Wellman's Leaf and Fruit Spot of Arabica Coffee in New Guinea.

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ABSTRACT.

A leaf and fruit spot of Arabica coffee, variety 'Bourbon', in New Guinea is similar to Wellman's blister spot of coffee in Costa Rica, attributed to a virus, and to Bitancourt's oily spot in Brazil. The leaf symptoms appear distinct from those of ring spot of coffee in the Philippines.

In experiments, spots occurred on leaves produced on tips of affected bushes kept under protective insecticide cover, indicating the probable systemic nature of the condition. Spots occurred on the cotyledons of volunteer seedlings in the field at 5,000 ft. altitude but not on the subsequent leaves of such seedlings transplanted to the glasshouse at sea level. In other experiments at sea level, spots were only rarely observed on new leaves grown after transplanting of older affected seedlings and a mature bush or on the new leaves of cuttings taken from affected plants. Nor were spots seen on leaves grown on healthy scions grafted onto affected bushes in the Highlands, except for four spots on three leaves of two grafts.

The condition was not transmitted through 477 seeds from affected bushes, the seedlings having been kept under observation for from 18 to 24 months.

In five areas totalling 629 trees with five per cent. of trees initially affected, only two additional trees (0.3 per cent. of the total) were observed to become newly infected during observation for one year.

No particles which could be ascribed to a virus were observed in preparations of sap extracts examined in the electron microscope.

As at least three common names are being used for conditions with similar symptoms in America, in New Guinea the condition is being designated as 'Wellman's leaf and fruit spot'.

INTRODUCTION.

In 1962, specimens were first received of a leaf spot of Bourbon coffee from the Eastern Highlands of New Guinea and later investigations showed that fruit from these trees was also affected.

The condition resembles blister spot of Arabica coffee described by Wellman (1957) in Costa Rica [1] and attributed to a virus which was not seed-borne but which was mechanically transmitted by the aphid *Toxoptera aurantiae* Koch, symptoms appearing in from two months and nine days up to fourteen months, and by grafting, the first symptoms appearing in two and a half months. The variety of coffee affected was not designated but Wellman (personal communication) stated that it was 'var. *typica*'. Rate of spread was up to 15 per cent. in one year.

Bitancourt (1958) recorded that he first observed a similar disease on coffee leaves and fruit in Brazil in 1938, and called it oily or greasy spot. Experiments on transmission carried out in Sao Paulo were negative. After two years the disease had not spread from the trees where it had been found towards neighbouring trees, which indicated very slow dissemination. The damage did not seem of sufficient importance to warrant further investigation into the disease. No further experimental work was reported in a recent review of coffee

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[1] In October, 1965, the author examined two bronze-tipped plants with blister spot at Turrialba in Costa Rica. The symptoms were identical with those under study on green tipped Bourbon in New Guinea. A few days later the author inspected many bronze-tipped spotted coffee bushes near San Jose with Dr. Luis C. Gonzales, the symptoms again being identical with those of the New Guinea condition.

diseases in Brazil (Silberschmidt and Bitancourt 1965).

The leaf symptoms of the blister or oily spot disease as described by Wellman and Bitancourt, and as seen in New Guinea (see description *below), appear to the author to be distinct from* those of the ring spot of coffee described by Bitancourt (1939) in Brazil (the transmissibility of which was proved by grafting by Silberschmidt (1941)), and by Reyes (1959, 1961) in the Philippines, where it was recorded affecting Arabica, Excelsa, Robusta and Liberica leaves and fruit, and stems of Excelsa. Reyes, however, considered ring spot to be identical with Wellman's blister spot disease, an opinion not supported by Valdez (1966).

Studies on the New Guinea conditions are reported below.

HOST.

The condition was found on Bourbon coffee in the Asaro Valley in the Eastern Highlands of New Guinea at an altitude of approximately 5,000 ft. and 260 miles from Port Moresby.

Coffee plantations in the Highlands grow only *Coffea arabica* L., consisting nearly exclusively of mixed stands of *C. arabica* var. *arabica* (syn. var. *typica* Cramer), locally called Typica coffee, and of *C. arabica* var. *bourbon* (B. Rodr.) Choussy., locally called Bourbon coffee ; in some cases the former predominates, and in others the latter. A little 'Maragogipe' coffee (sometimes given as *C. arabica* var. *maragogipe* Hort.) is also grown. The condition is confined to Bourbon coffee, even in those plantations where Bourbon and Typica are both growing, sometimes with intermingled branches [1]. Affected bushes are irregularly scattered throughout the plantations although adjacent bushes are occasionally affected.

SYMPTOMS AND MICROSCOPIC EXAMINATION OF LESIONS.

Leaves.

The leaf spots occur mainly on the upper surfaces of the leaves, only occasionally being evident on the under surfaces. They are circular, up to four mm. in diameter, either the same colour or slightly paler green than the unaffected tissue, and if few in number are inconspicuous. To the naked eye they usually have a dull rather *than a shiny appearance ; the surface itself* appears almost imperceptibly depressed, often with a faint stippling discernible only by moving the lesion under a strong light. Some lesions have a light brown spot the size of a pin prick in the centre. If the leaf is held against the light, the lesions are evident as translucent spots (compare *Plate* I, A and B, showing the same leaf by reflected and by transmitted light).

Apart from the tiny area of dead cells in the centre of some spots only, the tissue of the spots does not become necrotic. In fact, on aged yellow leaves the lesions are usually striking as green spots on the yellow tissue (*Plate* II). On faded leaves found beneath affected bushes the lesions stand out as distinct reddish-brown spots on the dead tissue. The surface of the spot is not convex as in the young leaves described by Wellman, but occasionally heavily affected young leaves have a slightly puckered appearance.

