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The Environment and Agriculture

ENVIRONMENTAL FACTORS AFFECTING PLANT DISEASE

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Agriculturists have long been aware of the effect of weather on plant growth. Plant Pathologists have studied the effects of the environmental variables on disease incidence and crop production in greater detail than students of any other discipline in Botany and more data are available on this subject. It is, therefore, appropriate to consider the effect of weather on plant diseases and crop production in this volume which deals with the subject of the environment and agriculture.

Climate is the outcome of the interaction between temperature, atmospheric humidity including rainfall, sunlight and air movement, None of these factors can be studied separately, as each has an effect on the other. The interaction of these factors, the weather, has a controlling influence on the spread of plant diseases by its action on the host or the causal agent, or both. A critical study of the climate may often offer the possibility of the control or reduction of a plant disease by manipulation of the microclimate. Further, accurate data on the environmental variables is basic to the understanding of the development of plant diseases, and it is on these that the goal of the plant pathologist, the economic control of plant diseases, is based. This knowledge will also help in forecasting the intensity of plant disease incidence, which again helps towards economizing on control measures. These concepts will be discussed in this paper.

Temperature

Temperature is perhaps the most important weather factor that affects the host, the pathogen and disease development (Yarwood 1965). With the development of instrumentation, extremely critical studies have been made on the effect of temperature on plant disease. Dimock (1967) has described temperature as the environmental factor most easily and accurately measured, described and controlled. Yarwood (1965) has recently made an excellent review of the available literature on this subject.

There is a minimum, optimum and maximum temperature for the growth and propagation of all plants and pathogens. The closer the ambient temperature is to the optimum for the growth of the host, the more it would be likely to resist infection. Similarly, temperature conditions conducive to the propagation of the fungus would tend to increase disease incidence, merely because inoculum potential would build up under such conditions, so that the foci of infection would increase, thus breaking down host resistance. Extremes of temperature, both high and low, are injurious to host and pathogen alike, as they both belong to the plant kingdom. Temperature approaching the optimum for the pathogen, even though they may be close to the optimum for the host too, would favour disease development owing to the rapid multiplication and build up of the inoculum of the pathogen, which increases the possibility of infection.

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Temperature has an overriding effect on the development and spread of many diseases. Taking local examples, it has been found that, the severity of blister blight incidence is low at temperatures above 35° C (Anon 1970) and *Phytophthora* leaf disease above 32° C (Peries & Fernando 1966), as these temperatures are harmful to the causal organisms *Exobasidium vexans* and *Phytophthora meadii,* respectively.

The controlling influences of temperature in disease development has been exploited to avoid the incidence of certain diseases, especially in temperate regions, by taking deliberate steps to bypass or reduce the disease by actions such as postponing the sowing date until the onset of warmer weather, deleterious to the pathogen (Byford 1967 ; Jones & Hayes 1971). Another aspect of this is exploited by late sowing of lima beans in temperate regions, to take advantage of the known fact that high summer temperatures (29° C), soon after favourable infection periods, completely nullifies the effect of the latter (Hyre 1964) and reduces disease severity.

Atmospheric Humidity

The importance of atmospheric moisture is only second to that of temperature in host-parasite interactions (Dimock 1967). The relation between humidity and disease incidence has been studied by several workers (Delp 1954 ; Longree 1939 ; Rogers 1959 and Yarwood 1939 ; 1956). In the tropics where atmospheric temperature does not vary markedly throughout the year, the main seasons are the wet and the dry, so that the time and duration of rainfall becomes important. In Ceylon, the incidence of the diseases caused by *Phytophthora* spp. on *Hevea* are closely associated with periods of continuous wet weather of long duration (Peries 1964 ; 1969 ; Satchuthananthavale 1970). Similarly the incidence of Blister Blight of tea is associated with periods of wet weather (Visser *et al.* 1961). The causal agents of these diseases are present on the plants throughout the year, but they produce sufficient inoculum to cause an epidemic only when wet weather conditions persist for long periods.

Phytophthora leaf fall and Bark Rot of rubber occur during periods of prolonged wet weather. *Phytophthora* leaf fall occurs only during the south-west monsoon season, as disease incidence is closely correlated with pod infection (Peries 1964), which occurs during this period. The severity of leaf fall varies from year to year and locality to locality, depending on weather patterns during the monsoon season.

