

***THE INFLUENCE OF SUNSHINE AND RAIN ON TEA
BLISTER BLIGHT, *EXOBASIDIUM VEXANS* MASSEE,
IN CEYLON**

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Summary

The germination of spores of Blister Blight of tea (*Exobasidium vexans* Masee) requires moisture, but 0.1 in. of rain in a day provides sufficient for a high percentage of germination to occur; more rain does not materially increase germination. Spores are killed by sunshine of a few hours' duration, even if there is adequate rain on the same day. An average of about $3\frac{3}{4}$ hr. of sunshine per day over 5 days is enough to reduce the blister-blight disease to sub-economic levels. Ten-day spraying rounds with copper fungicide usually give adequate control of the disease but add to the cost of production. A method is put forward of using recorded sunshine hours as the criterion in deciding on the frequency of spraying; spraying is postponed, by successive 5-day periods, until the average sunshine for the previous 5 days has dropped below $3\frac{3}{4}$ hr. A reduction approaching one-half of the number of spray applications can be made in this way.

Introduction

Blister Blight of tea has been known from Assam for a long time (Masee, 1898) but it did not appear in Ceylon until October 1946 (Tubbs, 1946). It then spread so fast as to threaten to destroy the tea industry in mid-country and up-country districts, but a remedy was quickly found in routine spraying with a copper fungicide. This spraying is now effective but makes a not inconsiderable addition to cost of production, so various attempts have been made to reduce the expense. The work here described provides a basis for making savings by omitting to spray when the weather conditions indicate that it will be unnecessary. Practical field tests on commercial estates have since demonstrated the value of the method (Mulder, 1959; Mulder & De Silva 1960).

Gadd & Loos (1949) showed that wind-borne spores germinate on the leaf in humid conditions, the leaf surface is penetrated and, after a week or two, a dense growth of hyphae inside becomes visible as a translucent spot. Further growth presses out and eventually bursts a blister on the underside of the leaf. Spores are produced there and discharged for about a week. The fungus then dies, leaving a damaged or perforated leaf. Only the youngest leaves and their stems are vulnerable but it is these that provide the tea crop. The disease not only reduces the crop but may also so limit the active foliage as to weaken the bush.

The disease is very active only in the wetter parts of the year when fungicidal sprays are normally applied every 5-10 days to fit in with the plucking rounds. It

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is not therefore surprising that the need for spraying is commonly associated with the incidence of rain, dew, or mist; in fact a system of control based on the average relative humidity has been recommended previously (Huysmans 1952). On the other hand, several workers have suspected or investigated the importance of sunshine (Gadd & Loos, 1949; Huysmans, 1952; Hamburg, 1953, 1955; Van der Knaap, 1955; De Weille, 1957*a, b*) and suggested that control measures could be relaxed in sunny periods. These workers have shown that exposure to direct sunshine for $\frac{1}{2}$ –1 hr. is sufficient to kill the spores. As rain and sunshine are obviously inversely correlated to some extent, careful work is required to separate their effects. The leaf must necessarily be wet with rain, mist, or dew for most of the time during the monsoon; the question is: how much sunshine is required at this period to suppress the disease? Both Van der Knaap (1955) and De Weille (1959) introduced control systems based on sunshine, but both systems require a specific loading of sunshine hours according to time of day or number of hours of sunshine in the day and are therefore not simple enough for routine use on estates.

Spore Germination

As it is mainly the spores that are affected by weather, they were investigated first. Spores were collected in the laboratory on glass slides kept for a few hours under detached tea shoots with sporulating blisters (Wolthuis, 1958). Pairs of these slides carrying the spores were then placed in a tea plantation in slits cut at the tops of 5-ft. sticks; usually five such sticks were stuck into the ground about 5 p.m. amongst the tea, with the slides at the height of the plucking table. After 24 hr. the percentage germination of the spores was assessed from five random counts of twenty spores per slide on ten slides. Under favourable conditions in the field, spores formed germ tubes two to four times the length of the spore in that time, but the appressorium stage was seldom reached. Weather observations were made both for the first day, when the slides were put out, and for the second, when they were taken in.

