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# SPRAYING AND DUSTING IN THE CONTROL OF BLISTER BLIGHT OF TEA

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## I.—INTRODUCTION

Fungicides, applied either by spraying or by dusting, play an important part in the control of the majority of fungal diseases. It is possible that Blister Blight may prove to be no exception, but three major difficulties require consideration in any plan for the wide-spread use of fungicides as a means of adding to that degree of control obtainable by the modification of the methods and timings of cultural operations. These are: firstly, the difficulties arising from the hilly terrain of the tea districts of Ceylon; secondly, the cost factor; thirdly, the need to avoid the

slightest risk of affecting the manufacturing qualities of the crop harvested. The importance of these factors is enhanced by the need for repeated treatment if adequate protection is to be obtained by spraying or dusting. The fungus is unaffected by applied chemicals when within the host tissues, and thus protection of the tea is dependent upon the prevention of infection. Since the majority of infections occur either upon the outermost of the embryo leaves forming the shoot-bud, or upon the first or second leaves, it follows that the protection afforded by any single applica-

cation is vitiated as new leaves unfold and expose their expanding and unprotected tissues to form a new and vulnerable leaf surface. Further, the increasing resistance of the earlier formed leaves renders the fungicide upon their surfaces finally redundant. The need for thorough, as well as repeated, treatment follows from the fact that infection can occur on both sides of the leaf and independently of the stomata, contrary to the statements in the early literature of the disease.

The steep hill faces on which tea is grown in Ceylon and the wide spaces between the narrow paths at present preclude any form of sprayer which cannot be taken up and down the narrow rows between the bushes and over the drains and rocks encountered. It is for this reason, together with the ease with which the spray can be placed on the young growth of individual bushes, that the knapsack sprayer has up till now been generally used in Ceylon. But since one such sprayer will treat only about 1-1½ acres a day, (or up to 3 acres if relays of spraying coolies are used) and since frequent sprayings are of great importance, the need arises for numerous sprayers if any large acreage of mature tea is to be protected. The use of motor borne sprayers of types at present available is precluded by the nature of the ground. Any machine involving generalised distribution of spray material in the form of fog or mist must surmount the wastage resulting, firstly, from indiscriminate treatment of soil, green manures and mature tea foliage in addition to the superficial immature growth and secondly, from the tea close to the generator being given excessive doses in order to ensure that the tea at the maximum distance received an adequate amount. At present, therefore, the terrain enforces outlay on numerous small sprayers together with an accompanying high labour require-

ment. These general considerations also apply, in varying degree, to the use of dusting machines.

While the cost of the spray material applied in an individual application may be low, the need for regular and frequent treatment is unlikely to allow of the spraying of bearing tea ever becoming an economic proposition. The protection of pruned tea during the recovery period before tipping falls into rather a different category, which must be considered in relation to the policy of pruning "for dry weather recovery from budbreak onwards" which has been recommended. The recommendation for estates suffering from blister blight to prune in December and January in the 'South-Western' zone receiving both monsoons, and in May and June in the zones receiving their main rainfall in the North-East Monsoon is normally feasible provided pruning gangs are materially increased. Nevertheless, the unbalancing of monthly crops and the labour problems that arise as a result render it desirable to extend the pruning period if possible. Since it is very desirable that a more complete plucking table should have been produced by the time the rainy season arrives than is present on a freshly 'tipped' bush, pruning later than the periods suggested is inadvisable. But the risks involved in pruning during late October or November in Dimbula, or during April in Uva, could however be met by artificially protecting the early recovery growth from blister blight. Tipping, and the full development of the plucking table thereafter, could then take place in the ensuing dry weather. Where the period between budbreak and tipping is materially lengthened by the slow growth experienced at high elevations, as in the Nuwara Eliya district, this possibility is of particular interest, since the normal annual period of dry weather

is too short to allow of complete recovery taking place within it.

The third factor can be briefly dealt with. No fungicide is at present known whose use on tea in plucking can be unequivocally recommended as free from any possibility of affecting the manufacture of the crop. There is, therefore, at present a necessary restriction of spraying and dusting to young tea and to mature tea not in plucking.

Nevertheless, this still allows of a wide field of usefulness and in the following sections the application of sprays and dusts, and their relative usefulness, will be discussed in greater detail.

## II—FUNGICIDES

Preliminary tests of the efficacy of different fungicides in protecting tea from blister blight were commenced at St. Coombs with the arrival of the pre-monsoon rains in April-May, 1947, when field conditions first allowed of a material increase in the frequency of the disease. At the time of writing (November), the untreated tea in the field in which the majority of the experiments were carried out is only just beginning to achieve a reasonable cover of leaf, after having been relatively lightly pruned in April. In all experiments a period of three weeks was allowed to elapse between the initial treatment and the first recordings, in order to allow for the "incubation period" of the fungus within the host tissues.