In some cases only a few spots occur per leaf, while in others they cover most of the lamina (*Plates* I and II). In the cases examined the young leaves just expanding were usually free from spots while the first expanded leaves were often spotted. Sometimes leaves without spots were found on the same branch as leaves with spots while occasionally whole branches without affected leaves were found on affected bushes.

The spots were also found on the cotyledons of some volunteer seedlings even before the appearance of true leaves. At that stage the plants would not have been more than six weeks old.[2]

In *Plate* III, a young seedling is shown with about 64 spots on the cotyledons, many being confluent. On other seedlings collected at the same time with spots on the cotyledons, the first true leaves had formed but were unspotted. The behaviour of such seedlings when removed from the field to the greenhouse is discussed later.

[1] In July, 1966, five spots were found on three leaves (which were removed for examination) on a well-grown bronze-tipped bush, presumably Typica, on one of the plantations, although no Bourbon with symptoms occurred in the immediate vicinity. Re-inspection of the plant and about 200 immediately adjacent coffee bushes eight months later did not reveal any spotted leaves.

[2] Estimated after comparison of growth records obtained by Mr. R. S. Carne, Agronomist-in-Charge, Highlands Agricultural Experiment Station, at the request of the author for the age of seedlings before the appearance of the first true leaves.

Plate I.—A. Leaf of Bourbon coffee with leaf spots, viewed by reflected light. B. Same leaf viewed by transmitted light.

Microscopically the affected tissue is very difficult to distinguish from the unaffected. The cells appear indistinguishable in shape, malformation of pallisade and spongy parenchyma tissue not being detected in sections. However, from the appearance of the spots, which remain green as the leaves yellow with age, it seems as if the main effect is in the chloroplasts, as stated by Wellman, as the spots usually retain their chlorophyll longer than normal leaf tissue. That a change of some magnitude has occurred is evident from the persistence of the spots, even on faded brown leaves.

No hyphae or bacteria were detected in sections or teasings of the leaf spots. Miscellaneous fungal spores were sometimes found on the leaf surfaces, but on unaffected as well as affected tissues.

Stems, Flowering and Fruit Setting.

No lesions have been noted on stems. The length of the internodes and the number of flowers and fruit set appeared to be about normal, whereas Wellman reported that in Costa Rica there was some dwarfing of growth and shortening of internodes, with a reduced number of flowers which set very few fruit. Blackening and early abscission of many of the fruit means that heavily affected bushes in New Guinea are often left with branches with few or no fruit at a time when the unaffected bushes are still carrying their full maturing crop.

Fruit.

Lesions on the fruit are similar to those described and illustrated by Wellman. The New Guinea spots are round, up to two mm. in diameter, light brown in colour and definitely

concave. *Plates* IV and V show fruit with various degrees of spotting, and seeds from slightly and severely affected fruit.

All the fruit on an affected branch does not always become spotted, especially on bushes with only a few spots on the leaves (such bushes presumably being fairly recently infected), but most cherries carry from one to about fourteen spots, the spots not being confined to one side although occasionally a preponderence does occur on the upper surface. A dark brown rot sets in on most fruit, often around a depressed spot, sometimes two or more rotted areas occurring on the same fruit and not necessarily towards the terminal half of the branches, as mentioned by Wellman. As

