Farming will never be a success unless the farmer had more voice in the disposal of his produce—P. Morrel.

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SOME OBSERVATIONS ON VARIETAL RESISTANCE TO 'RUST' OF COFFEE

BY

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The 'Rust' of Coffee caused by the fungus *Hemileia vastatrix* is the most important among Coffee diseases and is known to cause heavy losses to the crop in almost all the Coffee-growing countries of the world. The fungus has been responsible for the abandonment of several thousands of acres of Coffee in South India and Ceylon, and this fact alone has gained for it classic importance in Mycological literature. Of recent years, the Coffee industry in Java has been saved from ruin by the introduction of resistant species and varieties which are gradually replacing the susceptible ones. In India, as in other countries, there is an ever-growing demand among Coffee growers for resistant varieties and strains which combine in them such qualities as good setting of blossom, a high out-turn of parchment, and a bean of good flavour.

The commonest variety of Coffee in cultivation in South India is *Coffea arabica*. This variety is very susceptible to

'Rust' as evinced by the heavy defoliation of the plants caused by the fungus. But its cultivation still continues for the want of a better variety which is at once resistant to the disease and produces the quality of bean which commands a ready market. The cultivation of other varieties is comparatively rare, but some strains which are in any degree superior to Arabica are rapidly gaining popularity.

The following table summarises the prominent qualities of the several varieties studied, as judged by their growth in Coorg plantations under practically identical conditions of culture.

TABLE I

Variety or species.	Extent of cultivation.	Setting qualities of blossom and quality of bean as judged by markets.	Degree of Resistance to 'Rust.'
1. *Coffea arabica*	Universally cultivated.	Good. Yields dependent on good soil and manuring.	Very susceptible to Rust. Bushes heavily defoliated during the period between June to February.
2. *Coffea robusta*	Comparatively rare	Very good setting in some years, but poor in other years. Bean inferior to Arabica. Good out-turn of cherry.	Practically immune to Rust. Rust spots very rarely met with. Bushes show heavy foliage throughout the year.
3. *Coffea liberica. Var.*	Very rare. Never cultivated on a plantation scale. Stray bushes met with on many plantations.	Very poor bearer. Beans very inferior. Poor out-turn of cherry.	Very resistant to Rust, though stray spots are met with on the old leaves during bad seasons. Bushes show heavy foliage throughout the year.
4. Kent's Arabica	Of recent introduction, but increasing in popularity.	Good.	Fairly resistant to Rust. Stray spots appear on leaves particularly after heavy cropping.
5. Jackson's Hybrid.	Of recent introduction and still in the experimental stage.	Good. Yields dependent on soil and manuring.	Susceptible to Rust and practically indistinguishable from Coffea Arabica. Heavy defoliation as in Arabica.

The obviously wide range of variation in Rust resistance among the varieties mentioned in the above table suggested a comparative study of their leaf structure in the hope that it will lead to the discovery of one or more factors which determine the resistance to the fungus. The observations and inferences recorded in this paper are the results of a study made on the leaf structure of a few species and varieties of Coffee found cultivated in Coorg, during the years 1923 and 1924 when the writer had occasion to stay in Coorg in connection with spraying experiments carried out on the Control of Coffee leaf disease.

A comparison of the leaves showed that excepting in *C. robusta*, there is a general uniformity in their shape, size and texture, while in Robusta, the leaves are several times larger in size and possess a leathery texture. As resistance to the diseases did not bear any correlation to the size, shape or texture, it was decided to make a comparative study of the leaf anatomy. This study was made on the following particulars :

(1) The structure of the Parenchyma cells.

(2) The structure of stomata—their size and distribution.

(3) The structure of the lower epidermis.

(1) *Structure of Parenchyma cells.* Sections were prepared from the leaves of all the varieties in different stages of growth. A few measurements were made of the thickness of the epidermis and the mesophyll, but here again there was nothing abnormal which suggested relationship to Rust resistance; nor was there any peculiarity in the structure of the cells which tended to create variation in resistance. It was however observed that in all the varieties the epidermis as well as the Parenchyma contained numerous globules which were distributed indiscriminately. As there was no means of gauging the amount of these globules quantitatively, it is not possible to say whether one variety possesses more of them than another within the Parenchyma.

