INVESTIGATION OF THE BUNCHY TOP DISEASE OF PLANTAINS IN CEYLON

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HISTORY

BUNCHY top disease of plantains (*Musa paradisiaca* L.) is known in Fiji, Australia and Egypt. It was first recorded in Fiji and it is possible that infected suckers were exported from thence to Australia, Ceylon and Egypt. It is of interest to note that, while it is recorded that about forty years ago the disease threatened the banana industry in Fiji with extinction, it is no longer a serious menace in that colony. In Australia severe losses have been caused by the disease which almost wiped out the banana industry in many centres in north-eastern New South Wales and in south-eastern Queensland.

In Ceylon the disease first made its appearance in the Colombo district in 1913. Since then it has spread to the majority of the plantain-growing districts in the Island and during the earlier part of the last decade proved a limiting factor to the growth on a commercial scale of plantains in the Central and Western Provinces. The disease has not as yet been recorded on plantains grown in the Tissa area, the nearest diseased plants having been found in the Hambantota district. This freedom from disease is attributed to the isolation of the Tissa area and also to the fact that no plantain corms or plants have been introduced into that area from other parts of the Island for a number of years. Recently there has been a revival of plantain-growing in those districts in which the disease caused so much damage previously and it is to be hoped that efforts will be made to prevent a recurrence of the earlier losses.

SYMPTOMS

The symptoms exhibited by the aerial parts of plantains in the advanced stages of bunchy top disease, viz., the dwarfing and bunching of the leaves and the difference in colour of affected plants from the normal, are so well-known in Ceylon that it is unnecessary to describe them here in detail. The recognition of the disease in the early stages assumes importance in connection with the efficient control of the disease and it is therefore proposed to describe the first symptoms somewhat fully. Such

symptoms appear usually on the leaves of plants which have been recently infected by the disease. Magee [1] has enumerated the early symptoms and his description is quoted at length.

"The first external symptoms of bunchy top appear in the leaves of the plant. The normal leaf emerges from the centre of the pseudostem with the leaf-blade wrapped tightly around the midrib in the form of a rod or 'pipe.' The leaf remains tightly rolled until it has almost fully emerged, and then commences to unfurl more or less evenly along its whole length. While unfurling the leaf stands erect, and when fully unrolled the elongation of the leaf-stalk carries the blade clear of the pseudostem, and the leaf gradually assumes a position approaching the horizontal, making room for the next leaf which is pushing up through the pseudostem.

"In the case of secondary infection, it is in a leaf which has unfurled in this manner that the first symptom of bunchy top is usually observed. The first definite symptom of the disease is the appearance of irregular, nodular dark-green streaks about ·75 mm. wide along the secondary veins on the underside of the lower portion of the leaf-blade, along the leaf-stalk, or along the lower portion of the midrib.

"In the first instance one, two, or several of these streaks may be present. Usually others appear later in the same region. In character they may vary from a series of small dark-green dots to a continuous dark-green line with a ragged edge, an inch or more in length.

"The lamina of the normal leaf is of an even rich green colour. From the midrib prominent vascular strands run out more or less perpendicularly at intervals as main veins. The area between the main veins is lined by secondary veins which are even in colour throughout the leaf. The normal midrib and leaf-stalk are of an even pale-green colour, and are covered with a whitish waxy bloom.

"Usually the dark-green streaks are first seen in the leaf-blade, but may later appear in the midrib and leaf-stalk of the same leaf. In some cases of secondary infection, an earlier indication of the later appearance of green streaks in the lamina is seen. This occurs in the 'pipe' or tightly rolled heart-leaf. It takes the form of the appearance of a number of irregular pale-whitish streaks along the secondary veins of the tightly rolled lamina when the 'pipe' is about one half emerged from the pseudostem. When these pale-whitish streaks appear as the first symptom, the 'pipe' shows a slight transverse wrinkling along its length. On unfurling, a leaf which has shown these early streaks, bears numerous dark-green streaks, along the secondary veins of the lamina. In other respects this leaf may not differ from the normal preceding leaves.

"When, as usually is the case, the first symptoms take the form of a few characteristic green streaks in the lamina, midrib, or petiole, the 'first-symptom' leaf, except for these streaks, appears normal in size, shape and behaviour. In the following leaf however, while the pipe is still unfurled, pale-whitish streaks are seen along the secondary veins of the leaf-blade. These vary a great deal in number, depending on the degree of infection. The pipe or heart-leaf now unfurls slightly abnormally, beginning to unroll from the top region, giving the partly unfurled leaf a funnel-like appearance. In this leaf, when unfurled, dark-green streaks will be found to be present along many of the secondary veins of the lamina, and several dark-green dots or lines are seen along the midrib and petiole. This leaf will be smaller than normal, slightly chlorotic, and the marginal portion of the lamina will be wavy and slightly rolled upwards.

"The presence of the characteristic broken dark-green streaks along the secondary veins of the lamina, or along the midrib or petiole, is the most definite and reliable symptom of bunchy top. These streaks appear as the earliest external indication of the disease, and together with all other symptoms are not later retrospective in leaves which have been thrown earlier than the 'first-symptoms' leaf. The dark-green streaks are not apparent when viewing the dorsal surface of the leaf in reflected light. The leaf should be inspected from the underside so as to allow light to pass through it.