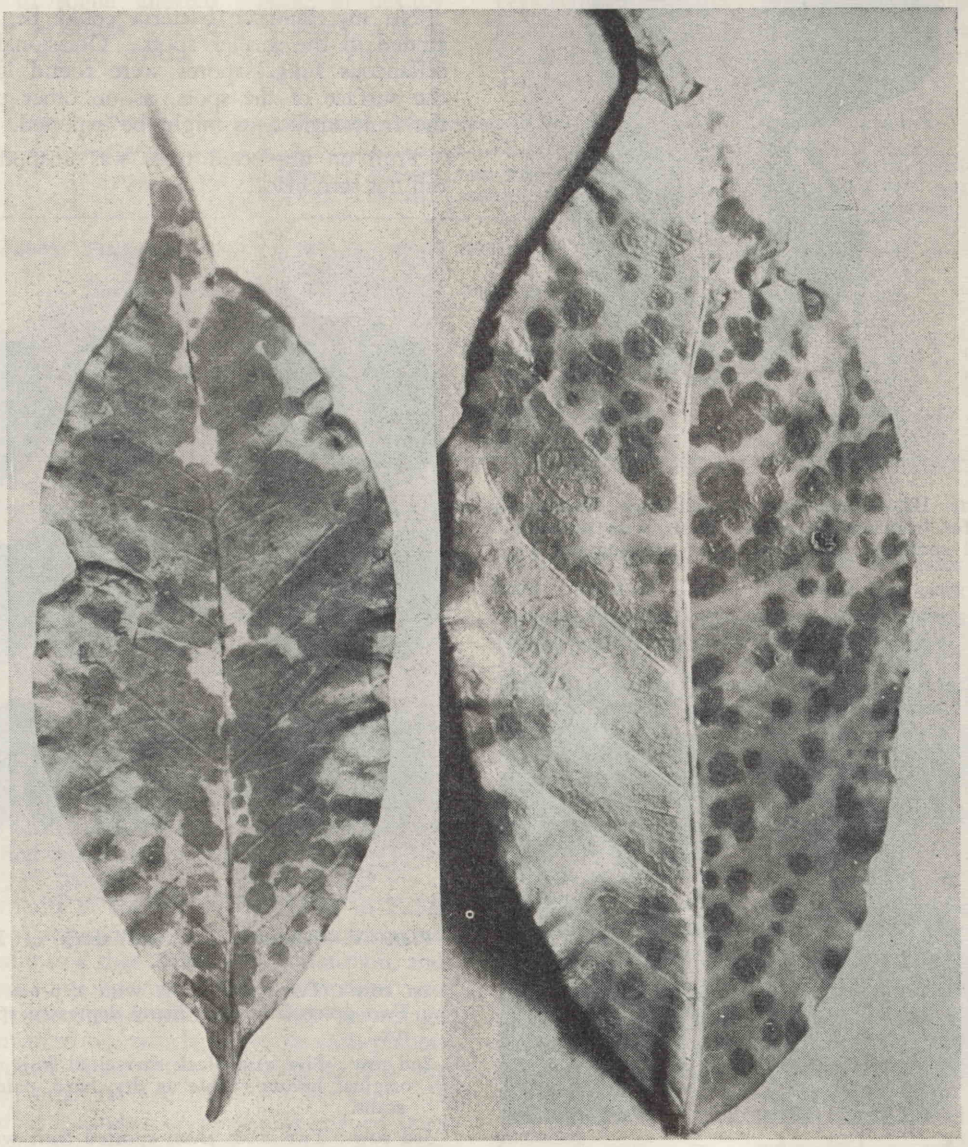

Plate II.—Faded (yellow) leaves of Bourbon coffee with the spots showing as distinct green areas.

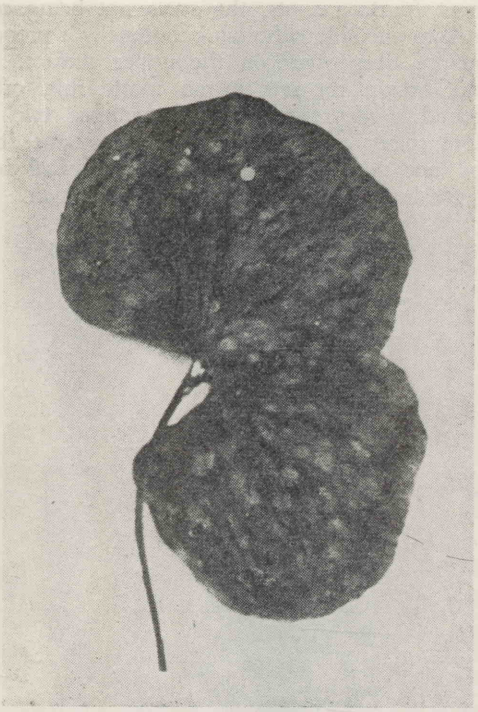

Plate III.—Cotyledons of self-sown Bourbon coffee from around affected bush, with separate and confluent leaf spots, after pressing for 24 hours.

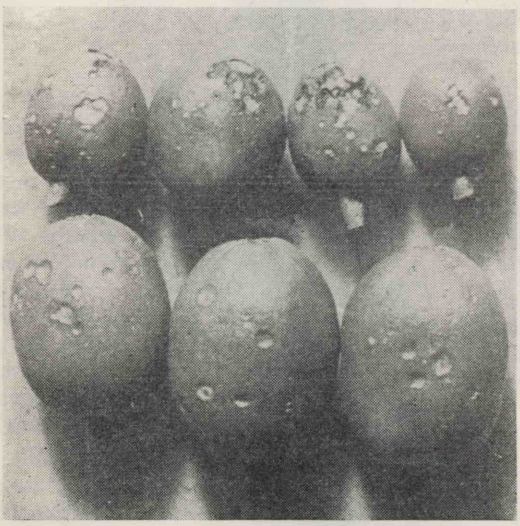

Plate IV.—Fruit of Bourbon coffee with depressed spots.

the fruit blackens and shrinks, the small depressed spot sometimes takes on the appearance of a small light-brown-coloured scab.

Sections through the depressed spots show a collapse of the tissue to a depth of about six to eight rows of cells, the area being most prominent when the fruit is red as the collapsed cells are without pigment.

No mycelium or bacteria could be demonstrated in the smaller spots. Occasionally miscellaneous fungal spores were found lying on the surface of the spots, as on other parts of the fruit surface, as might be expected.

Fruit on unaffected trees was unspotted and did not turn black.

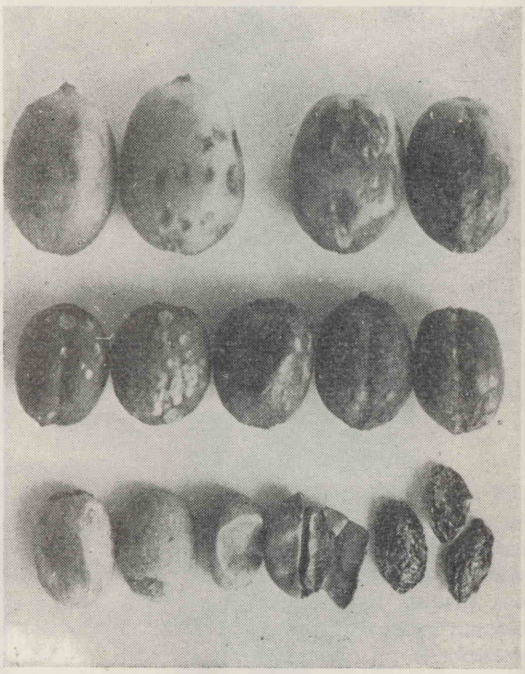

Plate V.—Affected fruit and seeds of Bourbon coffee.

1st row : Two green fruit with depressed spots. Two green fruit with many depressed spots and rot.

2nd row : Five hard black shrivelled fruit with the original lesions visible as dry, hard, pale brown scabs.

3rd row : Two seeds from spotted fruit with very little shrivelling. Two shrivelled seeds. Three very shrivelled seeds with testae removed.

INCIDENCE.

The disease to date has only been found in the Asaro Valley of the Eastern Highlands.

The incidence of the disease on affected plantations as noted in checks carried out at intervals since the condition was first reported has not been high. Growers have been continually advised to rogue affected bushes, to destroy volunteer seedlings with spotted leaves, and to carry out regular checks in order to eliminate possible sources of inoculum. This was done sporadically on some plantations and apparently not at all on others. It was estimated by officers that probably not more than 700 bushes were rogued prior to September, 1967.