The first trial involved the comparison of the effects of dusting with sulphur and with a proprietary 'Bordeaux' powder containing copper prepared by Tomlinson & Hayward Ltd., of Lincoln, and of spraying with the proprietary copper fungicide 'Perenox' at the strength of 4 oz. in 10 gallons of water. These treatments were repeated weekly in one series, and fortnightly in the

other. Blisters were removed and counted weekly, a total of 27,301 blisters being dealt with in 17 collections between 24th May, and the 13th September, 1947. These were distributed among the treatments as shown in Table I.

TABLE I.

	Weekly	Fortnightly
Control, untreated	3,920	6,480
Sulphur, dusted	1,031	5,597
'Bordeaux' dusted	938	2,011
Perenox, sprayed	245	1,079
Totals	12,134	15,167

These results illustrate the efficacy of copper fungicides in the case of this disease, and also the advantage resulting from frequent treatment.

At an early stage in the progress of this experiment, it was apparent that sulphur dusting gave little promise of providing an effective protection against the disease. This conclusion was supported by the results obtained from experiments involving the direct comparison of sulphur dusted and untreated bushes on several estates, including St. Coombs. In the latter case, the comparison was carried out for a period of eleven weeks. The mean infestation based upon a total of some twelve thousand blisters was —

Sulphur dusted	— 7.8
blisters per bush per week.	
Control	— 8.0
blisters per bush per week.	

The sulphur was applied weekly at a rate of approximately ten pounds per acre. Dusting was confined to the plucking table and no attempt was made to treat the whole of the bush. Although the treated plots gave off a sulphurous odour detectable at a considerable distance, there was no evidence of 'action at a distance' such as has rendered

sulphur dusting particularly efficacious in the case of those fungi, *e.g.*, the mildews, which are very susceptible to sulphur compounds.

Sulphur in the form of lime-sulphur was found to be more effective, however, and I am indebted to Dr. Padwick, of Imperial Chemical Industries (India) Ltd., for the suggestion that its efficacy would be still further increased by high pressure spraying. The lime-sulphur, in the form of 'Sulphinette' obtained locally, was used at a strength of 1 in 40 and at a rate equivalent to 120 gallons per acre, applied as a fine spray after the addition of a 'spreader.' Leaf scorch occurred on the young leaf in some cases, but not to any important extent. The total numbers of leaf blisters and of stem blisters collected from the three series of plots are shown in Table II.

germination of the fungal spores. However, experiments to determine the effects of spraying with lime suspensions of varying concentrations, and of spraying leaves with sodium phosphate solutions of different acidities gave negative results, as detailed below.

The lime experiment involved the comparison of Perenox, applied at the rate of 4 oz. in 10 gallons, with 4 per cent, 2 per cent and 1 per cent suspensions of calcium hydroxide in water sprayed on to the young growth on pruned tea, the first application being made immediately budbreak was observed. The rate of application in the latter stages lay between 80 and 100 gallons per acre, owing to particular care being taken to ensure that all young shoots were heavily coated. The numbers of blisters collected were as shown in Table III.

TABLE II

	Leaf blisters. (In eleven weeks)	Stem blisters (In three weeks)
Control	1,818	2
Sulphinette Weekly	338	7
Sulphinette Fortnightly	660	25

TABLE III

	Leaf blisters (In eight weeks)	Stem blisters (In three weeks)
Control	7,810	412
Perenox	298	5
Lime 1 per cent	9,042	372
Lime 2 per cent	7,744	278
Lime 4 per cent	7,761	295

The greater efficiency of the lime-sulphur in relation to sulphur dust raises the question whether the alkaline nature of the lime-sulphur deposit was influencing

As before, Perenox treatment was effective in markedly reducing the degree of infection, but the application of an alkaline coating was quite ineffective.

In the comparison of the effects of spraying the young leaves and buds with strongly buffered solutions of differing acidity, the solutions used were:—

A.—Sodium dihydrogen phosphate  
( $\text{NaH}_2\text{PO}_4 \cdot 2\text{H}_2\text{O}$ ) 10 gm. per  
litre — pH 3.8

B.—Distilled water — pH 7.0

C.—Sodium phosphate ( $\text{Na}_2\text{PO}_4 \cdot 12\text{H}_2\text{O}$ ) 24.4 gm. per litre — pH > 10.

The solutions were sprayed on the young shoots, in the form of a fine mist, at the rate of 23 ml. per bush, twice weekly. The number of leaf blisters removed over a period of nine weeks was as follows, the observed differences not being significant:—

Treatment A	...	13,674
Treatment B	...	15,713
Treatment C	...	12,999

These two experiments sufficed to indicate that control was unlikely to be obtained through efforts to render the acidity in vicinity of the germinating spore unsuitable for its effective growth.