"Successive leaves as they are thrown became more abnormal. There is a slight retardation in the rate of growth. The heart-leaf unfurls prematurely, and is slow in completing the process; often another leaf has begun to unfurl before the preceding one is fully unrolled. The leaves may become progressively smaller in size or successive leaves may be of smaller dimensions. (In normal growth each leaf is larger than the preceding one). There is a reduction both in width and length of the leaves, this being more noticeable in the case of the lamina than in the midrib. The petiole does not elongate normally, thus the leaves stand more erect than in the healthy plant. Leaves thrown seen after infection are distinctly chlorotic in appearance, but this character does not persist except on the margins of the laminae. After several abnormal leaves have appeared, extreme congestion is apparent at the apex of the pseudostem. The leaves are seen to have lost their normal symmetrical arrangements around the pseudostem, and to have assumed the 'rosetted' condition. This characteristic arrangement of the leaves of a bunchy top plant does not result until several weeks after infection, and is thus not an early diagnostic symptom.

"In colour the mature leaf of a secondary bunchy top plant is of a slightly more yellowish hue than that of a healthy plant. In the primary bunchy top plant the position is often reversed.

Owing to the dark-green streaking being present along the greater number of the secondary veins, the general colour of the leaf is sometimes darker than normal. The lamina of such a leaf usually has a light yellowish-green margin.

"In texture there is a difference between the bunchy top and healthy leaf. Whereas the latter is elastic and pliable, the petiole, midrib and lamina of the bunchy top leaf are harsh and brittle, and snap readily when bent or crushed in the hand. There is a distinct rigidity and apparent resistance to wilting shown by bunchy top leaves. They are not nearly so readily shaken by winds as healthy leaves.

"The surface of the lamina of a bunchy top leaf becomes markedly corrugated as it matures, due to the growth of tissue in the region of the main veins producing ridging on the dorsal surface, and troughing on the ventral surface. This prominence of the main veins is not a diagnostic symptom of the disease. It is often seen in the leaves of healthy plants growing under adverse, or even rank, conditions.

"The margin of the lamina of the young bunchy top leaf is wavy and slightly upward-rolled at intervals along its length. In the older bunchy top leaf the lamina is not supported normally by the midrib; both sides tend to hang down so as to be nearly parallel with each other, the margin, however, remaining upturned and rolled.

"In primary infected plants, symptoms of the disease are apparent as soon as the first leaf appears above ground. The leaves are small, rosetted, and numerous broken dark-green streaks are seen in the petioles, midribs and laminae. The margins of the leaves are usually highly chlorotic, and are slightly rolled upwards."

Associated with the changes in the aerial portions of bunchy top plants is an increase in the decay of the roots. It is a common experience in the examination of the roots of healthy plantains, particularly of mature plants, to find a proportion of the roots decaying through the agency of soil organisms or possibly degenerating through age. In bunchy top plants, however, this root decay is more marked and for a long time was considered to be the cause of the disease. Magee (*loc. cit.*) considered this increase of root decay to be of a secondary nature and suggested that it might be due to the loss of immunity on the part of the roots of an affected plant to the attack of otherwise harmless soil organisms. It is possible also that the reduction of the assimilating surface of the leaves consequent on infection may lead to a weakening of the roots through an insufficient supply of carbohydrate material.

In all countries in which the disease has occurred investigators have endeavoured to discover the cause of the disease and to devise means for its control. Gadd [2] reviewed the situation

Plate I.