In a survey carried out by agricultural officers (Mr. J. J. Nitsche and Mr. W. G. Cowie and assistants) in late 1967, each tree on seven out of the eight known affected plantations was checked and affected trees rogued ; a partial check was carried out on the eighth.

The results of the survey are shown in *Table* 1. Out of approximately 292,000 trees inspected it was estimated that 200,000 were Bourbon, and of these 680 trees were showing symptoms ; no Arabica was found affected. The percentage Bourbon infection, which varied on each plantation, ranged from 0.03 per cent, to 1.2 per cent., the total average being 0.3 per cent. If the estimated number of previously rogued trees is included, the estimated total average infection is 0.7 per cent.

The results of a survey of some smallholdings in the same valley are also shown in *Tables* 1 and 2. Infected coffee was found at 159 out of 931 sites inspected, involving an estimated 399,700 total trees of which the estimated number of Bourbon was 220,600. Of these 1,984 were found affected, giving an average infection of 0.5 per cent. of total trees and 0.9 per cent. of Bourbon (*Table* 1) with the greatest number of infections ranging between 1.1 and 5.0 per cent. (*Table* 2). Special checks carried out by the officers at the few sites with high infections failed to reveal any reason to account for the occurrence. No Arabica was found with symptoms during the survey.

Table 1.—Number of trees inspected and percentage infection in three coffee growing areas.

Area.	Property.	Number inspected.	Number infected.	Total trees inspected.*	Estimated number of Bourbon.	No. of infected Bourbon.	Infected Bourbon. Percentage.	Infected Arabica. Percentage.
Asaro Valley	Plantation	8	8	292,000	200,000	680 (est. 1,380) †	0.3 (0.7) †	0
	Smallholdings	931	159	399,700	220,600	1,984	0.9	0
Kainantu Subdistrict	Plantation and Station	8	0	149,750	24,000	0	0	0
	Smallholdings	4	0	500	200	0	0	0
Wahgi Valley	Plantations	10	0	49,680	16,800	0	0	0
	Smallholdings	172	0	76,200	33,650	0	0	0

* Round figures.

† Including number of trees said to have been rogued previously.

Table 2.—Classes of estimated percentage infection in smallholders' Bourbon coffee in the Asaro Valley.

Percentage of infected Bourbon * in the following classes.	No. of small holdings.
0.1-0.5	32
0.6-1.0	26
1.1-5.0	73
5.1-10.0	13
10.1-15.0	4
15.1-20.0	4
20.1-25.0	1
25.1-30.0	1
35.1-40.0	1
50.1-55.0	1
55.1-60.0	1
75.1-80.0	1
90.1-95.0	1

* Percentage infection of total trees not shown.

Spot checks by the same officers were made at ten plantations and stations and at 172 smallholdings in the Wahgi Valley, as shown in *Table* 1. Of the estimated 126,000 trees inspected, of which 50,500 were estimated to be Bourbon, none was found with symptoms.

In spot checks by Mr. R. S. Carne and assistants of eight plantations and stations and four smallholdings in the Kainantu Subdistrict of the Eastern Highlands, involving approximately 150,250 trees of which an estimated 24,200 were Bourbon, none was found infected (*Table* 1).

No special surveys have been carried out on coffee in the other parts of the Territory, but no specimens or reports of the disease have been received from growers or agricultural officers in these areas.

The incidence of the disease in New Guinea, therefore, has to date been much lower than that reported by Wellman (1957) in Costa Rica, or noted by the author during a visit to Costa Rica in 1965.

As a result of the surveys carried out and the publicity given to the disease in New Guinea especially in the last few years, it is hoped that the recommended control measures—roguing of infected bushes followed by regular inspections—will now be vigorously carried out by growers in the Asaro Valley. Growers elsewhere are urged to keep their crop under close observation and report any symptoms if these are detected.

SPREAD OF THE CONDITION.

While many coffee plantings in the Asaro Valley were started from seed, many others were started from seedlings raised in thousands at several plantations and at other centres. As seedlings up to one foot high have been found with leaf symptoms in nurseries, it is considered that distribution of such seedlings may have acccounted in some measure for the occurrence of the disease throughout the Asaro Valley.

In order to check rate of spread at an infected site four areas chosen at random consisting of 79, 103, 125 and 262 trees (totalling 569 trees, in a block of several thousand Bourbon [1]) were scored and kept under observation for one year in 1966-1967 during which three inspections were carried out. Twenty-nine of the 569 trees (5 per cent.) were affected at the begining of the period and thirty at the last inspection, the newly affected tree (an increase of 0.2 per cent.) having very few spots on some leaves of a few branches only. A further 60 trees were kept under observation for nine months. These originally included one affected tree (1.6 per cent.) but another was found with very few spots on a few leaves of a few branches at the end of the period, giving an increase of 1.6 per cent. If these two bushes had been even more lightly affected at previous inspections, the spots may have been overlooked, since the trees were up to ten feet high and about twenty feet in circumference, so that inspection of every leaf was impossible. A few affected trees were adjacent to one another, but on the whole distribution was non-aggregated (*Figure* 1).

[1] This block, which, except for a few Typica, consisted entirely of Bourbon, had the highest percentage infection known to the author at the time; infected trees were very irregularly distributed throughout the block.

Wellman (1957) found that in a large field in Costa Rica with 49 (10 per cent.) of the 497 trees affected with blister spot, 76 (15 per cent.), 42 (8 per cent.) and 52 (10 per cent.) of the trees were *newly* affected in the three following years, at the end of which period 42 per cent. of the total trees were affected, although ten had apparently recovered.

