*EPIDEMIOLOGY OF TEA BLISTER BLIGHT (*EXOBASIDIUM VEXANS*)

I—SPORULATION

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Two equations have been developed to estimate the sporulation of *Exobasidium vexans* Massee. The equations are

$$Y=2.5824-0.6169x_1+0.06x_2$$

for the period April to December, excluding August, and

$$Y=3.1411-0.9867x_1$$

for August, where Y = log spores per blister, x_1 = log blisters per 100 shoots and x_2 = mean daily sunshine. By calculating Y, converting to spores per blister and multiplying by the number of blisters per unit area of crop, the number of spores in the atmosphere can be estimated.

Blister Blight of tea, caused by *Exobasidium vexans*, has many advantages for epidemiological studies. First, the host plant is an evergreen perennial crop kept in an active vegetative state throughout most of its life. This means that there are no marked changes in susceptibility associated with changes in development of the host throughout the year, as occurs with many crops. Secondly, only the youngest leaves of a shoot are susceptible and tea is pruned and trained in such a way that almost all the young leaves are on top of the bushes, approximately 3 ft. above the ground. The susceptible leaves are thus exposed to the atmosphere and the micro-climate within the crop is unimportant in influencing infection and sporulation. Thirdly, in Ceylon, temperature is relatively uniform throughout the year, and although it does vary with altitude and has a marked influence on the distribution of the disease, at 4500 ft. where this work was carried out, temperature can be ignored as an important factor in disease development. Fourthly, the crop consists of young shoots (' two leaves and a bud ') and is harvested by hand-plucking at 7- to 10-day intervals. By a slight modification of this, *viz* plucking three leaves and a bud, regular records of disease incidence can be readily obtained throughout the year. Complicated sampling techniques need not be developed and plucking randomly selected bushes and assessing disease on the plucked shoots gives an accurate measure of disease incidence.

Because of the first three advantages it would seem likely that infection is largely dependent on : (*a*) the number of viable spores landing on susceptible leaves, and (*b*) suitable moisture conditions on the leaf surface to allow spore germination and infection. As the first criterion is almost certainly dependent on the number of spores in the atmosphere, conditions influencing sporulation were studied initially.

The investigation was carried out at this Institute which is subject to two monsoons annually, the South West Monsoon and the North East Monsoon. The former is experienced from about May to August and is characterized by wet, cloudy weather often accompanied by prolonged mist. The North East Monsoon usually occurs from about October to December, but sometimes extends even up to April,

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and is characterized by clear, bright mornings with afternoon or evening rains. The average rainfall is about 90 inches per year and Blister Blight is serious only during the monsoon periods. The intermonsoonal periods are relatively dry and sunny.

Relationship between percentage infection and number of blisters per unit area of crop

The number of spores per unit volume of air is likely to be dependent on the number of mature blisters per unit area of crop. In testing the relative efficiency of fungicides in controlling Blister Blight of tea, Webster & Park (1956) assessed disease incidence by measuring percentage infection on the third leaf. Since then until 1964 all disease assessments at this Institute have been made by this method. In 1964 and 1965, in addition to the 'third leaf' method, disease incidence was assessed by determining the percentage infection on shoots (three leaves and a bud) and also by counting the total number of blisters on 100 shoots (Figure 1).