Bark Rot occurs mainly during the south-west monsoon period, but there can also be sporadic attacks during the north-east monsoon. In the former case new new infections can occur from inoculum washed down from infected pods in the latter, lesions would mainly be the recrudescence of old infections. Clonal susceptibility would naturally have an effect on disease incidence, and the Bark Rot epidemics observed in the late 1950s and early 1960s were associated with the early tapping period of susceptible clones, such as Mil 3/2, PB 86 and PR 107, which were planted on a large scale, since 1953, under the Government subsidized rubber replanting scheme, which became operative in that year.

Bark Rot has been less prevalant in Malaysia than in Ceylon in the past ; because the normal weather conditions in Malaysia, with dry sunny mornings, ensure a dry tapping panel surface, so that disease inoculum is not likely to trickle down on to the freshly cut bark with moisture. Rain falls mainly in the afternoons in Malaysia, usually in heavy showers of short duration. Mouldy Rot, another panel disease was a problem in Malaysia during the period of rehabilitation after the last war, but this was associated with the neglect of rubber estates during the war. At present, this disease is seen only in low-lying and sheltered areas and where a high stand and dense undergrowth combine to provide humid conditions favourable to the disease (Anon 1970).

The incidence of Blister Blight disease of tea is closely correlated with atmospheric moisture, which has been found to be the essential factor required for the invasions of tea by the causal fungus, *E. vexans* (de Silva 1968). Moisture is necessary for spore germination and it appears that high relative humidity is required for spore production. Therefore, mist, cloud and rain increase disease incidence. The spores of *E. vexans* are killed by desiccation as well as by exposure to direct sunlight (Visser *et al.* 1961). Consequently, dry weather conditions reduce, and the presence of shade, which promotes humid conditions, increases the incidence of Blister Blight. The increasing severity of this disease with elevation is also associated with the cooler temperature and higher relative humidity prevalent at high elevations. This effect can be seen even in different areas of the same estate, where it is observed that disease incidence is higher in fields situated in valleys, and lower on hill tops. One of the reasons for this is that mist persists for longer periods in valleys than elsewhere; also temperatures tend to be lower, relative humidites higher and duration of sunlight less in such situations (de Silva 1968).

The detailed information that is now available on the correlation that exists between atmospheric moisture and disease incidence has led to the adoption of various devices to reduce disease incidence or its severity and economize on the control costs of many diseases. It is known that bark and stem diseases of rubber, which affect some high yielding clones, occur mainly in wet months. Therefore the opening of tapping cuts on young rubber and the change over of panels are never carried out in wet weather periods, as this leads to severe bark disease on susceptible clones (de Silva 1954). In Ceylon the incidence of Bark Rot on susceptible clones such as Mil 3/2 and PB 86 has been brought down from about 75% to under 5% by ensuring that trees are never tapped when they are wet (Peries 1966). The rapid drying of trees and general lowering of moist conditions in rubber plantations is achieved by the judicious thinning of the leaf canopies. This leads to the penetration of sunlight and free air circulation which encourages rapid drying. This has been achieved in tea plantations by the removal of shade. Atmospheric moisture in the form of rainfall is an important factor in disease control. Continuous wet weather in addition to favouring disease development, hinders the adoption of appropriate control measures (Anon 1970). It is generally accepted that control measures are best avoided during heavy rains ; because of the possibility of the fungicide being washed off the treated surface (de Silva 1968). This would necessitate frequent and repeated applications, which would make the use of fungicides uneconomic in many situations, such as the control of Blister Blight of tea and *Oidium* and *Phytophthora*

leaf disease of *Hevea*. Many fungicides have been specially formulated with additives to make them rain resistant, because of the close correlation between moisture and disease incidence ; but it is often difficult to find adequately rainfast fungicides to control certain wet weather diseases (Lloyd 1963). Sometimes the effectiveness of a fungicide may even be lost through excessive formulation to achieve rainfastness (Peries & Dayaratne 1966).