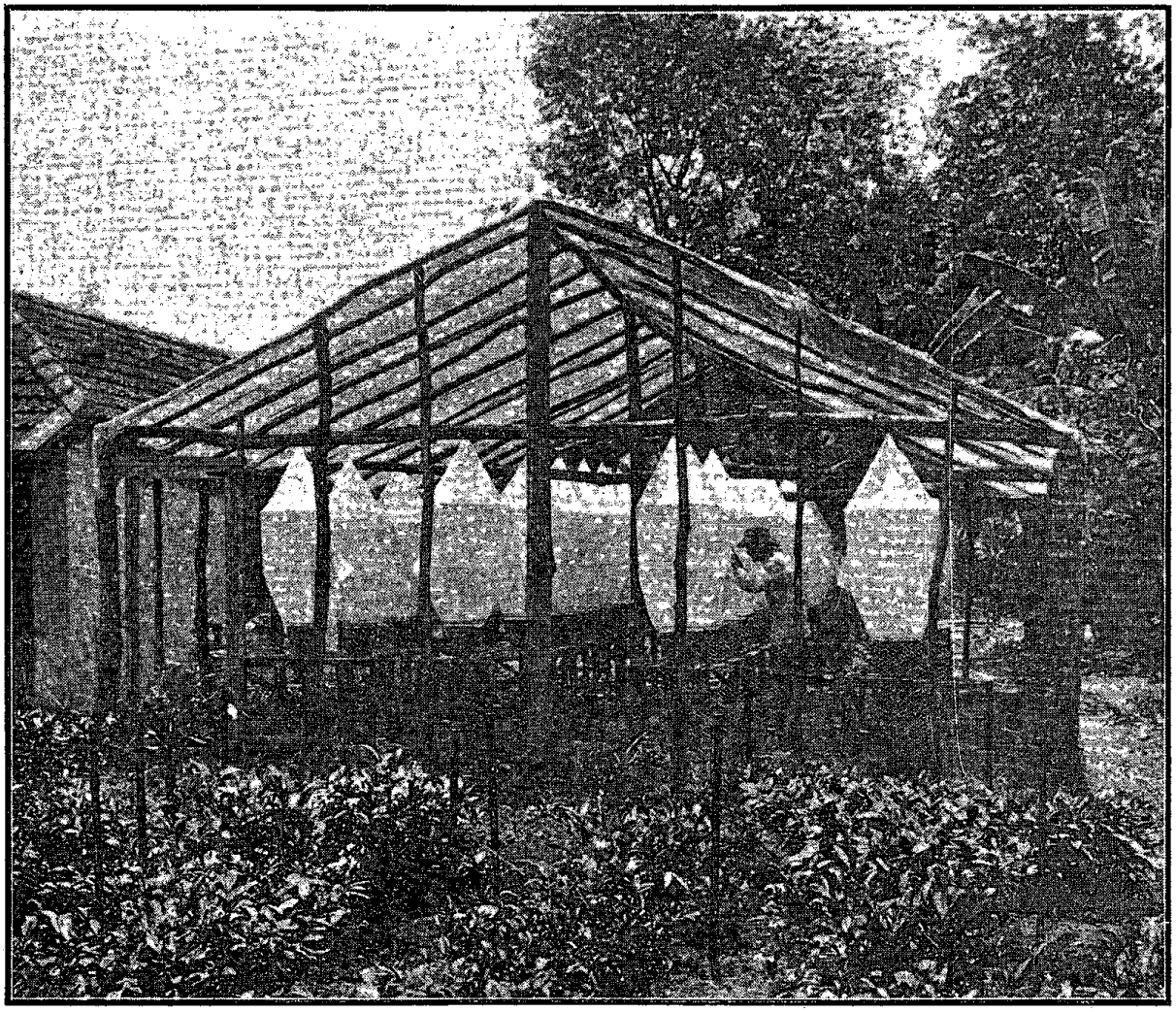

Photo by *L. S. Bertus.*

General View of Cages.

in regard to bunchy top disease in 1926 and it is not proposed again to describe the results obtained by early workers. Efforts to elucidate the problem were without success until Magee (*loc. cit.*) working in Australia demonstrated that the disease was transmissible from diseased to healthy plants by the agency of the banana aphid (*Pentalonia nigronervosa*). When the results of his experiments became known in Ceylon evidence was sought to determine if the Ceylon disease was identical with that found in Australia. The symptoms were found to be the same and in addition the aphis found on plantains in Ceylon was identified as *Pentalonia nigronervosa*. It appeared therefore that the disease was identical in the two countries and subsequently Magee while on a visit to Ceylon examined diseased plants and reported that the disease was identical with that in Australia. In 1928 Small [3], who had carried out a number of experiments to determine the significance of *Rhizoctonia bataticola* in cases of root disease of a wide range of plants, reported a preliminary experiment which indicated that *Rhizoctonia bataticola* might be associated with bunchy top disease and criticised Magee's paper on the ground that insufficient attention had been given to the study of root factors. He stated that "Ceylon bunchy top requires to be investigated *ab initio* with due attention to each possible causal factor and with repeated tests of each under controlled conditions." It was therefore resolved that an investigation should be initiated to determine, if possible, the cause of bunchy top disease in Ceylon. The experiments described below were formulated with the intention of determining, if possible, if the banana aphis, *Pentalonia nigronervosa*, could transmit the disease from affected to healthy plants under controlled conditions, endeavours being made to eliminate the complications arising from the presence of root parasites, with special reference to *Rhizoctonia bataticola* and the eelworm, *Caconema radicicola*.

EXPERIMENTS

The experiments were carried out in a framework enclosure made of rough jungle posts and completely covered with iron netting. A jute hessian screen was placed on the roof to break the force of heavy rains. The enclosure was 36 feet long by 24 feet broad by 7 feet high at the sides from which the roof sloped up to the ridge pole along the top. Plate I is a reproduction of a photograph of the enclosure taken during the course of the experiments.

Eight wooden stands, each 15 feet long by 2 feet wide by 2 feet 6 inches high, were arranged in four rows inside the enclosure to hold forty pot plants, ten plants in each row.

Forty cloth cages of the type shown in the illustration were made. Each cage was strengthened at the apex and suspended by a cord from the galvanized wires which reinforced the netting

of the enclosure. Round the lower open end of each cage a tape was threaded through the hem, the tape being of sufficient length to pass twice round the circumference of the pots and to be tied securely. The cages were fitted with short sleeves to admit of easy examination of the plants and these sleeves were tied with tapes when not in use. Bands of 'tanglefoot' were placed on the legs of the wooden stands and on the tapes suspending the cages in order to exclude insects.

The soil used for the experiments was a mixture of good soil and leaf mould and was sterilized in an autoclave for two hours at 125-130°C. Owing to delay in the arrival of plants for experiment, it was found necessary to sterilize the soil again and this was done after an interval of about one month. The pots were filled and the corms planted very shortly after the second sterilisation. The pots, which were new, were washed thoroughly with a solution of copper sulphate before filling with soil.