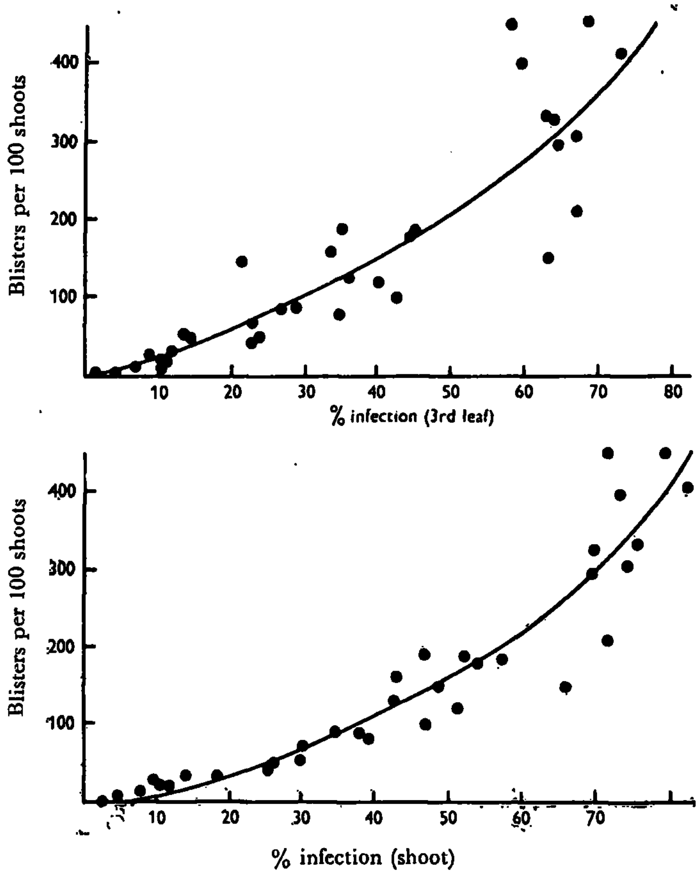

FIGURE 1—*The relation between percentage infection and number of blisters*

A straight line relationship is obtained if number of blisters (x) is plotted against the logarithm of the percentage of uninfected shoots (Y) (Gregory 1961).

The regression equations are

$$Y = 1.938 - 0.0011x \qquad (1)$$

for the 'third leaf' method, and

$$Y = 1.921 - 0.0014x \qquad (2)$$

for the 'whole shoot' method.

Blisters per unit area of crop will depend not only on the number of blisters per 100 shoots, but also on the number of shoots per unit area, which, in tea, can be directly measured by yield. Daily records of yield are kept by tea estates and, by multiplying the number of blisters per 100 shoots by yield, the number of blisters per unit area of crop can be estimated.

Relationship between spores in atmosphere, number of blisters and sunshine

Since 1962, atmospheric spore counts of *E. vexans* have been measured daily by a Hirst Automatic Volumetric Spore Trap. Disease incidence was measured at approximately weekly intervals on 1/3 acre of seedling tea that was not sprayed with fungicide to control Blister Blight. The mean percentage infection of two adjacent measurements approximately one week apart was taken, converted to blisters per 100 shoots (from Figure 1) and multiplied by the average daily yield of the whole estate during this period, to give blisters per unit area. The mean daily number of spores per unit volume of air for the same period was calculated from spore-trap data.

The relationship between the number of spores in the atmosphere and number of blisters per unit area of crop is shown in Figure 2 for the period April to December 1964. It is clear that the relationship is not simple. For example, on 27 May 105 blisters per unit area of crop correspond with 961 spores per unit volume of air, while on 6 August 658 blisters per unit area correspond with 280 spores per unit volume. In general it would appear that, as infection is building up at the beginning of a monsoon period, sporulation is very active, whereas towards the end of a monsoon period, when disease incidence is high, sporulation is limited. This would indicate that there are more spores released per blister when infection is low than when it is high.