It became apparent early in the progress of the first experiment described that, of the fungicides tested, the most promising were dusts and sprays containing copper. Two further field experiments of more elaborate design were therefore set up without awaiting the completion of the experiments referred to above. The first allowed of comparison of two proprietary fungicidal dusts containing copper with Perenox spray while the second compared the effects of varying the concentration of Perenox. A further variable — that of interval between successive treatments — was also investi-

gated in both experiments. They were laid down on tea clean pruned in April 1947, on which budbreak had just commenced. At this time little evidence existed as to the degree of variation to be expected between similarly treated plots, and therefore no guide was available as to the plot size or replication necessary for reasonably accurate comparison. In the result, the errors proved to be very high, but not high enough to prevent useful conclusions being drawn. Still further experiments with enhanced replication, were subsequently laid down to test under field conditions the effect of the addition of a 'fixative' to the spray fluid and also to compare further fungicidal dusts and spraying material as supplies became available.

The results of these experiments are discussed in the succeeding sections.

### III—FUNGICIDAL DUSTS CONTAINING COPPER

The experiment designed to test the efficiency of copper dusts involved the comparison of Perelan I, a product supplied by Imperial Chemical Industries (India) Ltd., Colombo, and of "Colloidal Copper Dust," a product of Messrs. Strawson Ltd., supplied by Messrs. Brown & Co., Ltd., Colombo. These two fungicides were applied at rates of 15 lb. per acre and 30 per acre; weekly, fortnightly and monthly applications were tested at each rate. The experiment consisted of five randomised blocks each of three plots, each of six sub-plots, each of eight bushes, the plots being allocated to time treatments and the sub-plots to fungicides. The latter included, for comparative purposes, sub-plots allocated to nil treatment (control) and to Perenox applied at the rate of 70 gallons per acre, and a strength of 4 oz. in 10 gallons. Leaf blisters were removed weekly, with as little damage to the rest of the leaf as possible. Towards

the end of the experiment, which continued for fourteen weeks through the South-West Monsoon, records were made of the occurrence of stem lesions while finally the opportunity was taken to collect data on the amount of new ('recovery') growth made after pruning. The results are set out in Table IV.

Dusting significantly reduces the number of infections provided the treatment interval is sufficiently short (Section A). Application at the rate of 15 lb. of dust per acre, while effecting a considerable reduction in the number of leaf blisters, did not produce as good results as treatment at the rate of 30 lb. an acre. At the latter rate Perelan I, applied weekly, did not vary significantly in effect from spraying with Perenox. On the whole, however, Perenox gave the better results save when the time interval between treatments was so great that effective control of the disease was lost. At the rate of 30 lb. an acre Perelan I gave just significantly better results than "Colloidal Copper Dust" but no significant difference was detected at the 15 lb. level. It is a matter of interest that the dusts, in this experiment, were more efficient, relative to Perenox, in preventing stem blisters than leaf blisters (Section B). The high errors associated with the observations render it desirable that this subject should receive further investigation, in order to determine whether stem infections in nurseries, from which the major damage results, can be adequately reduced at an economic cost by light, but frequent applications of a fungicidal dust.

Sections C; D and E of Table IV provide data upon the amount of growth present on the bushes at the end of the experiment, by which time the bushes were in full plucking. The application of fungicides markedly improved the degree of recovery from prun-

ing, provided the interval between applications did not exceed a fortnight. The differences in effectiveness of the various fungicides were small, and far outweighed by the effects of more frequent treatment.

In those plots on which the ravages of blister blight were reduced to relatively negligible proportions, the ratio of new leaf to new stem was 2.59 (Section F). In unprotected bushes the mean ratio was only 1.04, indicative of the considerable proportion of leaf lost by premature abscission following upon stem infections on or near the axillary bud and leaf infections on or near the petiole, and also by reduction of leaf area through severe infection. The effect was somewhat exaggerated by the difficulty of removing blisters during the course of the experiment without loss of some additional leaf tissue, but field experience confirms that it is nevertheless a very real one. With weekly application, all four dusting treatments were equally effective in reducing such defoliation, but were significantly inferior to the Perenox spray. With a larger interval between successive applications, the latter distinction vanished.

The effects of the observed differences in 'recovery' growth upon infection are discussed in Section IV.