Bitancourt (1958), however, reported that in Brazil the 'oily' spot disease had not spread after two years from the trees where it had been found towards neighbouring trees.

No recovery of marked trees was apparent for the observation period in New Guinea. The apparent rate of spread was markedly less than that reported by Wellman in Costa Rica, being approximately only 0.3 per cent. for the year in the area under study.

ISOLATIONS.

Isolations were attempted from both diseased leaves and young spots on the fruit, as well as from blackened berries after surface sterilization. Only occasional fungi (particularly *Gloeosporium* sp.) were obtained from the leaf and cherry spots, although various saprophytes were isolated from the blackened cherries. Bacteria obtained from unsterilized leaf tissue did not produce

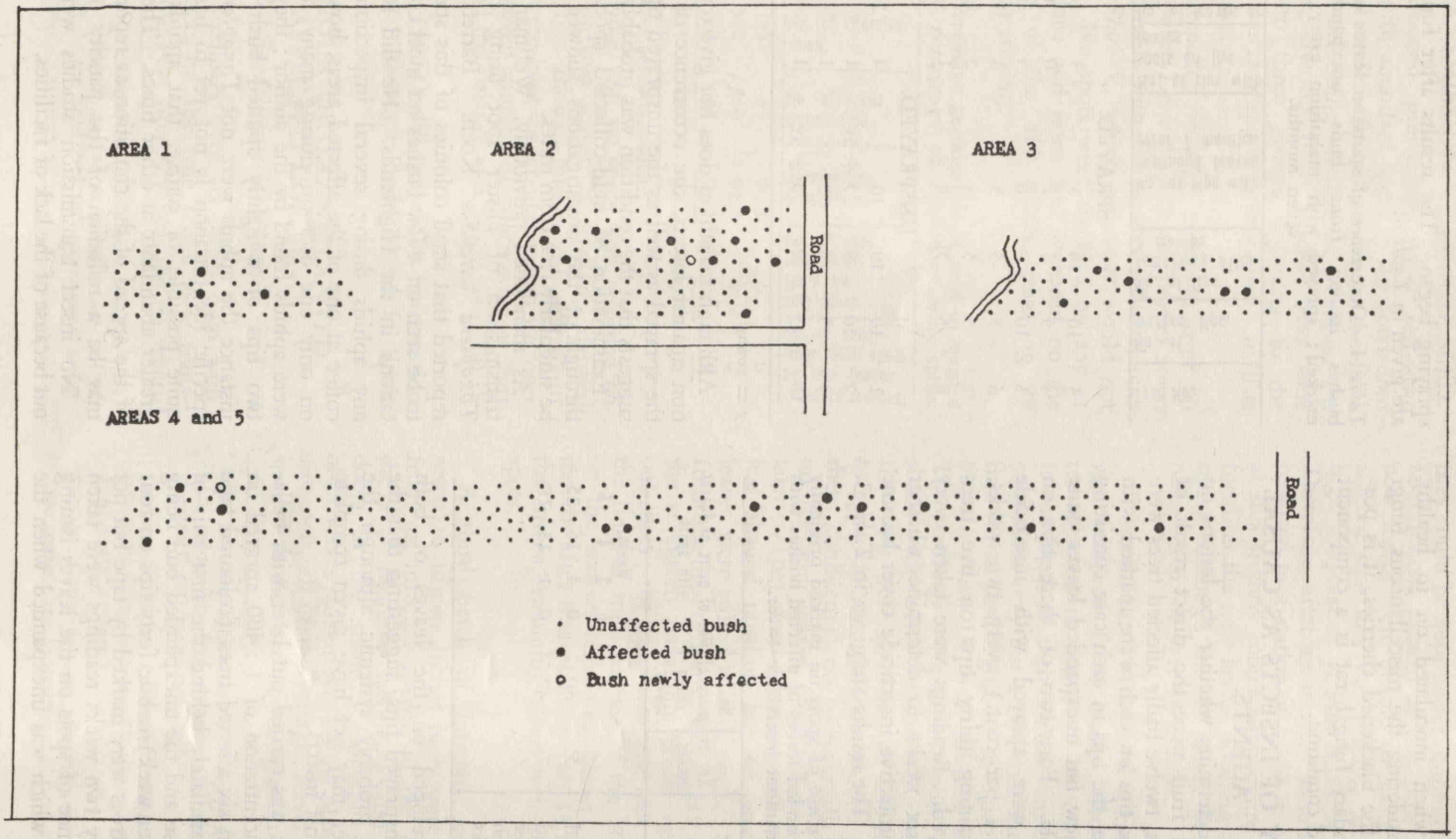

Figure 1.—Distribution of affected and newly affected bushes in five area s of the one block in approximately one year; all plants Bourbon except four Typica in Area 2.

the condition when inoculated on to healthy seedlings. Considering the miscellaneous fungi obtained from the blackened cherries, it is possible that secondary fungal rot is a component of the blackened condition.

POSSIBILITY OF INSECTS AS CAUSAL AGENTS.

In order to determine whether the lesions on the leaves and fruit were the direct result of insect punctures, twelve badly affected trees were selected and six tips on each were marked with identifying tape, the tips in each case consisting of a pair of new but unexpanded leaves quite free from spots. Forty-two of these tips on seven bushes were sprayed with insecticide (dieldrin at 0.4 per cent.) every two weeks, while the remaining thirty tips on five trees were not sprayed. Readings were taken every fortnight for six weeks to determine whether the tips with protective insecticide cover became spotted or not. The results are given in *Table* 3.

Table 3.—Occurrence of spots on marked originally unspotted, unexpanded leaves of affected bushes with and without insecticide cover.