Apart from the above host-pathogen-fungicide interactions, which militate against disease control measures, frequent rains lead to soggy, heavy ground conditions which can retard control measures by bogging down machinery and equipment used for the application of fungicides. Mud is an important consideration in agriculture, but often overlooked (Wadham, personal communication).

Sunlight

Plant pathogens are sensitive to intensity and quality of light (Yarwood 1959). Both visible and ultra-violet light can prove lethal to the mycelium or to spores. Sporulation and even the shape of spores can be influenced in some instances by irradiation (Foister 1946). In general fungi and bacteria are retarded in growth or killed by the action of direct sunlight, for relatively short periods. The effect of light on the host, the green plant, quite apart from the role of solar radiation as the ultimate source of energy, has also been carefully studied (Burkholder 1936 ; Mohr 1962 ; Vince 1962), and the interaction of host and parasite under varying light conditions is well established (Anon 1951 ; Fernando 1940), the host being favoured generally under conditions of high light intensity.

The effect of sunshine on the incidence of Blister Blight has been extensively studied, and it has been established that direct sunlight is lethal to *E. vexans* (Visser *et al.* 1961). Similar effects have been observed for *P. meadii*, the causal fungus of *Phytophthora* leaf and bark disease of *Hevea* (Peries & Fernando 1966).

It has been shown that the lethal effect that sunshine has on *E. vexans* can be exploited with advantage in the control of Blister Blight, resulting in the reduction of the cost of control. The decision whether to spray or not is based on the amount of sunshine recorded during a period of 4-5 days immediately prior to the date of spraying. The critical period of sunshine is an average of five hours per day in this period. If this is exceeded, the spray round is postponed for a short period, depending on the plucking cycle. This scheme has been found to be effective and economical, particularly at the beginning and end of the monsoons, and where adopted, it has reduced disease incidence to low levels. The scheme is not recommended for heavily shaded areas or for well known "mist pockets" or other areas where the sunshine recorder readings may not truly represent the sunshine in such areas (Mulder 1961 ; Mulder & de Silva 1960). This helps to illustrate the necessity to interpret weather data correctly in disease control.

It has been found that sunny periods occuring during the South West Monsoon season, when *Phytophthora* leaf disease of *Hevea* is prevalent, checks the spread of the disease. This is perhaps due both to the direct lethal action of sunshine on the

fungus and also to its drying effect which checks the activity of the swimming fungal spore (Peries & Fernando 1966). Control measures against the disease can be postponed or dispensed with in relation to the occurrence of sunny periods during the monsoon season (Peries 1968).

Air Movement

Air movement is of direct importance in the transport of certain fungus spores, but there is no evidence that wind in itself has any effect on disease development. To the extent that air movement affects heat transfer, evapo-transpiration and gas interchange, it may significantly affect the physiology of the host cells and consequently the host-parasite interaction (Dimock 1967).

The most imporatnt role of the wind in the development of plant disease is that of the dissemination of the disease propagules. It has been recorded that Blister Blight of tea was first observed in Ceylon in 1946, and that the disease spread with alarming rapidity and was recorded in every tea growing district in the country within six weeks of its first occurrence (de Silva 1968). There is no doubt that the agent of disposal here was the wind. Pathogens like the powdery mildews, downy mildews and the moulds can be spread rapidly by the wind. However, little can be done to restrict fungal dissemination by the wind. Viruses from a special category under this section, as many of them are spread by insects and dissemination can be restricted by the erection of wind breaks (Broadbent 1959).

Forecasting Plant Disease

The relationship between weather and disease is the basis for meteo-pathological forecasting, which is concerned with predicting, on the basis of observed or forecast weather conditions, the course which a plant disease is likely to take. There have been numerous scientific papers or this subject and some excellent recent reviews (Bourke 1955 ; 1970 ; Cox & Large 1960 ; Miller 1967), which describe in detail the operational methods employed in a number of countries, to predict certain plant diseases. These have been quite accurate ; as the environmental requirements of a plant disease involve a combination of meteorological events occurring in a certain sequence, and this can be established.

Bourke (1970) lists four basic requirements to define plant diseases which can be forecast with practical value to the grower, *viz* 1—The disease must cause damage of economic significance, 2—it must be variable in seasonal impact and this variability should be largely dependent on weather factors, acting directly or indirectly, 3—economically acceptable control measures should be available, 4—sufficient data should be available on the nature of the dependence of the disease on weather.