Four dozen young plantain suckers, twenty-four of *Hondarawala*, a variety generally considered to be somewhat resistant to bunchy top disease, and twenty-four of *Kolikuttu*, a variety relatively susceptible to the disease, were received early in January 1929 from the Tissa area in the Southern Province, an area in which bunchy top disease has not been found to occur. The suckers on arrival were examined carefully and found to be free from aphids and borer. The roots were removed with a flamed knife and examined. Neither eelworms nor *Rhizoctonia bataticola* were found in any of the roots. Samples of the roots were kept in damp chambers for a period of six months; at the end of the period the roots had degenerated but *Rhizoctonia bataticola* was not found. The forty best suckers were selected and freed of all soil. They were fumigated with hydrocyanic acid gas and were then topped at the collar with a knife sterilized in flame before each cutting. The corms were washed in a dilute solution of copper sulphate and planted. The planting of all forty plants and the fitting of the cloth cages were completed by January 23rd, 1929.

The pots were arranged on the benches in four rows of ten plants each as illustrated in plate I, the rows from left to right of the illustration being as follows:

Row I	Pots	numbered	1 to 10	*Hondarawala* infested (H.I.)
Row II	,,	,,	1 to 10	*Hondarawala* control (H.C.)
Row III	,,	,,	1 to 10	*Kolikuttu* infested (K.I.)
Row IV	,,	,,	1 to 10	*Kolikuttu* control (K.C.)

Examinations of the plants were made at short intervals and the results of these examinations are summarised in table I. It has been thought necessary to include only the results of those examinations in which changes were noted.

Table I

Row No.	Date of Examination	PLANT NUMBER 1	2	3	4	5	6	7	8	9	10	Remarks
I (*Hondarawala* infested)	17. 6.29	Plant dead	—	—	—	Str +	Str +	Plant dead	—	—	—	Aphids put in originally on 10.4.29. Plants (except Nos. 5 & 6) re-infected with aphids on 15.7.29.
	2. 7.29		—	—	—	Str +B+	Str +B+		—	—	—	
	29. 7.29		—	Str +	Str ?	Str +B+	Str +B+		Str ?	—	—	
	13. 8.29		Str +	Str +B+	Str +B+	Str +B+	Str +B+		Str ? B+	Str ?	Str +	
	31. 8.29		Str +B+	Str +B+	Str +B+	Str +B+	Str +B+		Str +B+	Str +B+	Str +B+	
	3. 9.29		Str +B+	Str +B+	Str +B+	Str +B+	Str +B+		Str +B+	Str +B+	Str +B+	
II (*Hondarawala* control)	17. 6.29	—	—	—	—	—	—	—	—	—	—	No aphids found on any of the plants during the course of the experiment.
	2. 7.29	—	—	—	—	—	—	—	—	—	—	
	29. 7.29	—	Plant	—	—	—	—	—	—	—	—	
	13. 8.29	—	taken into	—	—	—	—	—	—	—	—	
	31. 8.29	—	open	—	—	—	—	—	—	—	—	
	3. 9.29	—		—	—	—	—	—	—	—	—	
III (*Kolikuttu* infested)	17. 6.29	—	—	—	—	—	Plant dead	—	—	—	—	Aphids put in originally on 10.4.29
	2. 7.29	Str ?	—	—	—	—		—	—	—	—	
	29. 7.29	Str +	—	—	—	Cut back		Cut back dead	—	Cut back	—	All plants re-infested with aphids on 15.7.29.
	13. 8.29	Str +B+	—	Str +	Str ?	—			Str ?	Str +	—	
	31. 8.29	Str +B+	Str +	Str +B+	Str +	—			Str +	Str +B+	—	
	3. 9.29	Str +B+	Str +B+	Str +B+	Str +B+	Str +			Str +B+	Str +B+	Str ?	
IV (*Kolikuttu* control)	17. 6.29	—	—	—	—	—	Plant dead	—	—	—	Plant dead	
	2. 7.29	—	—	—	—	—		—	—	—		
	29. 7.29	—	—	—	—	Plant		—	—	—		
	13. 8.29	—	—	—	—	taken into		—	—	—		
	31. 8.29	—	—	—	—	open		—	—	—		
	3. 9.29	—	—	—	—			—	—	—		

Str = Streaking. B = Bunching (of leaves).

The corms were all planted by January 23rd. By March 15th the plants, with the exception of those which failed to grow (Nos. I. 1, I. 7, III. 6, IV. 6 and IV. 10) were growing well. Search had been made for a supply of aphids from diseased plants but without success and it was therefore decided to cut back all growing plants to ground level. The knife used for the purpose was flame-sterilized before each operation. On April 10th a few aphids were obtained from some bunchy top plants. Of these the majority were young nymphs, but weather conditions at the time were such that it was deemed advisable to use these for infestation. Plants in rows I and III were therefore infested. The aphids multiplied rapidly on infested plants and on May 16th it was found necessary to control their numbers by a mild dose of calcium cyanide which was introduced into the cages containing control as well as infested plants. As the plants grew it was found that the leaves came into contact with the bags and in order to prevent any chance of infection from outside, such leaves were cut back with a flamed knife.