—	No. of bushes.	No. of pairs of young leaves.	No. of pairs of leaves with spots			
			Weeks.			
			0	2	4	6
Tips not sprayed	5	30	0	4	16	25
Tips sprayed with 0.4 per cent. dieldrin every 2 weeks	7	42	0	1	13	18

Lesions developed on the leaves of both sprayed and unsprayed tips, suggesting that the condition was probably systemic although the insecticide cover may not have given complete protection against insects.

Another test was carried out later with malathion at a concentration of 1 : 400 sprayed on to forty tips on six affected trees (coloured tape being tied immediately behind the first pair of leaves and these and the unexpanded bud being sprayed once per week), while forty tips on four other affected trees were marked by tape but not sprayed. Every two weeks readings were taken on the occurrence of spots on the leaves issuing from the bud which was unexpanded when the spraying began. The results after four months are given in *Table* 4.

Table 4.—Occurrence of spots on leaves on affected bushes issuing from buds unexpanded when marked; sprayed with malathion every week for seven months.

Tree No.	No. of marked tips.	No. of tips remaining after 7 months.	No. of tips with expanded leaves after 7 months.	No. of tips with spots on the leaves.	No. of leaves on affected tips.	No. of leaves with spots.
SPRAYED.						
3	10	10	5	3	16	6
4	5	3	2	0	0	0
5	10	9	6	4	18	9
6	5	5	5	3	12	6
7	5	5	4	2	12	5
8	5	5	4	1	6	2
UNSPRAYED.						
1	10	10	10	4	24	12
2	10	9	5 + 3y	1	4	2
9	5	4	2	1	5	1
10	15	12	5 + 4y	1	4	1

y = young

Although malathion does not give total protection against insects, the occurrence of spots on the sprayed as well as the unsprayed tips further suggests that the condition was probably systemic.

Examination of field-collected spotted leaves throughout the investigations showed them to be singularly free from mites.

As mentioned previously, Wellman obtained transmission of blister spot using the aphid *Toxoptera aurantiae* Koch. Barrett (1966) reported that small colonies of this species were to be seen on a few bushes on most coffee plantations in the Highlands. He did not record any aphids during several inspections of the coffee at one of the affected areas, however, and on only one occasion during many inspections were aphids found by the author; they were on two tips of a lightly spotted bush. In this instance the aphids were not *Toxoptera* but the specific identification is not yet to hand. It is quite possible, of course, that aphids occur in greater abundance at other times. The slowness of the spread of the condition as reported above may be a reflection of the paucity of vectors.

No insect transmission studies were carried out because of the lack of facilities.

NON-TRANSMISSION THROUGH SEED.

As mentioned previously, many self-sown seedlings with abundant spots on the cotyledons were found under affected bushes in the field. In order to determine whether the condition was seed borne, cherries from affected trees were divided into three groups according to the amount of surface spotting and sown [1] in flats at Port Moresby.

The germination in each class was over 90 per cent. (refer *Table* 5) but no cherries sown were comparable with the severely affected ones shown in *Plate* V, which obviously would not germinate. No spots were recorded on any of the cotyledons and none had appeared on the true leaves of the 410 plants remaining 29 months after sowing.

Table 5.—Percentage germination of seed in spotted cherries and percentage of cotyledons with spots.

Amount of spotting on cherries.	No. of cherries sown.	No. of seeds germinated.	Germination percentage.	No. of seedlings with spots on cotyledons.	No. of seedlings with spots on true leaves after 18 months.
Slight	35	33	94.3	0	0
Medium	340	310	91.2	0	0
Severe *	70	67	95.7	0	0
	445	410	92.1	0	0

* But shrivelled seeds excluded.

In a previous test, no spots were recorded on cotyledons or true leaves of seedlings derived from seed from affected bushes, although 67 of the plants were kept under observation for over two years, seven months of which were at Port Moresby and the balance at a Station at 1,700 ft. altitude.

Wellman (1957) did not obtain transmission of blister spot through Arabica seed in Costa Rica.

BEHAVIOUR OF TRANSPLANTED AFFECTED COFFEE.

Transplanted Seedlings with Spots.

Affected seedlings over six inches high with abundant spots on the true leaves were transplanted to the Port Moresby laboratories, where they could be kept under continuous observation. Leaf lesions present at that time remained, but new leaves were devoid of spots. It was considered that this was possibly an effect of the high temperature at Port Moresby [2] at sea level. Therefore, after six months these seedlings were removed to a station at 1,700 ft. altitude. Even at this slightly cooler temperature spots did not form on the new leaves, totalling 403 at the last count, although the 59 plants were kept under observation for over 34 months.

A second batch of affected volunteer seedlings was removed from under affected trees and transplanted to the Port Moresby greenhouse. It consisted of eighteen seedlings, mainly with cotyledons only but a few with the first pairs of true leaves just beginning to expand. The seedling in *Plate* III was included in this group. The seedlings were kept in pots, mainly in the shade with only a little morning sun. Although the spots were abundant on the cotyledons (up to approximately 64 spots on one pair, many of them confluent), no spots at all had appeared on the true leaves (totalling 41) two months later. They were then moved into a slightly less shaded position but six weeks later true leaves were still devoid of spots. Seven months from the time of transplanting 219 true leaves on the seventeen remaining plants were still without spots ; the same was true nine months from the time of transplanting of the 260 true leaves on the sixteen remaining plants ; and fourteen months after transplanting the 353 true leaves on the fifteen remaining plants were still devoid of spots.

A third batch of infected seedlings from seven to fifteen inches high were transplanted from an infected garden in the Highlands to the Port Moresby laboratory and kept out of doors in the shade. Although some of the older leaves still present on the plants were without spots, all of the younger leaves were heavily spotted at the time of transplanting.

[1] The cherries (with seed enclosed) were sown *in toto*, in order to simulate as far as possible the fall of affected fruit in the field and the germination under affected trees.

