulated leaf wetness would be required but if the rate of infection is slow, a longer period of accumulated leaf wetness would be required. The maximum level of infection with non-limiting wetness periods, will vary with temperature since it depends to a large extent on the proportion of spores that germinate.

The model has three parameters (Fig. 6): an initial delay (D) when no infection occurs, the period (A) beyond which there is no further increase in disease, and a severity (S) which determines the maximum level of infection in relation to temperature. S accounts for the effect of temperature on percentage germination of conidia. If the parameters D and A are expressed as rates (1/D and 1/A) it is likely that the temperature response will be linear, as has been found in an analogous situation of seeds germination (Garcia-Huidobro et al. 1982). Current experiments at ICRISAT Center aim to obtain relationships between temperature and the parameters D, A, and S.

To use the model, it is necessary to have a measure of leaf wetness as well as temperature. This could be either measured directly with an electronic sensor or estimated from humidity and rainfall records. We are exploring methods to obtain estimates of leaf wetness from weather records. We believe that such an approach will be a valuable aid to disease prediction, which is an important component of efficient disease control. It will also help interpret results of screening trials where weather conditions may not be ideal for infection.

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Discussion

Doto: What is the practical utility of information depicted by the last figure you presented?

Subrahmanyam: It is useful in disease prediction and providing advice on effective disease control.

Ismael: How much does the growth stage affect the requirement of temperature and relative humidity for disease development?

Subrahmanyam: We don't have adequate information.

Ismael: Is the plant more susceptible at a particular growth stage when the required temperature and relative humidity is present?

Subrahmanyam: Plants are susceptible at all stages of development.