Rate of germination as observed on glass slides is not necessarily the same as that on leaves, *e.g.* the age of the leaf has an effect on germination (Loos, 1951). However, it was found by Wolthuis (1958) and confirmed by ourselves that the germination as observed on glass slides gives a good qualitative indication of conditions in the field.

Spore germination percentages recorded daily (I) in May–June 1958 (thirty-five observations) in a shaded field and (II) in June–July (fifty observations) in an unshaded field were correlated with daily sunshine and rainfall; (III) the average germination percentage over twenty-nine consecutive 5-day periods between June and October 1958 was correlated with average sun and rain over the same 5-day periods. There was a significant inverse correlation ($-r=0.44-0.60$) between sunshine and rainfall. Consequently, it is not surprising that the correlation between spore germination and sunshine ($-r=0.46-0.71$) on the one hand and between germination and rainfall ($+r=0.35-0.66$) on the other were significant in both instances.

These correlations did not suggest that either sunshine or rainfall had the greater importance. Figs. 1 and 2 represent all the data in a summarized form (averages of consecutive classes of daily rainfall or sunshine) showing (average) germination as a function of (average) rain or sun.

In Fig. 1 is shown the relation between germination and rainfall. There was a clear relationship up to 0.1 or possibly 0.2 in. of rain per day, but above 0.25 in., the percentage of germination hardly depended on rain.

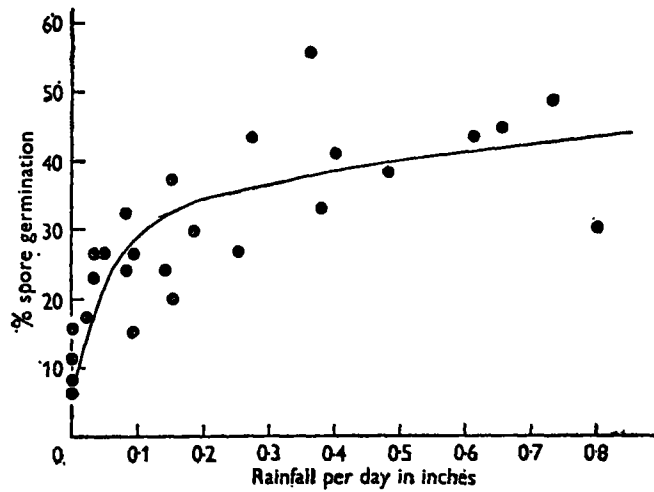


Figure 1. Relationship between germination of spores of Blister Blight and daily rainfall.

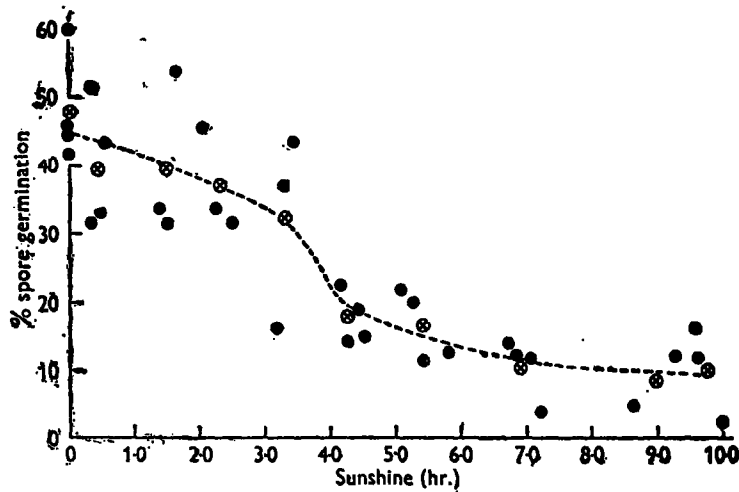


Figure 2. Relationship between germination of spores of Blister Blight and duration of sunshine in the day; black dots are observations, crossed circles are averages per sunshine category.