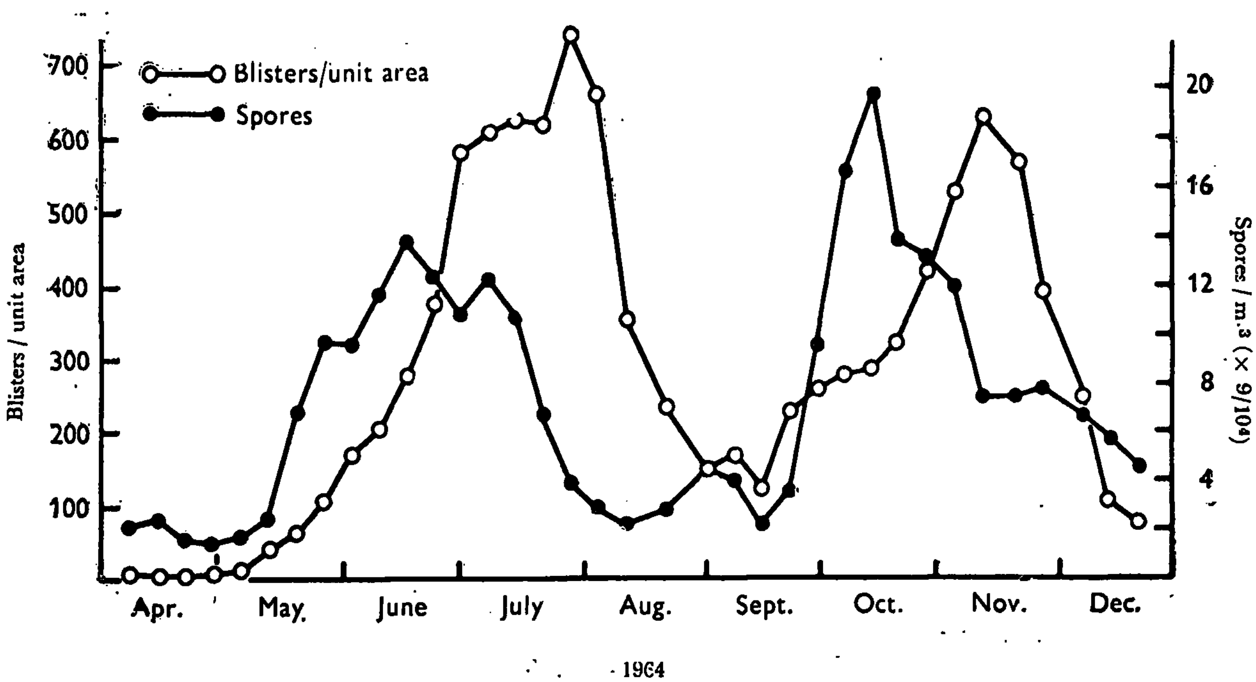

FIGURE 2—*The relation between number of spores in the atmosphere and number of blisters per unit area of crop*