A further comparison of commercial fungicidal dusts was carried out during the North-East Monsoon. Over a period of seven weeks, when infection was relatively light, control plots gave a total of 6377 blisters per 54 bushes. The results obtained on the treated plots were:—

	Approximate rate per acre 15 lb.	30 lb
Perelan I	... 1366	1086
Folosan	... 4342	2990
Sandoz Dust	... 1352	675

TABLE IV

Comparison of effects of copper spray and copper dusts on recovery of tea pruned 27th April, 1947

Section	Measurement	TREATMENT								TREATMENT INTERVAL	
		Treatment interval in weeks	Control	Perelan I Dust 15 lb. per acre	Strawson Dust 15 lb. per acre	Perelan I Dust 30 lb. per acre	Strawson Dust 30 lb. per acre	Perenox 4 oz. in 10 gallons	Sig. diff.	Totals	Sig. diff.
A	Total leaf blisters recorded from totals of 35 bushes during 14 weekly collections from 11-6-47 to 9-9-47 inclusive.	1	11,369*	4,110	5,006	1,580	3,116	952	1,516	14,764	} 13,367
		2	11,903	11,648	8,918	7,710	11,568	4,880	3,075	44,724	
		4	12,973	12,109	11,682	11,935	13,243	10,322	—	59,291	
B	Total stem lesions recorded from totals of 35 bushes during 3 weekly collections from 9-7-47. to 23-7-47.	1	119*	8	29	4	7	3	—	51	} —
		2	85	29	40	41	30	12	—	152	
		4	84	107	113	128	85	81	—	514	
C	Total dry weight of new growth (stems & leaves) present below the plucking table 21 weeks from pruning in grammes per 35 bushes.	1	1,230*	4,889	3,647	3,516	3,563	4,160	—	19,775	} 3,171
		2	1,115*	2,107	2,035	2,653	3,215	3,799	1,051	13,809	
		4	1,088	1,508	1,394	1,508	1,658	1,362	—	7,930	
D	Dry weight of new stems present below the plucking table 21 weeks after pruning, in grammes per 35 bushes.	1	574*	1,550	1,249	1,123	1,219	1,228	—	6,639	} 463
		2	532*	847	776	996	1,219	1,313	349	5,151	
		4	559	650	658	684	691	747	—	3,430	
E	Dry weight of new leaves present below the plucking table 21 weeks after pruning, in grammes per 35 bushes.	1	656*	3,339	2,398	2,393	2,344	2,932	—	13,406	} 2,149
		2	583*	1,260	1,259	1,657	1,996	2,486	717	8,658	
		4	529	858	736	824	967	1,115	311	4,500	
F	Ratio $\frac{\text{New leaf}}{\text{New stem}}$	1	1.13*	2.16	1.95	2.14	1.91	2.59	0.39	10.75	} 1.28
		2	1.05*	1.50	1.66	1.70	1.67	1.35	—	8.36	
		4	0.94	1.30	1.13	1.14	1.45	1.48	0.32	6.50	

NOTES.—The data for the comparison of the effects of the different treatments have been analysed separately for each treatment interval.

Where no value "Significant Difference" is given the treatments have not varied significantly in their effects save as noted below. Values of the "Significant Difference" shown have been calculated after omission of the data for those treatments whose effects are undoubtedly significant and far outweigh the remaining treatment effects. (see Cochran, *Empir. J. Exptl. Agric.*, 1938, VI, 157-175). Values omitted for this purpose are marked with an asterisk to indicate that they vary significantly from the remaining values. The "Spray Interval" totals do not include the values for the "Control" plots.

Experiment has thus shown that dusting with copper dusts is capable of giving a fairly high degree of control of blister blight; although in some respects spraying gave rather better results than dusting. The choice of fungicide and also the choice between dusting and spraying will depend in practice upon the cost of obtaining equivalent degrees of protection. The prices of the various fungicides on the Colombo market vary, but the dusts in general have a relatively high landed cost owing to their bulk. On a basis of 30 lb. per acre per treatment dusts compare badly with sprays using about 1½ lb. per acre. They further suffer from the difficulty of concentrating treatment upon the young, infectable, growth and the inconvenience of keeping the powder dry under field conditions. They have the advantages of not requiring the carriage of large quantities of water as in the case of sprays and of easy and rapid application. But even were methods of application evolved that allowed of a substantial reduction in the labour involved compared to spraying, the cost of dust would itself involve expenditure out of all proportion to the advantages to be gained unless prices are materially reduced.