Fig. 2 shows the relation between germination and sunshine. With up to 3 hr. of sunshine in the day, germination was always high but with 4 hr. or more, it was low. Such relations are not expected to give a large value of correlation coefficient.

Fig. 3 therefore re-classifies the observations on germination; in Fig. 3a, where germination is shown against hours of sunshine, observations from days with less

than 0.1 in. rain are shown as solid columns, and those with 0.1 in. or over in cross-hatched columns. With 6 hr. or more of sunshine, the amount of rain was immaterial and indeed it was not very important unless there had been 2 hr. or less of sunshine. In the same way, from Fig. 3*b*, it can be seen that with less than 4 hr. of sunshine, germination was high, especially with more than 0.1 in. rain; but with more than 4 hr. of sunshine it was almost independent of rainfall. For practical purposes, therefore, it would seem that 4 hr. of sunshine, or a little less, is a threshold, providing the simplest single measurement as a criterion in those situations where the position cannot be estimated by eye (*i.e.* some rain and some sunshine). These observations provide indirect confirmation of the results of De Weille (1957*a*) on the direct action of sunshine on spore viability.

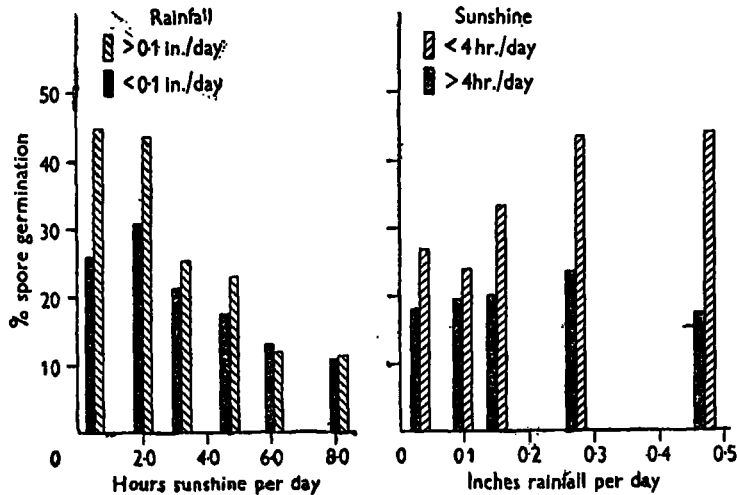


Figure 3. (a) Average percentage of spore germination of Blister Blight in relation to sunshine: black columns—with rain less than 0.1 in. in the day; shaded columns—with rain more than 0.1 in. in the day. (b) Average percentage of spore germination in relation to rain: black columns—with more than 4 hr. sunshine in the day; shaded columns—with less than 4 hr. sunshine in the day.

Blister Blight incidence and weather

The situation dealt with in the germination experiments was too simple for everyday practice, so correlations were sought between (a) translucent spot and (b) blister incidence on the one hand and (1) spore germination, (2) sunshine, and (3) rainfall occurring various numbers of days before (a) and (b) on the other hand. The incidence of translucent spots or blisters is defined as the numbers present per 100 leaves from crop shoots taken at random in the field. All the observations were made daily both (I) in a field with a normal number of shade trees (May—June, 1958) and also (II) where there was no shade (June—July, 1958) during the south-west monsoon rains.