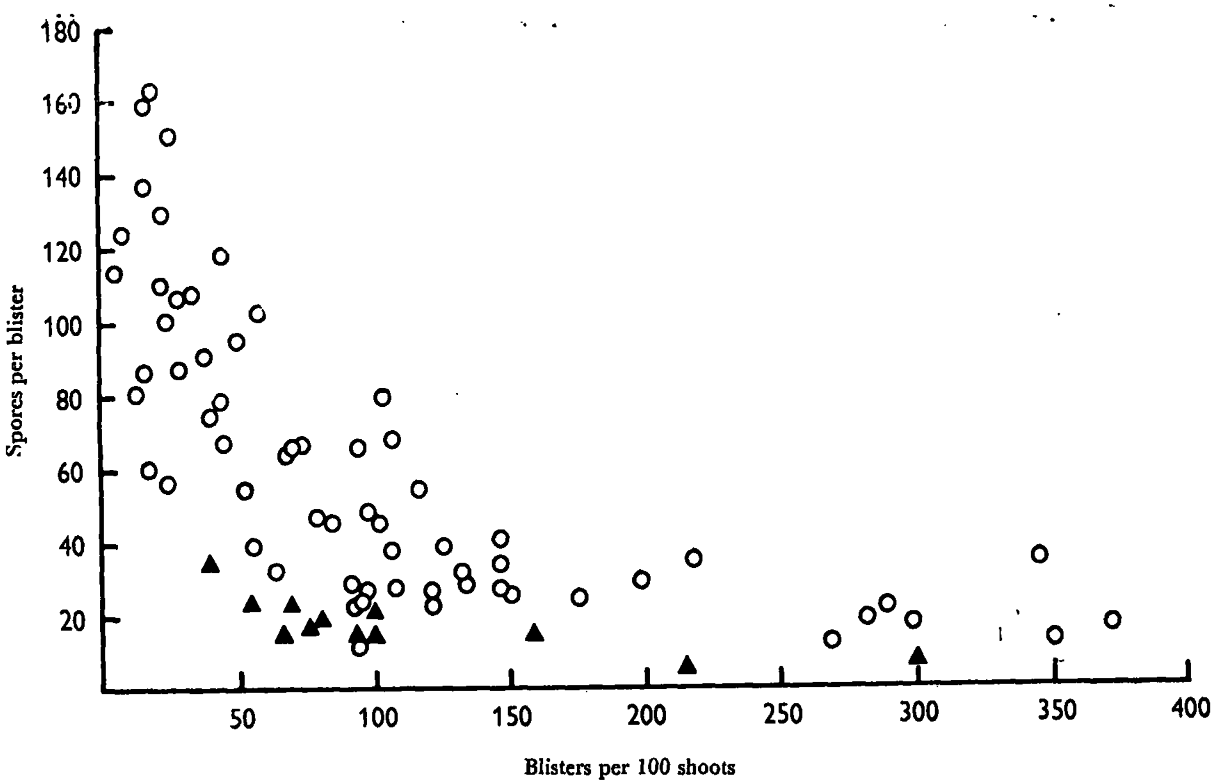

FIGURE 3—*The relation between number of spores per blister and number of blisters per 100 shoots.* ○, *data from April to December, excluding August ;* ▲, *data from August*

The number of spores per blister was calculated by dividing number of spores per unit volume of air by number of blisters per unit area, and this is plotted against number of blisters per 100 shoots in Figure 3. A logarithmic transformation of both axes gives a straight line relationship.

Sunshine is another possible factor influencing sporulation because meteorological records indicate that periods of high sporulation per blister are associated with periods of high sunshine, whereas periods of low sporulation are associated with prolonged cloudy weather.

Mean daily sunshine for approximately 3 weeks (2 weeks preceding spore counts and the period during which spores were counted) was calculated and this was used with log spores per blisters, and log blisters per 100 shoots to calculate a multiple regression. Data for August were calculated separately. The regression equations were