[2] Port Moresby (Jackson's Airstrip), mean maximum and minimum temperatures : 88 degrees and 73 degrees F (20 years' average).

Goroka, 5,200 ft. (Airstrip), mean maximum and minimum temperatures : 78 degees and 57 degrees F (7 years' average)

Station, 1,700 ft.—no temperature records, but a little cooler than Moresby.

Four months later 66 fully expanded or new leaves had been produced on 13 plants, one plant having died. Small and not very definite spots were present on six leaves [1] of four of the plants ; all of the other new leaves were unspotted (*Plate* VI). At that stage three of the plants, including two of those with faint spots on the leaves, were placed in an air conditioned laboratory whose temperature range was 65 to 73 degrees F compared with the outside temperature range of 72 to 94 degrees F. The plants, however, were placed outside the laboratory in the same environment as the remaining plants, for eight hours each day on five days of each week. This arrangement subjected the plants to a temperature range which was the nearest which could be obtained to the range operating in the field in the Highlands.

The plants were again examined three months later. The small faint spots were still present on the same few leaves as noted previously, but no other spots occurred on the other new leaves which totalled 126.

In another instance one lightly infected coffee tree in the Highlands with a trunk diameter of two and one half inches at ground level was cut back to fifteen inches above ground level and transplanted into soil outside the Port Moresby laboratory. Seven months later 336 new leaves had been produced but none was spotted.

All the transplanted seedlings and the tree reported above were transferred in a quantity of the soil in which they had been growing.

Cuttings from Affected Bushes.

Cuttings from affected bushes were established in the Highlands and five months later were transferred to Port Moresby. Four months later faint spots were found on a few leaves of three of the twenty-five surviving plants. As it was thought that the high temperatures at Port Moresby may have been responsible for suppression of symptoms, the plants were removed to the Station at 1,700 ft. Fourteen months later, however, no symptoms were found on any of the 163 leaves then present on these plants, nor had any spots appeared 30 months after removal to this altitude.

[1] Affected new leaves were the second pairs expanded after transplanting.

Transplanted Healthy Seedlings.

Healthy seedlings transplanted from the Highlands to Port Moresby kept within feet of the diseased seedlings and cuttings mentioned above remained free from spots until discarded 34 months later.

GRAFTING EXPERIMENTS.

Investigations were hampered by the lack of suitable facilities such as an insect-proof house in the Highlands at about 5,000 ft., the difficulty of transporting material for grafting to the laboratories at Port Moresby 260 miles away, and, when transplants and seedlings were established at Port Moresby, the high temperature conditions on the coast.

The graftings and buddings first attempted at Port Moresby with material flown from the Highlands failed to survive. Another set of grafts was made in the plantation by agricultural officers, but the majority of the grafts failed or were broken off by labourers during harvesting and maintenance operations. On the three grafts which remained seven months later (two scions from diseased trees onto healthy stocks and one healthy onto diseased stock), no transmission of symptoms occurred.

As the plantations were roguing affected trees, it was decided to try to establish grafts and buddings at Port Moresby so that the material could be kept under closer observation, although it was realized that the change in temperature would adversely affect the host and possibly mask the symptoms.

Affected seedlings and cuttings which had been established at Goroka from affected bushes, as well as healthy seedlings were transferred to Port Moresby and then to the nearby Station at 1,700 ft., where a third set of grafts was attempted by Mr. A. van Haaren. They consisted of healthy scions grafted onto the following stocks :—

Ten of the transplanted seedlings which had previously had abundant spots on the true leaves, although no spots had appeared on the new leaves since the transfer to Port Moresby ; and

Three of the cuttings established from branches carrying the condition, being the only ones which had produced a few affected leaves.

These grafts were kept under close observation but no spots appeared on the scion leaves,

Plate VI.—A. Seedling with two old spotted leaves (os) visible and six unspotted leaves, the latter having been produced after transplanting from an altitude of 5,000 ft. to sea level.
B. Seedling with four old spotted leaves (os) visible and four unspotted leaves, the latter having been produced after transplanting from an altitude of 5,000 feet to sea level.

of which there were 86 five months after grafting. Further checks at eight and thirteen months were still negative.

By that time very few of the plantations were roguing regularly, so a fourth series of grafts was carried out by Mr. A. van Haaren in a section of an affected Highland plantation that could be kept under close surveillance. The grafts were examined every two weeks by the local agricultural officer, Mr. R. N. Amos, who reported on the successful ' takes ', the emergence of new leaves and fruit, and the occurrence of symptoms. From time to time the author checked the results in the field.

The details of this series are as follows :—

Forty-five healthy Bourbon scions from an unaffected plantation were grafted onto eight affected trees using a single node wedge or cleft graft, 26 being plagiotropic and 19 orthotropic.

Twenty-two healthy Bourbon scions from an unaffected plantation were grafted on to six presumably healthly Bourbon bushes on the affected plantation, 17 grafts being plagiotropic and five orthotropic.

Very wet weather occurred immediately after the grafts were made, but after two months 16 grafts were still alive ; after three months one of the 13 surviving scions had one new pair of leaves. At this stage fortnightly spraying began with 0.4 per cent dieldrin and was continued for the next twelve months in order to provide some protection against insects, including possible vectors, so that if lesions did appear on the scions there would be a good chance that it was the result of transmission through the graft and not the result of any subsequent factor. Readings were as follows :—

After six months eight grafts remained, all except one having leaves, and two were bearing fruit ;

After seven months two spots were found on one leaf on Tree M, and the leaf was removed ;

After nine months one spot was found on each of two leaves of Tree J and the leaves were removed ; and

After 13 months—

(i) three healthy scions on affected stocks remained, with 110 scions leaves altogether, all being quite free from spots ; and

(ii) two healthy scions on healthy stocks remained, with eight scion leaves and one cherry, all being quite free from spots.