Fig. 4 shows that the correlation between percentage germination and incidence of translucent spots was at a maximum when the interval between them was about 12 days, whereas the maximum correlation with blisters was at 16 days. These times were unaffected by the presence of shade. They suggest the occurrence of correlations of the incidence of the disease with the weather (rainfall and sunshine) of 12 days (translucent spot) and 16 days (blister) earlier. In fact, the highest

correlation coefficient of spot incidence and weather occurred with an interval of 10 days with both sunshine (-0.67) and rain ($+0.25$) in the shaded field and of 13 days in the unshaded field, again with both sunshine (-0.48) and rain ($+0.71$). Blister incidence correlated best with the weather 16-17 days earlier. Again, there was a higher rainfall correlation without shade ($+0.80$) than with ($+0.37$) and a higher sunshine correlation (-0.56) when shade interfered than when there was none (-0.32). In both this instance and in the case of spot incidence, the infection appeared to have been affected most by sunshine in the presence of shade and by rain in the absence of shade, presumably because shade interferes with the drying of leaves.

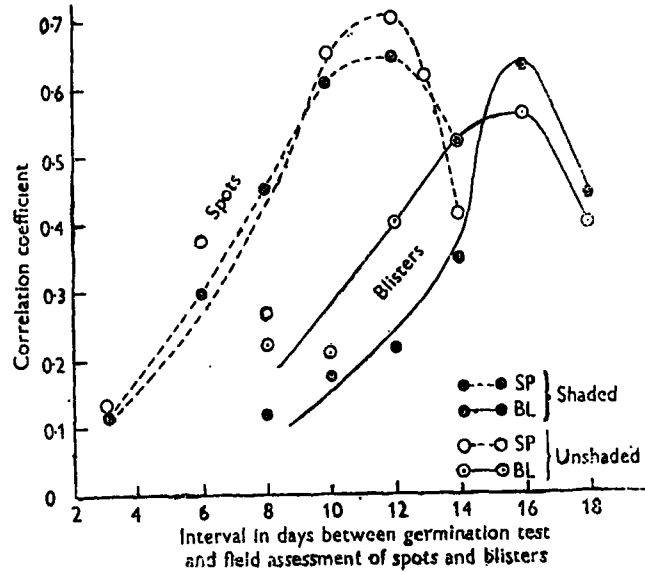


Figure 4. Correlations between percentage of spore germination of Blister Blight on the one hand and incidence of translucent spot (SP) and blisters (BL) on the other, at various intervals (days) between the germination test and field assessment of spots and blisters.

The period of 10-13 days required for translucent-spot development and 16-17 days for blister development found on the basis of calculation are in fair agreement with direct observations by Huysmans (1952) and Loos (1951).

A further assessment made was of percentage shoot infestation by the standard method; this necessitates a careful system of random sampling of crop shoots to find the percentage of shoots that have the third leaf infected by visible blisters or translucent spots. This sampling was done at 5-day intervals for 4½ months (June to October 1958) both in a shaded field (III) and in an unshaded one (II). Sunshine hours and inches of rain were totalled over 5-day periods and correlations with the incidence of the disease worked out. Maximal correlation existed with sunshine (-0.45 and -0.69) recorded 18-22 days and with rainfall ($+0.42$ and $+0.69$) recorded 16-20 days before shoot infection (twenty-nine averages).

The interval between weather and shoot infection was certainly longer than the interval for maximal correlation in the previous observations. This follows from an observation by Tubbs (1947), namely that spores on the first or youngest leaf germinate in much less time than those on the older third leaf.

Blister Blight and Shade

It is well known that the natural incidence of Blister Blight is much higher in shaded tea than in unshaded and indeed the first measure of control was to reduce shade. This is readily explicable as effects of both differences in sunshine and in

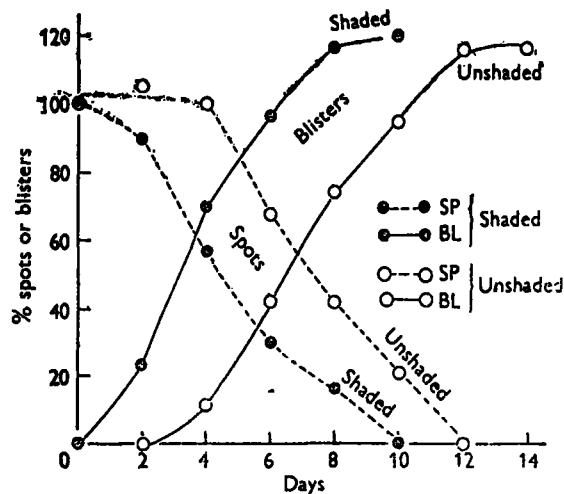


Figure 5. The percentages of translucent spots (SP) of Blister Blight remaining as such after various periods in days (broken lines) and the percentages converted to blisters (BL). Some spots were initially missed, giving eventually over 100% of blisters.