$$Y = 2.5824 - 0.6169x_1 + 0.06x_2 \quad (3)$$

for the period April-December, excluding August, and

$$Y = 3.1411 - 0.9867x_1 \quad (4)$$

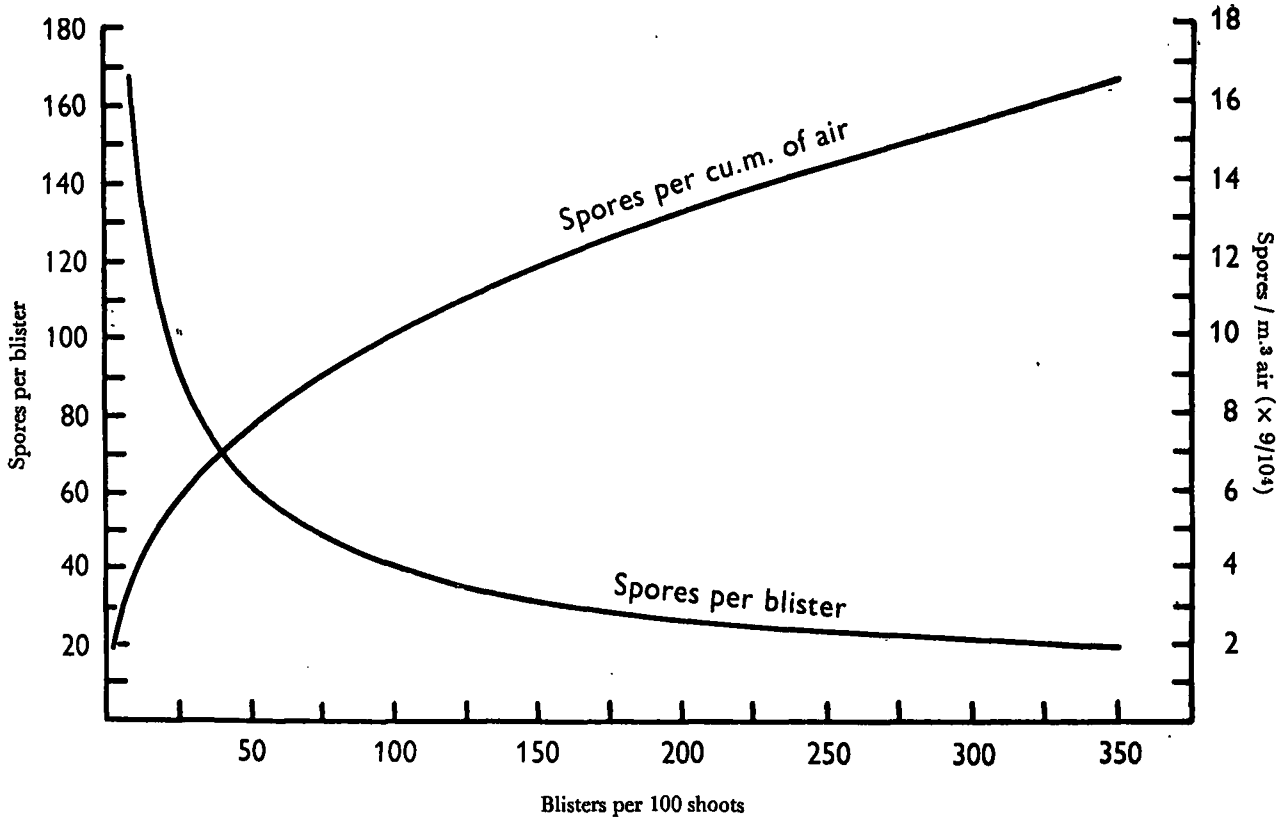

FIGURE 4—*Calculated relation between* (a) *number of spores per blister and number of blisters per 100 shoots ;* *and* (b) *spores per cubic metre of air and number of blisters per 100 shoots*

for August, where Y = log spores per blister, x_1 = log blisters per 100 shoots and x_2 = mean daily sunshine. In equation (3) the values — 0.6169 for b_1 and + 0.06 for b_2 were both significant ($P < 0.001$ and $P < 0.01$, respectively). In equation (4) the value for b was significant ($P < 0.001$) but, during August, sunshine had no significant influence on sporulation. The slopes of the two equations are significantly different ($P < 0.05$).

If sunshine is removed from equation (3) by substituting mean daily sunshine (4.36 hr) for x_2 the equation becomes

$$Y = 2.8440 - 0.6169x_1. \qquad (5)$$

After back transformation from logarithms, this equation is shown in Figure 4 along with estimated spores per cubic metre air obtained by multiplying spores per blister by blisters per unit area (= blisters per 100 shoots × yield of 5000 lb).

Using equations (3) and (4) along with yield records, it is now possible to estimate spores per cubic metre air for any given period and compare this with spore trap data (Figure 5). In general there is very good agreement between the estimated and measured number of spores.