A great deal of work has been done in Ceylon on the feasibility of forecasting plant diseases, particularly those of rubber and tea. Methods of forecasting *Phytophthora* leaf disease of rubber (Peries 1965, b ; 1969) and Blister Blight of tea (Mulder 1961 ; Mulder & de Silva 1960), on the basis of weather records obtained from relatively simple equipment, are now available. Further, critical studies on the relationship between weather and disease incidence has led to significant savings on the control costs of these diseases. At present no control measures are advocated

against *Phytophthora* leaf fall of rubber ; long term studies have shown that the pattern of weather in Ceylon is such that this disease is not likely to occur at levels which would result in economic losses to the industry (Peries 1965a). This is in sharp contrast to the position in India, where the distribution of rainfall is ideal for the propagation of the causal fungus, leading to almost complete defoliation of rubber trees by *Phytophthora* leaf disease, unless adequate control measures are adopted (Ramakrishnan 1961).

In the case of Blister Blight of tea, expenditure on control measures has been reduced significantly on the basis of detailed studies that have been carried out, giving due consideration to the available data on the effect of weather on the disease. On this basis, the amount of fungicide used has been reduced to a minimum, and spraying rounds are adjusted according to the pattern of rainfall and number of hours of sunshine incident on particular locations (de Silva 1966a, b, 1967 a, b).

Discussion

The close association between disease incidence and weather, as presented in this paper, should not be interpreted to mean that weather is exclusively to be blamed for the level of all diseases. Weather affects the fungus as well as the host, the former aspect has been generally discussed in this paper. Some aspects of the host, in regard to disease incidence, should also be considered. Apart from its inherent resistance to a particular disease, there are other attributes of the host which may be significant for epidemiology. The density and distribution of the crop is important ; crops grown on a limited scale and in scattered locations may not suffer serious losses, dense populations in pure stands are highly vulnerable. The rapid spread, within six weeks of its first record, of Blister Blight to all tea growing districts in Ceylon (de Silva 1968) is a good example. The general condition of the host and its different parts are also significant from the disease viewpoint. Fragile, etiolated potato leaves produced under low light intensity have been found to be more susceptible to infection by certain viruses than the tough leaves produced in strong sunlight (Broadbent 1949). Weather conditions can cause an accumulation of carbohydrates in wheat leaves and stems, which is favourable for rust infection (Green & Samborski 1961). Soft lush growth produced with excess fertilization with nitrogen is well known to be particularly susceptible to many fungal pathogen. In fact, Grainger (1967) has claimed that the susceptibility of plants to disease at different stages of growth is related to the ratio of carbohydrate to the residual dry weight in the shoot. This theory has not been fully accepted, but there is undoubtedly a change in disease susceptibility of plants with are (Bourke 1970). Cultivation practices are also relevant in this connexion, and in annual crops, the date of sowing or its depth can be deliberately altered in relation to the weather, in order to avoid certain diseases (Byford 1967). The spacing of plants and pruning of trees in order to create a more open microclimate, enabling free air movement and sublight penetration, or the removal of shade from tea fields for the same purpose, are now well established.

There is no doubt then that a critical study of the weather is an essential prerequisite to economic plant disease control. However, the interpretation of the weather data must be made with a full awareness of the "disease potential" of the crop. In general it has been noted that weather conditions slightly cooler, more humid and with lower light intensities than normal, during a disease season, are likely to increase disease incidence. The recent dramatic increase of coffee berry disease in East Africa is related by Bent (1969) to a climatic change towards wetter, cooler conditions which favour infection.

The incidence of many plant diseases can be predicted by a careful study of weather data. This paper discusses some of this data and shows that it is important for all crop research stations to study weather patterns in relation to plant disease incidence. Quite substantial economies can be affected in control costs by such studies, and every advantage must be taken of forecasts. Bourke (1970) refers to the position in Italy, where local warnings to spray against vine mildew are conveyed dramatically by the ringing of church bells, growers have been known to abandon political meetings *en masse* on hearing the signal, leaving the speaker in mid-sentence, showing a correct sense of priorities, which should be an example to us all.

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