#### IV—SPRAYS CONTAINING COPPER

The experiment to determine the optimum strength and interval between applications for a copper spray, Perenox, consisted of six blocks of three plots, each of the latter consisting of four sub-plots, each of 15 bushes. Comparison was made between the effects of intervals between spraying of one week, two weeks and three weeks on the whole plot basis, while the effects of spraying at a rate of approximately 70 gallons per acre with varying concentrations of Perenox were examined on the sub-

plot basis. The rate of application was considerably less in the earlier stages of recovery, when the shoots were few and small. The concentrations used were nil, 2 oz., 4 oz. and 6 oz. per ten gallons of water. The experiment was carried out on tea pruned in April 1947 and was continued throughout the South-West Monsoon from budbreak until the bushes were in full plucking. As in the case of the dusting experiment described earlier, primaries were plucked ("tipped") as each formed a bud and two leaves above the pre-determined level of 4½ inches above the pruning level. Leaf blisters were removed and counted over a period of fourteen weeks, while records were also made for a limited period of the number of stem lesions occurring. At the end of the experiment the whole of the "recovery growth" produced by the bushes was removed, and the dry weight of new stems and leaves from each plot recorded. The results are set out in Table V.

The degree of infection of the "control plots" during the period was high, and as the experiment progressed, the amount of young leaf and of buds on the control plots fell behind that on the treated plots. The differences between the total recovery weights of the control series and those of the treated series (Section C, Table V) represent tissues, at one time infectable, absent from the control plots. In other words, by virtue of their continued successful recovery, the treated plots exposed between treatments a greater surface of potentially infectable tissue than the controls. If differences in weight of 'recovery growth' be taken as a rough measure of this difference in potential opportunity, it would appear that had equal infectable surfaces been maintainable on all plots,

TABLE V.

Perenox.—Effects of varying concentration and spraying interval on recovery of tea pruned 12th April, 1947.

Section	Measurement	T R E A T M E N T							
		Interval in weeks	Nil	Weight in 10 gallons water				Spray interval	
				2 oz.	4 oz.	6 oz.	Sig. diff.	Totals	Sig. diff.
A	Total leaf blisters recorded from totals of 90 bushes during 20 weekly collections from 3-5-47 to 13-9-47 inclusive.	1	27,250*	1,922	1,802	939	496	4,663	} 7,710
		2	34,318*	8,922	9,954	5,917	2,534	24,793	
		3	33,506*	18,298	17,558	16,046	—	51,902	
B	Total stem lesions recorded from totals of 90 bushes during 3 weekly collections from 15-7-47 to 29-7-47 inclusive.	1	456*	21	17	18	—	56	} 225
		2	406*	122	123	102	—	353	
		3	679*	318	220	193	—	731	
C	Total dry weight of new growth (stems and leaves) present below the plucking table 22 weeks from pruning, in grammes per 90 bushes.	1	4,451*	7,763	7,458	6,718	—	21,939	} 2,643
		2	3,650*	6,087	7,683	7,422	—	21,192	
		3	3,809	5,653	5,212	5,815	—	16,680	
D	Dry weight of new stems present below the plucking table 22 weeks after pruning, in grammes per 90 bushes.	1	1,474*	2,271	2,017	1,869	—	6,157	} Just not signi- ficant
		2	1,301*	1,901	2,216	2,171	—	6,288	
		3	1,346	1,847	1,636	1,845	—	5,328	
E	Dry weight of new leaf remaining on the bushes 22 weeks after pruning and after 5 weeks plucking, in grammes per 90 bushes.	1	2,977*	5,492	5,441	4,849	—	15,782	} 1,880
		2	2,349*	4,186	5,467	5,251	—	14,904	
		3	2,463	3,806	3,576	3,970	—	11,352	
F	Ratio $\frac{\text{New leaf}}{\text{New stem}}$	1	1.99*	2.47	2.72	2.65	—	7.84	} 0.61
		2	1.80*	2.18	2.46	2.40	0.22	7.04	
		3	1.76*	2.04	2.19	2.13	—	6.41	

NOTE.—The Notes to Table IV apply to Table V also

the controls in the monthly (Table IV) and three weekly (Table V) series would have exhibited significantly greater infections than the treated series. The smaller differences in recovery growth between treated series, excluding controls, here renders this factor of little importance, save in the examination of the effect of variations in the treatment interval to be discussed in Section V.

The interest in the effects of the spraying treatments centres in the questions whether the good control already shown to result from the use of Perenox can be markedly improved upon by the use of higher concentrations, whether the same result is achievable at lower cost by the use of lower concentrations and whether the effects of variations in treatment interval are relatively important.