dampness on spore germination. What has not previously been recorded is that the weather also affects the development of the fungus at a stage as late as from translucent spot to blister. Two shaded bushes and two unshaded bushes were chosen in the same area and, on each bush, two shoots with three leaves were marked. They were observed every second day, the numbers of translucent spots and of blisters being counted. It is evident (Fig. 5) that the spots developed into blisters about 4 days more quickly under shade than without shade trees.

In this context Huysmans's (1952) observations may be mentioned; he found that the weather conditions prevailing during the period of blister development also have an affect on the germination rate of the spores subsequently released. Accordingly, the shading density of a field influences both the level and rate of infection.

Control measures in Relation to Spore Germination

The planning of a practical control programme on the basis of the above information was done in two fairly direct stages without detailed working out of the course of events—namely using, first, spore germination and, second, recorded sunshine, to determine whether to spray or not. The spore-germination procedure was taken from Wolthuis (1958), who determined daily the percentage germination on slides. There were four treatments:

- (1) unsprayed control;
- (2) sprayed when germination exceeded 50%;
- (3) sprayed when germination exceeded 25%;
- (4) sprayed on normal routine every 9–10 days.

The treatments were replicated five times in shaded plots of 0.1 acre and unreplicated in an unshaded field (0.25 acre per plot). The percentage infection of crop shoots was determined at 5-day intervals, thirty-five times in the shaded field (May—October 1958) and twenty-nine times in the unshaded one (June—October 1958).

TABLE 1.—Average monthly shoot infection of plots treated according to the degree of spore germination in the field

The significant difference for means is 8.0 at $P=0.05$ (shaded field).

Treatments	Shoot infection (%)						Mean	No. of sprays
	May	June	July	Aug.	Sept.	Oct.		
Shaded field (spraying was begun on 20 May in the sprayed control)								
(1) Control (unsprayed)	47.2	41.2	52.7	31.0	53.0	26.6	42.0	0
(2) Spore germ. > 50%	54.6	45.7	29.6	14.4	35.0	24.6	34.0	10
(3) Spore germ. > 25%	37.8	40.4	26.9	6.9	21.9	12.8	24.5	16
(4) Control (sprayed)	53.6	41.6	28.0	9.3	23.0	13.9	28.2	17
Unshaded field								
(1) Control (unsprayed)		8.7	19.6	15.3	18.2	10.1	14.4	0
(2) Spore germ. > 50%		4.4	12.6	3.1	10.9	6.5	7.5	6
(3) Spore germ. > 25%		4.3	7.4	2.6	3.2	2.0	3.9	13
(4) Control (sprayed)		8.3	11.1	4.7	3.3	2.3	5.9	14

In the experimental treatments, spraying was never done after a shorter interval than 10 days. In the 50%-germination plots, germination in the first 5-days after spraying was ignored. If, in the next 5-days, germination exceeded 50% on any one day, the spraying was done on the 10th day; but if it did not, spraying was postponed until the first day on which a 50% germination was observed. That began a new cycle, with germination ignored in the first 5-days. In the 25%-germination plots the routine was the same except that the criterion was 25% instead of 50%. The spray was high-volume, with a 50% Cu fungicide at 6 oz. per acre.