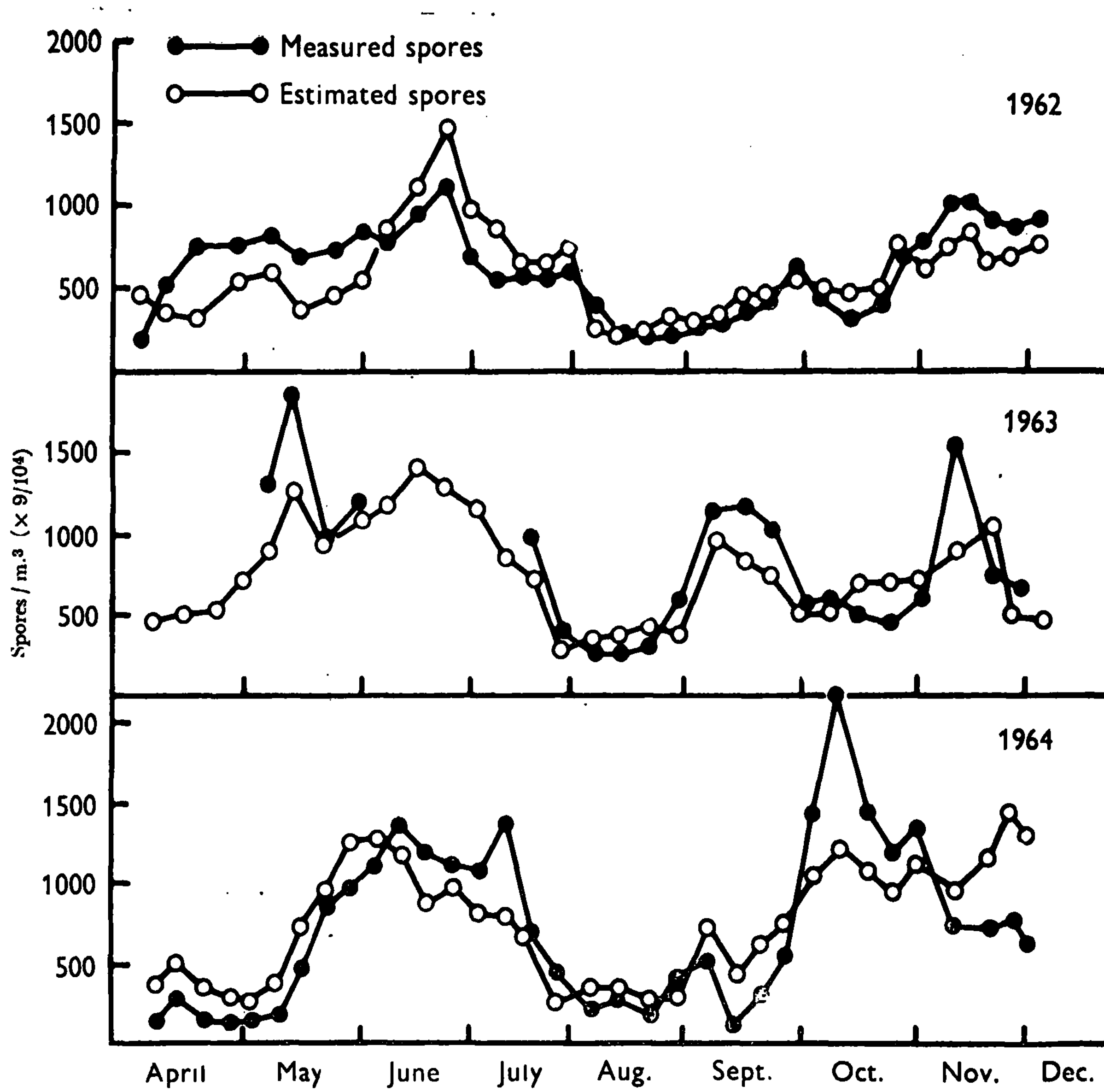

FIGURE 5—*Estimated and measured spores per cubic metre of air from 1962-64*

Discussion

Because of the suitability of Blister Blight of tea for epidemiological investigations, it has been possible to develop accurate equations to predict sporulation. The equations have been developed entirely from records of disease incidence, spore trap and sunshine data. No experimental evidence has been used, but this is certainly required. It has been shown that the lower the level of infection, the higher the sporulation per blister. Experimental evidence is required to determine if, as infection increases, each mature blister produces fewer spores, or whether an increasing number of blisters produce no spores. Presumably the difference in sporulation is based on a physiological difference within the leaf and there seem to be two possible reasons for this. First, an increase in the level of infection causes this physiological change, perhaps by inducing an increase in the level of polyphenols or other chemicals within the leaf. Secondly, the physiological change is caused directly by meteorological conditions. Again there is no experimental evidence to indicate which of these two alternatives is more likely.

Disease incidence is increased by wet, cloudy weather (Visser, Shanmuganathan & Sabanayagam 1961), but the present study has shown that these conditions are associated with a decrease in sporulation per blister. After prolonged monsoon conditions, particularly towards the end of the South West Monsoon, there may be a high level of infection, but relatively few spores in the atmosphere. There is some evidence that the effect is cumulative because during August sporulation is at a much lower level and a different equation must be used to estimate it. Also recovery from this condition appears to be delayed because high sunshine during August does not increase sporulation.

The converse of this is also important, because at the beginning of the South West Monsoon sunshine is invariably high, resulting in relatively high sporulation even although percentage infection is still low. This is important in timing the first fungicidal application to control Blister Blight and will be considered in more detail in a later paper of this series.

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References

GREGORY, P. H. (1961). *The microbiology of the atmosphere.* London : Leonard Hill.

VISSER, T., SHANMUGANATHAN, N. & SABANAYAGAM, J. V. (1961). The influence of sunshine and rain on tea Blister Blight, *Exobasidium vexans* Massee, in Ceylon. *Ann. appl. Biol.* **49** : 306-315.

WEBSTER, B. N. & PARK, P. O. (1956). Developments in blister blight control. I. Introduction to the 1955 series of blister blight control experiments. *Tea Quart.* **27** : 3-6.

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