Study of Sections A and B of Table IV indicates that, provided the spraying interval is small, the effect of increasing the concentration of the spray is also small. In other words, effective control is achievable by weekly spraying with Perenox at the strength of 2 oz. in 10 gallons, and the solitary advantage resulting from the use of 6 oz., i.e., the small reduction in leaf blister, is quite unimportant. Since labour, however, represents the most important item of cost in field spraying with knapsack sprayers, a ruling is desirable as to whether additional strength would compensate for less frequent sprayings. The data for both leaf blisters and stem lesions indicate that substantial loss of control occurs with fortnightly spraying, and that this is by no means compensated for by the effect of using a strength of 6 oz. in 10 gallons. Further, it is apparent from Sections C, D and E that, although fortnightly spraying permits of good recovery, three weekly

spraying results in a marked drop in the amount of recovery growth. Although this drop is less in the case of the higher concentration of Perenox, the improvement is insufficient to justify the greater cost. A practical rule would appear to be: "Where protection of tipping growth is desired, spray from budbreak to tipping at the rate of 2 oz. of Perenox in 10 gallons of water at intervals of 7-10 days according to the weather, but never exceeding fourteen days." Where protection of relatively small plants in the nursery is the aim, it is desirable to achieve a much higher degree of protection owing to the damage that can result from a single infection, and more frequent treatment is desirable. Spraying with a concentration of 2 oz. in 10 gallons of water once or twice weekly will provide this.

At elevations below 3,000 feet, where leaf area on the bush during recovery has special importance, the defoliation aspect must be considered. Section F of Table IV indicates that weekly spraying is preferable to fortnightly where avoidance of defoliation is important. In such cases, if the spraying interval exceeds 7 days, the strength used should not be less than 4 oz. in 10 gallons.

Having examined some of the factors effecting the field use of copper sprays, a comparison was made of two commercial compounds available on the Colombo market. The concentration of 2 oz. per 10 gallons was adopted and the opportunity taken to test whether the presence or absence of a fixative (Albolineum 2, sold by Imperial Chemical Industries (India) Ltd., affected the efficiency of the spray. This compound was originally used as recommended at the rate of 0.33 oz. in 10 gallons of spray. In order to ascertain

whether any of the four treatments would permit of an extension of the spraying interval, and thereby of a reduction in treatments costs, each of the four treatments were applied weekly and fortnightly to unplucked shoots growing on bearing tea nineteen months from pruning, during the North-East Monsoon. The mean rate of application was at the rate of fifty gallons per acre. The results obtained per unit of sixty-four bushes over a period of seven weeks are shown in Table VI.

extension of originally immature tissues to such a degree that the original protective film is no longer effective, and fourthly from the exposure of new, unprotected, and enlarging surfaces following upon the production of additional leaves and internodes by the bud. Compensating to some extent for these factors, there is the rapidly increasing resistance that the tissues acquire as they mature in time and in morphological development through the stages of bud-leaf, first leaf, second leaf, etc., until in the third and

TABLE VI

		Weekly		Fortnightly	
		Alone	With Albolineum	Alone	With Albolineum
Perenox	...	743	1,087	2,626	2327
Sandoz	...	695	983	2,074	2008

Over the same period the blisters in untreated plots amounted to a total of 7,558 per unit.

These results are to be regarded as interim findings. The evidence is that the effect of varying the spray compound was not significant, while under the conditions experienced in October-December, 1947, Albolineum at the concentration used had no effect. The makers have now issued recommendations for the use of a considerably enhanced strength (1.5 oz. per 10 gallons of spray fluid), and the experiment is being continued using the latter concentration.

#### V—TREATMENT INTERVAL

Inefficient protection of the vulnerable tissues may result firstly from inefficient spray application or coverage, secondly from loss of the protective film by rain action between sprayings or before the underlying tissues have become resistant, thirdly, from

fourth leaf liability to infection is quite small. The totals in Sections A of Tables IV and V express the resultant of all these factors. The importance of the treatment interval in affecting the nett result is obvious from the data in the last columns of Tables IV and V.

The interplay of treatment interval and degree of infection is most easily examined in those cases where there is little doubt of the efficiency of the spray treatment when applied, and where the treatment interval is not so great as to lead to material reduction in the amount of recovery growth and, therefore, of infectable surface. The following discussion is confined to the results of spraying with Perenox during the South-West Monsoon, when liability to infection was high. The ratio of *additional* infection in the plots sprayed fortnightly to that in the plots sprayed weekly in the various experiments described was as follows:—

Strength	Ratio
4 oz. in 10 gallons	1:3.4
4 " " " "	1:4.1
6 " " " "	1:5.3
4 " " " "	1:4.5
2 " " " "	1:3.6
Mean	1:4.18

It is known (Bulletin 19, pp. 51-53, 1938) that on the average a leaf unfolds every 6.3 days from the bud of an actively growing shoot. Two leaves are unfolded on the average every 13.1 days; here, for convenience, an average period of 6.5 days per leaf will be assumed. Further, the ratio of surface areas in shoots where a further leaf will shortly unfold from the bud is in the neighbourhood of:—