It will be seen from table I that at the beginning of July only two plants of the infested *Hondarawala* series showed any symptoms of bunchy top disease. On July 15th a plentiful supply of aphids being found on a stool of definitely bunchy top plants growing at Peradeniya, the plants were first fumigated with a mild dose of calcium cyanide and then series I and III (with the exception of those two plants in series I which displayed positive disease symptoms) were re-infested with the aphids from the bunchy top plants. Unfortunately the fumigant was added while the pots and cages were in a wet condition and some of the leaves were scorched. Two plants in series III were scorched so severely that they were cut back to ground level. One of these (III.7) failed to recover from the treatment. The remaining plants recovered and the experiment proceeded satisfactorily. At this stage of the experiment it was found necessary to replace the cages which were showing signs of rotting. The replacement was carried out carefully, control plants first.

From the end of July the experiment began to give regular results until, at the beginning of September when the main experiment was concluded, all the infested *Hondarawala* plants were showing symptoms of bunchy top while seven out of eight of the infested *Kolikuttu* plants were positively infected, the remaining one plant being doubtful. (This plant subsequently developed typical bunchy top symptoms). The control plants remained healthy. This main experiment therefore demonstrated conclusively that bunchy top disease of plantains can be transmitted from diseased to healthy plants by the agency of the aphid *Pentalonia nigronervosa*.

Plate II.

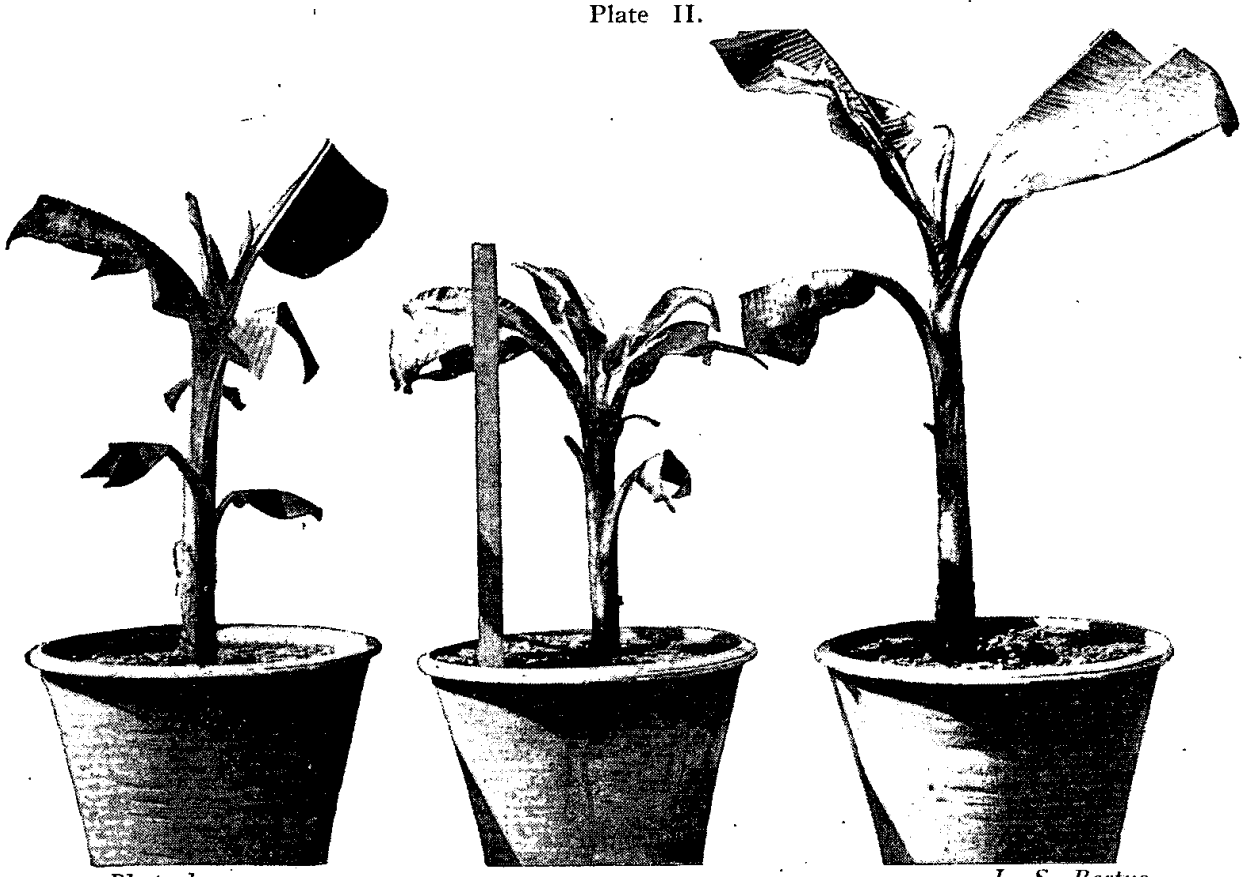

Photo by *L. S. Bertus.*

Hondarawala—Infected Plants.

Photo by *L. S. Bertus.*

Hondarawala—Control Plants.

Plate III.

Photo by *L. S. Bertus.*

Kolikuttu—Infected Plants.