Table 1 shows the results. In the unshaded field, infection never reached economically damaging levels (35% infection—Webster & Park, 1956; Visser, Shanmuganathan & Sabanayagam, 1958) and it is evident that fourteen spraying rounds could have been saved. In the shaded field, infection in the 25%-germination plots did not differ from that in the normally sprayed plots, but only one spraying round was saved. In the 50%-germination plots, infection was always higher than in the normally sprayed plots, though protection was on the whole not unsatisfactory, and it saved seven spraying rounds. These observations confirmed the favourable results obtained by Wolthuis (1958). The idea was worth following up; but percentage germination of spores was not a suitable measure for routine work on estates.

Control measures in Relation to Sunshine

The basis of decision in this experiment (previously summarized by Visser *et al.* 1959) was similar to that in the previous trials, except that the number of hours of sunshine in 5 days provided the criterion for one set and in 7 days for the other. Considering the 5-day set and the criterion of an average of 3 hr. sunshine per day, spraying was not done after 10 days if the total sunshine in the previous 5-days exceeded 15 hr.; spraying was withheld by 5-day periods until the previous 5-day total fell below 15 hr. The treatments were randomized and replicated six times (0.1 acre each plot), with the two sets (5- and 7-day totals), and, in each set, averages of 2½, 3 and 3½ hr. per day used as the criterion (Table 2).

TABLE 2.—Average monthly shoot infection of plots sprayed according to the amount of sunshine recorded over 5- and 7-day periods, respectively.

Treatments	Average monthly shoot infection (%)									11 Total no. of sprays
	2 May	3 June	4 July	5 Aug.	6 Sept.	7 Oct.	8 Nov.	9 Dec.	10 Mean	
(A) Control (sprayed)	14.0	26.0	28.5	7.7	22.1	10.7	17.1	8.3	16.8	24
(B) Control (un-sprayed)	15.9	43.4	54.8	19.3	48.7	37.8	39.1	32.5	36.2	0
Sun/5 days										
(C) < 12½ hr.	14.5	42.2	45.2	16.0	24.7	28.1	20.9	20.1	26.5	11
(D) 12½–15 hr.	13.8	37.2	39.4	17.4	23.5	23.5	15.0	17.5	25.5	11
(E) 15–18½ hr.	15.3	33.8	26.0	12.3	16.5	18.1	15.9	19.5	19.7	13
Sun/7 days										
(F) < 17½ hr.	18.4	47.7	42.9	17.7	14.1	27.7	23.3	25.9	27.2	9
(G) 17½–21 hr.	17.5	46.3	39.0	14.6	12.8	21.2	21.8	33.4	25.8	11
(H) 21–26½ hr.	15.9	45.3	34.8	12.7	17.7	19.5	18.6	12.6	22.1	17
Sign. diff. for P=0.05	10.6	13.8	7.4	5.5	10.0	6.2	11.0	8.8	5.9	

The unsprayed plots were infected to damaging levels in all months except May, August and December (marginal). The normally sprayed plots (twenty-four spray rounds) were not badly infected at any time. The six series of experimental plots were generally more heavily infected than the normally sprayed plots, but up to economic levels (35% or higher) only in June and July (with the exception of the best treatment—E). Between seven and thirteen spray rounds were saved. Evidently the critical figures are those in June and July. Although the differences are not generally significant in pairs, there is a strong suggestion that the highest average used (3½ hr.) is marginal and that a 5-day total is more satisfactory than a 7-day total. In fact, the 5-day total for an average of 3½ hr. sunshine daily was satisfactory in all months and saved nearly half the spraying rounds.

In order to give a visual illustration of blister-blight incidence throughout the greater part of the period concerned, the percentage shoot-infections of three treatments (A, B and E, of Table 2) are presented in Fig. 6. This figure also gives the daily sunshine, averaged over 5-day periods, recorded between 18 and 22 days (on an average, 20-days) before leaf examination, on the assumption that the sunshine prevailing then is critical for subsequent shoot infection (see p. 38). The symbols at the top of the figure show the dates on which spraying was carried out on the control plots (B) and on the plots sprayed when daily sunshine averaged less than 30 hr. (E).