After 15 months, all the remaining 127 scion leaves were still free from spots.

A summary of the results of the transplantings and graftings is given in *Table* 6.

ELECTRON MICROSCOPE CHECK FOR VIRUS PARTICLES.

In March 1967, Dr. Adrian Gibbs of the Australian National University, Canberra, kindly examined in the electron microscope sap extracts from the sources listed below. In Port Moresby the material was mounted on grids and negatively stained with potassium phosphotungstate using the methods described by Hitchborn and Hills (1965), the grids being forwarded to Canberra.

The sap extract sources were as follows :—

Unaffected coffee.

Strips of tissue from the underside of Bourbon leaves and from cotyledons and fruit.

Affected coffee

Strips of tissue from the underside of a spot on a Bourbon leaf (samples from two plantations).

Strips of tissue from the underside of a spot on a Bourbon cotyledon (samples from two plantations).

Strips of tissue from a spotted Bourbon fruit (samples from two plantations).

Gibbs (personal communication) found no virus-like particles in the preparations, although extracts of *Crotalaria anagyroides* leaves showing mosaic symptoms, mounted in the same way and at the same time, contained filamentous virus-like particles. In Dr. Gibbs' opinion these results suggest that there was little likelihood of a virus with elongated particles being present in the affected coffee trees. A virus with isometric particles whose concentration was lower than 10^{11} or so per millilitre might have been present, however, because small isometric virus particles are not easily distinguished from round plant sap constituents in the electron microscope, unless they are abundant.

DISCUSSION.

The leaf and fruit spot of Bourbon coffee in New Guinea is dissimilar to ring spot described

Table 6.—Summary of results after transplanting and grafting affected Bourbon coffee.

Treatment.	Location.	No. surviving.	Period of observation (months).	Results.
Grafts—				
Grafts and buddings on potted seedlings	Port Moresby	None	—	—
Grafts on to plantation bushes	Goroka	3	7	No spots on leaves.
Grafts on to transplanted seedlings	Station at 1,700 ft.	10	5	No spots on 86 leaves.
Grafts on to transplanted cuttings	Station at 1,700 ft.	3	5	
Grafts on to plantation bushes	Goroka	8	7	Two spots on 1 leaf.*†
		8	9	Two spots on 2 leaves.*†
		5	13	No spots on 110 leaves.
		5	15	No spots on 127 leaves.
Transplants—				
Affected seedlings over 6 in. high	Goroka to Port Moresby to Station at 1,700 ft.	59	34	No spots on 403 leaves.
Affected seedlings mainly with spotted cotyledons only	Goroka to Port Moresby	18	2	No spots on 41 leaves.
		17	7	No spots on 219 leaves.
		16	9	No spots on 260 leaves.
		15	14	No spots on 353 leaves.
Affected seedlings 7 to 15 in. high	Goroka to Port Moresby	13	4	13 small faint spots on 6 new leaves ‡ of 4 plants, no spots on 60 other new leaves.
		13	7	19 faint spots on 6 new leaves ‡ of 4 plants, no spots on 126 other new leaves.
Mature tree stubbed to 6 in. above soil level	Goroka to Port Moresby	1	7	No spots on 336 new leaves.
Affected cuttings	Goroka to Port Moresby to Station at 1,700 ft.	25	4	Faint spots on a few leaves of 3 plants.
			18	No spots on 163 leaves.
			34	No spots on many leaves.

* Spotted leaves removed after inspection.

† Total leaves not counted.

‡ Affected new leaves were the second pairs expanded after transplanting.

by Bitancourt (1939) in Brazil and by Reyes (1959, 1961) and Valdez (1966) in the Philippines.

The symptoms are similar to those of blister spot of coffee in Costa Rica, attributed to a virus (Wellman 1957), and to oily spot in Brazil (Bitancourt 1958).

Although Bitancourt's grafting experiments were negative, Wellman reported transmission of symptoms by aphids and by grafting. Difficulty was experienced in the present study, however, in obtaining symptoms on new leaves of transplanted affected cuttings, seedlings and one tree and after grafting, even though some of the plants were under observation for nearly three years. Most of the mainly negative results obtained could possibly be attributed to the high temperature at the Port Moresby laboratories (260 miles away and 5,000 ft. lower in altitude than the infected area) where most of the work was carried out. Lack of facilities prevented feeding experiments with aphids.

Wellman (1957) reported apparent recovery of over four per cent. of affected trees in an observation block in a three year period in Costa Rica, but did not report any apparent recovery of affected plants under study in the glasshouse.

No symptoms were obtained at Port Moresby on the cotyledons or true leaves of 410 plants raised from spotted fruit and kept under observation for over 29 months, or on 67 plants derived from seed from affected bushes, kept under observation for over two years. Wellman likewise reported non-transmission through seed.

It must be pointed out, however, that under affected bushes in the field, the cotyledons of seedlings with no true leaves were covered with spots, such seedlings being probably not more than six weeks old. No spots occurred on the true leaves of these seedlings when they were transplanted to Port Moresby.

True leaves issuing from buds which were kept under protective insecticide cover from before expansion of the leaves throughout months of observation became spotted, indicating the probable systemic nature of the condition.

No virus-like particles were found in preparations of sap extracts from affected fruit, leaves or cotyledons when examined in the electron microscope by Dr. A. Gibbs. This does not rule out the possibility that a virus with isometric particles at a low concentration might have been present.

Wellman called the disease 'blister' spot, Bitancourt referred to the Brazil disease as 'oily' or 'greasy' spot, and apparently in parts of Costa Rica it is being referred to as 'buttery' spot. As none of these designations seems fully appropriate to the author, the disease in New Guinea is being referred to as 'Wellman's leaf and fruit spot', as Wellman was the first to publish a description of the condition and the first to conclude that it was apparently of virus causation.

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