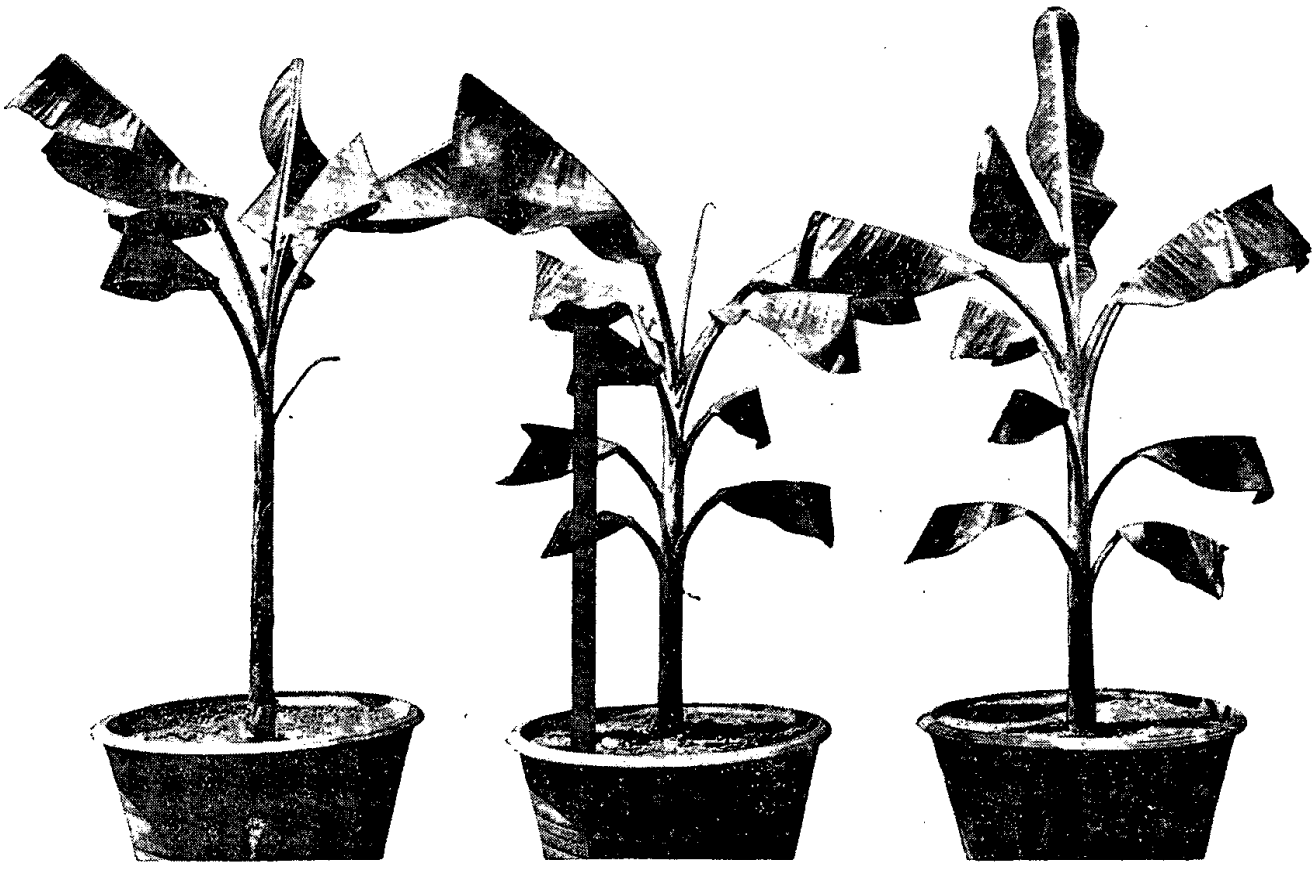

Photo by *L. S. Bertus.*

Kolikuttu—Control Plants.

Plates 2 and 3 give comparative photographs of infected and control plants. In plate 2 the lower plants were three of the *Hondarawala* control plants; the middle plant remained small throughout the experiment. The middle plant of the infected plants was one of the two plants which showed positive infection in June and which subsequent to that date remained small and stunted, with marked bunching of the leaves.

Plate 3 gives comparative photographs of the *Kolikuttu* series. The control plants (below) wilted temporarily on exposure to strong sunlight. Of the infected plants (above) the middle plant was a sucker thrown up after plant III. 5 had been cut back consequent on fumigation scorch. It will be seen that the leaves of the plants in both plates were cut back in order to avoid contact with cloth cages.

The relative lack of success of the first infestation of aphids rendered difficult the calculation of the incubation period, *i.e.*, the period which elapsed after the infestation of plants with infested aphids before disease symptoms appeared. The two plants (I. 5 and I. 6) which gave positive results from the first infestation did not show definite symptoms until two months after infestation. This period differed from that given by Magee (*loc. cit.*) who found that the incubation period varied from 23 to 29 days, with an average period of 25 days. A subsidiary experiment was therefore initiated to determine this point. Three each of the healthy control plants of the two varieties were infested on September 9th with aphids from the infected plants. The plants were not kept in cages but the control plants, three of the *Hondarawala* series and two of the *Kolikuttu* series remained healthy throughout the experiment. The results are given in table II.