Bud :	First leaf	Second leaf
1	8	20

Thus in about 6.5 days the tiny leaf curled round the bud expands to about 8 times its size, and in turn expands, another 2½ times in the next period. If a large number of shoots, in all stages of development, are sprayed on a given day, buds and unfolded leaves will acquire a protective film. Each day thereafter some buds will unfold, and unprotected surfaces, themselves extending in area, will be exposed to infection. Using for convenience the figures already given, and measuring leaf areas in terms of the bud area, the following argument can be developed to obtain an explanation of the size of the increase in infection resulting from longer treatment intervals. A bud just after a leaf has unfolded from it is taken to have a size of 0.3 and the mature bud just before another leaf is due to unfold from it a size of 1.0. Using the ratio of areas referred to above, allowing for the increases in average size of the leaves during the relevant periods, and considering an average shoot unfolding

3.25 days after spraying, in the last 3.75 days of the week following spraying the mean relative size over the period of the newly exposed, unprotected bud, will be  $0.3 + \frac{(3.75)}{6.5} 0.7 = 0.50$ , if a linear rate of development is assumed. The small leaf unfolded from it and 3.75 days old at the end of the week will have an average relative size during the period of  $1 + \frac{(3.75)}{6.5} 7 = 3.00$ . The product of the average area multiplied by the exposure time of the unprotected tissues until they are again protected seven days after the initial spraying is thus  $3.50 \times 3.75 = 13.125$ .

If spraying takes place once more after a lapse of seven days from the initial treatment the risk of infection is immediately greatly reduced by the deposition of a protective film over the surfaces under discussion, only to rise once more during the succeeding week. Thus 13.125 may be used to express the weekly exposure of the average shoot. But if instead of weekly treatment fortnight spraying is the rule additional exposure occurs during the second week of the fortnight after each spraying. This additional exposure is increased by the further expansion of the bud and leaf already discussed and by the unfolding of yet another leaf from the bud  $3.25 + 6.5 = 9.75$  days after the first spraying. The areas exposed over the period may be approximated to as follows:—

- (a) Until the bud unfolds a further leaf at 9.75 days after the first spraying, the mean relative size of the bud over the period 7 to 9.75 days is  $0.7 + \frac{0.3}{2} = 0.85$  and of the leaf  $5.0 + \frac{3.0}{2} = 6.50$ . The exposure is  $6.5 - 3.75$  days = 2.75 days.

(b) Between 9.75 days and 14 days after the initial spraying the mean size of the bud over the period drops to  $0.3 + \frac{1}{2} \frac{(4.25)}{6.5} 0.7 = 0.53$  as a result of a new leaf unfolding which grows to a mean relative size over the period of  $1 + \frac{1}{2} \frac{(4.25)}{6.5} 7 = 3.29$  while the now second leaf increases to a mean size of  $8 + \frac{1}{2} \frac{(4.25)}{6.5} 12 = 11.92$ .

On this basis, the total product of average unprotected area multiplied by exposure time during the second week is  $2.75 (0.85 + 6.50) + 4.25(0.53 + 3.29 + 11.92) = 87.108$ . The ratio of 'opportunity' in the first week to that in the second week thus becomes  $13.125:87.108 = 1:6.63$ . As is to be expected, since no allowance has been made for the reduction in the susceptibility of the ageing and developing tissues, this value is higher than the observed mean ratio of infection in first and second week of 1:4.18.

A correction for varying susceptibility requires some measure of susceptibility. It is of considerable interest that the mean rate of germination on leaves of differing morphological status have been found, in laboratory experiments, to bear the ratios to one another of:—

Bud	First leaf	Second leaf
1	0.50	0.11

Applying these values as "susceptibility factors" by multiplying the areas used in the above calculations by them, the opportunity ratio becomes as:—

$$3.75 \cdot (0.50 + 0.50 \times 3.00) : 2.75(0.85 + 0.50 \times 6.50) + 4.25(0.53 + 0.50 \times 3.29 + 0.11 \times 11.92), \text{ i.e., as } 1:4.01.$$

This value is very close to that of 1:4.18 observed in the field. Thus it is possible, by relating leaf development rates, areas of unprotected surface, time of exposure, and spore germination rates to obtain a calculated value for the infection ratio which

agrees closely, considering the number of approximations and assumptions involved, with the average effects observed in a number of field experiments. The lower increase in infection resulting from fortnightly compared with weekly spraying of unplucked shoots growing on tea eighteen months from pruning during the North-East Monsoon is interesting and, if confirmed, may indicate more rapid increase in resistance of the young tissues under warmer and drier conditions.

## VI ESTATE PRACTICE

It is apparent from the foregoing sections that blister blight can be adequately controlled in the field even under monsoon conditions by dusting, and especially by spraying, provided the treatment interval is sufficiently short. The extent to which such treatments are adopted in practice depends upon cost, which in turn is closely associated with the conditions in which tea is grown in Ceylon while in the case of bearing tea the risk of taint must be borne in mind. It is convenient to discuss estate practice under the separate headings of tea in plucking, of young clearings, pruned tea and nurseries, noting in passing the amendments to the costs given in the *Tea Quarterly*, Vol. XIX Pt. II, page 38, July 1947.