Fig. 6 demonstrates that the degree of infection on the unsprayed plots was largely dependent on the amount of sunshine prevailing about 20-days earlier. The same trends occurred in the sprayed plots, but the level of infection was lower.

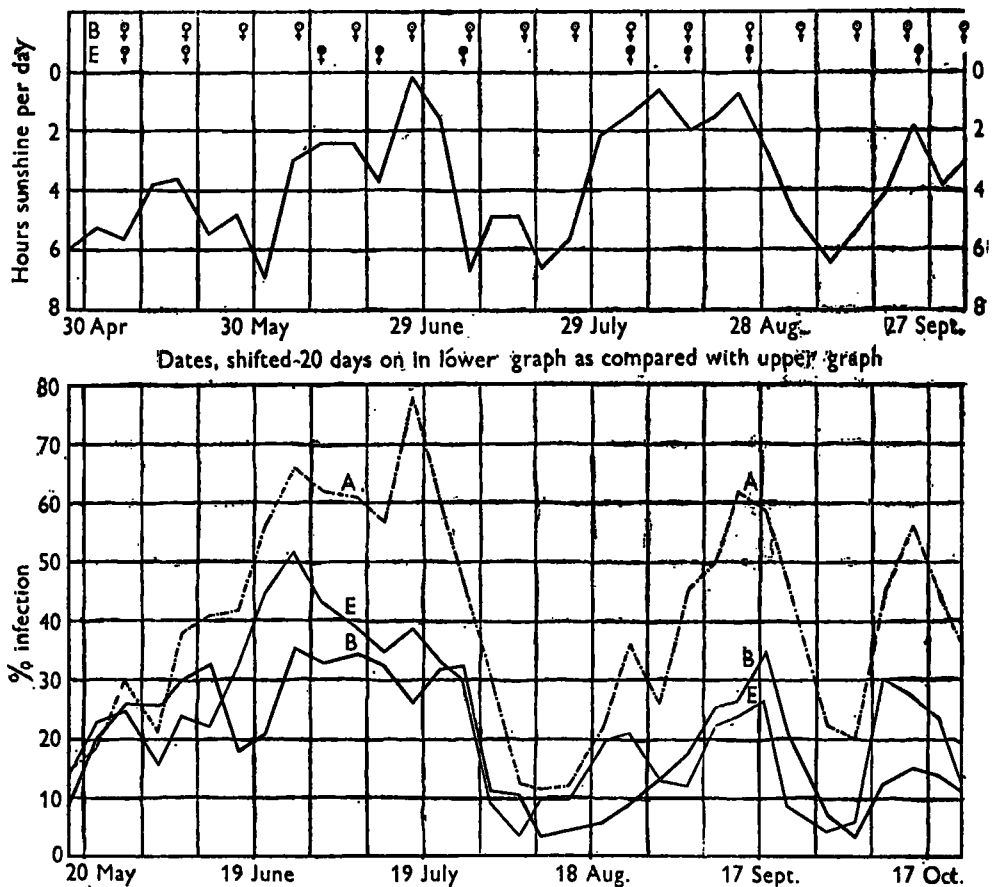


Figure 6. Incidence of Blister Blight over 5 months on (A) unsprayed plots, (B) plots given the routine sprayings, and (E) plots sprayed only if the average daily sunshine was less than $3\frac{1}{2}$ hr. per 5-day period at 20 (18-22) days previously. The upper part of the figure shows the 5-day averages of daily sunshine with an inverted scale and with the dates shifted 20 days compared with the lower figure; open circles give the dates of routine spraying (B), solid circles the dates of spraying decided on the basis of previous sunshine (E). The lower part of the figure gives the incidence of Blister Blight with three different treatments.

The figure also shows that the protection obtained when control measures were timed on the basis of sunshine records was nearly as good as that obtained with routine spraying; but when sunshine records were used for timing, only nine sprays were required instead of sixteen for the control.

The above observations indicate that sunshine—at least for practical purposes—is the dominant factor for blister-blight incidence.

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