Table II

Plant No.		Treatment	Date of appearance of first symptom	Incubation period
Hondarawala				
II	1	Infested	24-10-29	45 days
	5	Control	—	—
	6	Infested	7-11-29	59 days
	8	Control	—	—
	9	Infested	12-11-29	63 days
	10	Control	—	—
Kolikuttu				
IV	2	Infested	24-10-29	45 days
	4	do	15-10-29	36 days
	7	do	15-10-29	36 days
	8	Control	—	—
	9	do	—	—

The experiments described above were considered conclusively to support Magee's results although there were slight differences

of detail. The experiments had for their object also the determination of the extent, if any, to which root affection had a bearing on the problem. At the conclusion of the main experiment, *i.e.*, at the beginning of September the root systems of four of the *Hondarawala* infected plants (I. 2, I. 3, I. 5 and I. 6), of three of the *Hondarawala* control plants (II. 3, II. 4 and II. 7), of five of the *Kolikuttu* infested plants (III. 1, III. 2, III. 3, III. 4, and III. 7) and two of the *Kolikuttu* control plants (IV. 1 and IV. 3) were examined. The soil from the pots was put on to sheets of paper and the roots separated therefrom and washed, together with those cut from the base of the plants. The proportion of dead to healthy roots was very small and in no root were found either *Rhizoctonia bataticola* or eelworms. Plant III. 7, which was one of those that had made no growth at all, was found to consist of the empty skin of the corm the remainder having rotted away completely. In order to confirm the above observations a few of the roots of each plant were kept in damp chambers in order that, if *Rhizoctonia bataticola* were present, the sclerotia might develop. They were examined after three months with negative results.

During the earlier stages of the experiments a mottling of the leaves of all plants were observed. The areas of lamina between the veins became yellowish. It was thought that the unnatural conditions of growth, combined with the effects of fumigation might be responsible. Two of the control plants, one of each variety (plants II. 3 and IV. 5) were taken out of the cages and planted in the open on July 20th. Both these plants showed the mottling but leaves which developed subsequently were normal and healthy. The mottling was therefore attributed to the effect of the conditions under which the plants were grown.

DISCUSSION OF RESULTS

The experiments described in this paper have demonstrated clearly that bunchy top disease of plantains is a disease which can be transmitted from diseased to healthy plants by the aphid *Pentalonia nigronervosa*. Seeing that the aphid may be found on almost every plantain sucker at some stage in its existence it is to be assumed that the aphid itself is not the only agent concerned with the disease. Proof of this has not been sought in Ceylon but Magee (*loc. cit.*) showed that aphids when transferred from healthy plants to healthy plants did not cause the disease. This fact and the symptoms exhibited by the diseased plants place it in the class of virus diseases.

Two varieties of plantain were used for the experiments, *Hondarawala* and *Kolikuttu*. These were chosen as the former variety is reputed (without statistical evidence) to be relatively resistant and the latter relatively susceptible to the disease. The

results obtained, *i.e.*, 100 per cent infection in each variety, gave no indication of relative immunity or resistance. The small subsidiary experiment, in which three plants of each variety were used, indicated that there was a difference in the incubation period in the two varieties. The plants of the reputedly more susceptible variety, *Kolikuttu*, developed bunchy top symptoms 45 days, 36 days and 36 days respectively after infestation with infective aphids, the average being 39 days. The plants of the *Hondarawala* variety displayed bunchy top symptoms 45 days, 59 days and 63 days respectively after infestation, the average incubation period being $55\frac{2}{3}$ days. The number of plants being so small, these figures cannot be taken as conclusive but they indicate a difference between the two varieties which may have given rise to the impression of relative susceptibility and resistance. None of the figures for the period of incubation were as low as those obtained by Magee (*loc. cit.*) in Australia. He used Cavendish bananas for his experiments and obtained figures varying from 23 to 29 days with an average of 25 days for 20 plants. It would appear probable therefore that the incubation period may differ with different varieties and it is also possible that the conditions under which the plants are grown will have an effect on this period.

With regard to the association of root disease with bunchy top disease suggested by Small (*loc. cit.*), the absence of root decay in the roots of suckers examined prior to the experiments, the use of sterilized soil and the failure to find either *Rhizoctonia bataticola* or eelworms in the roots of the plants at the conclusion of the experiments may be considered to have eliminated the root factor from the experiments under review. It is concluded that, in Ceylon, bunchy top disease of plantains can be caused by a virus disease transmitted by infective aphids without the previous action of some root-destroying organism which might affect the vitality of the plant and render it more susceptible. It is still conceivable that in Ceylon there is a root disease which is characterised by symptoms similar to those displayed by bunchy top disease. It would be necessary to attack the problem from another angle, *i.e.*, to endeavour to reproduce symptoms through the agency of root parasites alone or of root parasites in conjunction with non-infective aphids, to determine if bunchy top symptoms can be caused by these factors also. Extensive experiments would be necessary before the question could be decided and it may be significant that *Rhizoctonia bataticola*, eelworms and aphids have all been found on healthy plants under natural conditions.

Fahmy [4] working in Egypt, described a disease very similar to, if not indistinguishable from, bunchy top disease which he attributed to eelworm infection of the roots. It would be

interesting, in view of our present knowledge, if a search for *Pentalonia nigronervosa* were made in Egypt and experiments set up to determine the possibility of the responsibility of a virus infection there also.