In the case of tea in plucking, no risk of adverse effects upon the manufactured product can be entertained. But even were a compound available that was entirely above suspicion in this respect, the cost of regular protection would normally be prohibitive using existing methods.

Young clearings containing seedling plants present an entirely different problem. The contour planting of modern clearings greatly facilitates protective treatment while the amount of fluid required is small. In consequence, the cost of spraying may amount only to about 75 cents per acre per

treatment. Spraying should be repeated approximately weekly, using Perenox or Sandoz at the rate of 2 oz. per ten gallons. When spraying seedlings it is very desirable to ensure thorough treatment of the young stems as they emerge from the soil. The number of functioning sprayers required will be about one per 10 acres of clearing, allowing for an average total of five days' spraying per week. Spraying should be continued in the intervals of rain, since even a trace of copper remaining on the bud is preferable to allowing it to develop unprotected. In this connection, it may be noted that the only deviation permitted in the spraying experiments described earlier was the postponement to the afternoon or next morning when on the rare occasions that *continuous* heavy rain occurred. Spraying was continued irrespective of light rain, in order that the conclusions reached should refer to the results of field spraying under monsoon conditions.

The cost of protection of clearings of 2-4 years of age will be greater, but should not exceed that of one cooly per acre and half-a-pound of fungicide per treatment, i.e., about Rs. 2. Treatment of such clearings would normally only be necessary in special circumstances, e.g., to allow of a longer period of blister-free growth following centring or pruning than would be provided by the dry season normally experienced in a particular district.

It has already been observed that spraying of pruned tea during recovery should be regarded as a means of commencing pruning earlier than the climatically 'safe time,' but not of continuing it later. Spraying with knapsack sprayers of mature pruned tea on steep slopes has been carried out at less than 2 coolies an acre, the amount of fluid required varying from 30 to 60 gallons per acre according to the amount of new growth. A cost in the neighbourhood of

Rs. 3 per acre is thus involved for labour and spray material. Previously, spraying costs have been considered on the basis that spraying should pay for itself in profit on crop saved. It has, however, been pointed out that on many estates additional crop obtained by spraying would cost relatively little over and above the money spent on spraying, plucking and manufacture. Where such is the case, spraying pruned tea to facilitate recovery may well prove a very profitable proposition. In passing, however, two warnings must be given. Firstly, spraying is a costly substitute for pruning for "dry weather recovery from budbreak onwards" and secondly, it is unwise to attempt a more ambitious programme than the number of functioning sprayers warrants. At  $1\frac{1}{2}$  acres a day, and a total of 5 days' spraying per week, one sprayer will protect  $7\frac{1}{2}$  acres. This acreage can be increased by the use of spraying coolies in relays to allow of continuous use of the machines.

As labour ranks so high in the cost of spraying, labour-saving methods of application are of the greatest interest to the Industry. Various motor sprayers have received notice from the agricultural press lately, but none so far fully meet the stringent requirements of the tea crop. It seems likely that manually operated pump or pressure types which permit of movement up and down the rows of tea, and of the application of the spray fluid exactly where it is required, will prove most useful at present. The pump types have certain advantages in practice in the field, but at least one such type is supplied with too coarse a nozzle. It seems very desirable that makers should interest themselves in local requirements, rather than on the sale of machines elaborated for use under far different conditions. Again, a really mobile and efficient power duster might well alter the economic relationship between

dusting and spraying, provided cheaper dusts could also be obtained.

In nurseries, where the object is to prevent any infection whatsoever, and where nursery labour is usually regularly available in any case, it is desirable to spray twice weekly during the period of rapid elongation of the stems after germination, and once weekly thereafter. Spray concentration need not exceed 2-3 oz. of Perenox or Sandoz in 10 gallons of water while a mulch of powdered dried fern refuse, or tea fibre, etc., placed over the ground and replaced periodically will retain any excess of spray fluid. In this connection, it may be noted, that the finer the spray jet the greater the economy

of fluid and the less the risk of adding large quantities of copper to the soil. Robust "pressure chamber" types of miniature flit gun, such as the "Maney" (Colombo Commercial Co., Ltd.), may be used. It is desirable to spray the lines of the seedlings from both sides when the basal stem is young, in order to ensure complete protection.

The data quoted earlier provide some indication of the very considerable labour involved in the investigations discussed, and in this connection it is pleasant to record the invaluable assistance received from Messrs. C. A. Loos, D. J. W. Ranaweera and F. H. Kehl, without which they could not have been completed.