CONTROL

The systemic nature of bunchy top disease and our imperfect knowledge of the nature of virus diseases render impossible direct control measures, *i.e.*, prophylactic measures against the virus itself. Again, the aphid which has been shown to transmit the disease is difficult to control under field conditions; spraying is impracticable owing to the fact that the aphids usually occupy such positions between the closely adherent leaf-sheaths of the pseudostems that it is most difficult to bring insecticides into contact with them by spraying. In a well-cultivated garden in which bunchy top disease occurs only infrequently the proportion of infective to normal aphids must be extremely low and this furnishes another argument against attempts to control the disease by controlling the aphid. There remains therefore only indirect control which can be effected by exclusion and eradication. Plantain-growing districts in which the disease does not occur will be kept free from bunchy top only by complete exclusion of plantain material from infected areas. The effects of the disease in other districts in Ceylon should provide an object lesson sufficiently striking to plantain-growers in free areas, *e.g.*, Tissa, to prevent them from importing plantain material from other free areas except under special conditions.

In view of what has been stated above the treatment of areas in which bunchy top occurs must consist in eradication. This may be effected in two ways, either by the complete eradication of diseased and healthy plants in affected areas or by the removal and destruction of diseased plants only. The former method would appear to have theoretical advantages and has been attempted in Australia. In that country two districts were completely cleared of banana plants and so retained for a period of eighteen months after which they were replanted. The nearest banana-growing district was nine miles distant and in this district the disease was treated by periodical inspection and the removal of diseased plants. The two districts which had been completely cleared became re-infested, although only to a very slight extent, and it is to be assumed that the neighbouring district, although nine miles distant, was responsible for the re-infestation. These experiments point unmistakably to the fact that total eradication of the disease can only be attained by the complete clearing of all infected plantations and gardens within a large area. In Ceylon this would mean that all plantains in the Island, with the exception of plantains in districts such as Tissa in which the disease

does not occur, would have to be destroyed and replanting prohibited for a period of at least one year and probably longer. In a country in which the growing of plantains is so general as it is in Ceylon this policy would be practically impossible since the cost of enforcing eradication would be out of all proportion to the amount of money which would be saved as a result of eradication of the disease.

There remains therefore treatment by removal of diseased plants as they appear. This method has its disadvantages since the disease is present in plants for some time before outward symptoms are displayed. Nevertheless, if the disease is discovered in the early stages and prompt control measures are undertaken it should be possible to reduce the incidence of the disease to such an extent that the damage caused by it would be of little practical importance. The first essential for successful treatment by this method is the recognition of the early stages of the disease. For that reason the first symptoms as described by Magee have been quoted at some length in this paper. The streaking which is found in the leaves of plants in an early stage of infection is typical and once appreciated renders diagnosis relatively simple. It is necessary to examine only the youngest leaves of apparently healthy plants for the streaking and routine inspections are therefore not unduly laborious.

The nature of the disease is such that, if any one sucker of a stool is infected, the infective principle or virus may pass to all the other suckers or plants in that stool. It is therefore not sufficient to remove only the sucker which is obviously infected since the remaining component plants of the stool will serve as centres from which infection may be carried to neighbouring healthy stools. It is most important that, when a sucker is found to be infected, the whole of the stool be destroyed. It is false economy to leave parts of the stool in the hope that a bunch or bunches will be produced. In a certain small percentage of cases in which infected suckers have been cut out early enough, this may succeed. The risk of leaving infected portions is, however, so great that complete eradication of the whole stool containing infected suckers is the only safe form of treatment.

The disposal of diseased plants is best accomplished by cutting them up into small pieces and allowing them to dry, after which they may be burned or buried. The plantain stem and corm is soft and the most satisfactory method of cutting would appear to be into thin longitudinal slices which would dry rapidly. Once dried burial provides an adequate method of disposal.

If a strain of plantains immune to bunchy top disease could be found, the growth of immune plants only would solve the problem of control of the disease. Unfortunately no completely

immune strain has been discovered in Ceylon and the experiments detailed above indicate that apparently resistant strains may be completely susceptible. The period of incubation, *i.e.*, the period which elapses after infection before symptoms of the disease appear, may vary in different strains and, as has been suggested above, this may lead to apparent variations in susceptibility. It is reported that a strain of bananas highly resistant to the disease is grown in Fiji but published results of tests with that strain under controlled conditions have not been seen.

SUMMARY

1. A short review of bunchy top disease of plantains in Ceylon is given. Symptoms are described.

2. Experiments are described which were set up to determine whether bunchy top disease of plantains in Ceylon is similar to that in Australia, *i.e.*, a virus disease transmitted by aphids, and also to determine whether root disease is associated with bunchy top.

3. Two local varieties of plantains were used, *Hondarawala*, a variety considered to be somewhat resistant to bunchy top disease, and *Kolikuttu*, a very susceptible variety.

4. The experiments demonstrated conclusively that bunchy top disease is transmitted from diseased to healthy plants by the banana aphis, *Pentalonia nigronervosa*. Root examinations indicated that root disease was not necessarily a factor in the causation of the disease.

5. A subsidiary experiment indicated that apparent differences of susceptibility may be associated with variations in the length of the period between infection and the display of symptoms of the disease by plants of different varieties.

6. Methods of control are discussed. It is suggested that, for Ceylon conditions, the most satisfactory method of control is the periodical examination of plants and the complete eradication of the whole stools in which symptoms of the disease appear.

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