(2) *Structure, size and distribution of stomata.* Since the fungus is known to make its entry into the leaf through the stomata [1] it was expected that a study of the structure, size and distribution of the stomata would explain why some varieties are distinctly more susceptible than others.' The examination of the stomata was rendered easy by the fact that in all the varieties studied, bits of the lower epidermis measuring up to 1 or 2 sq. c.m. and containing

[1] Butler—*Fungi and disease in plants*, page 472.

several hundreds of stomata could be easily peeled off the leaves, by making a small incision in the leaf with a scalpel and pulling off a bit of the leaf obliquely. By this means it was possible to observe and sketch a number of stomata with the aid of an Abbe drawing apparatus. It was found that the structure of the stomata (vide plates I, II, III and IV) was the same in all the varieties. The length of the stomatal opening was measured, but as variations in their measurements occurred among the stomata of the same leaf and which was inevitable due to variations in the distension of the guard cells, it was thought advisable to measure the maximum length and breadth of the area occupied by the guard cells as a surer basis of the measurements of the stomata. The following table (Table II) summarises the results of these measurements and each figure represents the average of 10 measurements :

TABLE II

Measurements of stomata in microns

Variety.	1st pair of developed leaves from growing point.		2nd pair of leaves from growing point.		3rd pair of leaves from growing point.	
	Length	Breadth	Length	Breadth	Length	Breadth
1. *Coffea arabica* ...	27·0	18·8	26·6	16·8	25·5	16·2
2. *C. robusta* ...	23·4	14·9	22·1	15·3	22·2	14·1
3. *C. liberica* ...	26·3	16·5	28·1	17·4	27·3	16·8
4. Kent's Arabica ...	26·9	18·2	27·5	17·4	27·0	18·2
5. Jackson's Hybrid	27·2	17·4	28·7	17·0	29·6	18·0

From the above table it is evident that excepting in the case of *Coffea robusta*, the stomata are practically of the same dimensions. The size of stomata in Robusta is distinctly smaller, but here again size does not give any indication of the degree of resistance, since two of the resistant varieties and the two susceptible ones do not show any appreciable difference.

Counts were made of the number of stomata per unit area with the aid of an Ocular Micrometer disc divided into 100 equal squares. The following table (Table III) summarises the results

of the counts and each figure represents the average of three readings from different portions of the same leaf.

TABLE III

Frequency of stomata (number per unit area)

Variety.	Degree of resistance to Rust.	1st pair of leaves (from growing point).	2nd pair of leaves.	3rd pair of leaves.	4th pair of leaves.	5th pair of leaves.
1. *Coffea arabica* ...	Nil ...	188	169	159	153	87
2. *Coffea robusta* ...	Very good ...	367	234	220	203	246
3. *Coffea liberica* ...	Very good ...	144	157	160	169	157
4. Kent's Arabica ...	Fairly good ...	161	136	127	135	80
5. Jackson's Hybrid	poor ...	171	121	132	126	113
6. Hall's Coffee ...	good ...	172	160	160	147	152

NOTE—In the above table a sixth variety—Hall's coffee—of which a few young plants were available at the Coffee experiment station, Sidapur, has been included. This variety (as far as it could be judged from three year old plants) was very resistant to Rust.

(3) *Structure of the lower epidermis.* A critical examination of bits of the epidermis peeled off from the leaves of all the varieties and mounted in distilled water or 10 per cent glycerine invariably showed the presence of a number of globules which varied in number and size according to the age of the leaf. A series of micro-chemical tests showed that these globules were of an oily or waxy nature as the following tests indicate.

(i) Solubility in ether.

(ii) Solubility in Benzine.

(iii) Staining yellow with iodine.

Detailed observations on the occurrence and behaviour of these globules revealed the following interesting facts:

(1) The gloubles are present in all the varieties of Coffee and the bigger ones are identical in appearance to those detected in the Parenchyma.

(2) In young leaves the globules are small and are found in large numbers evenly distributed on the epidermis.

(3) With the maturity of the leaves, a number of small globules fuse together to form bigger globules two of which, as a rule, are found one on each guard cell or secondary cell of a stoma.

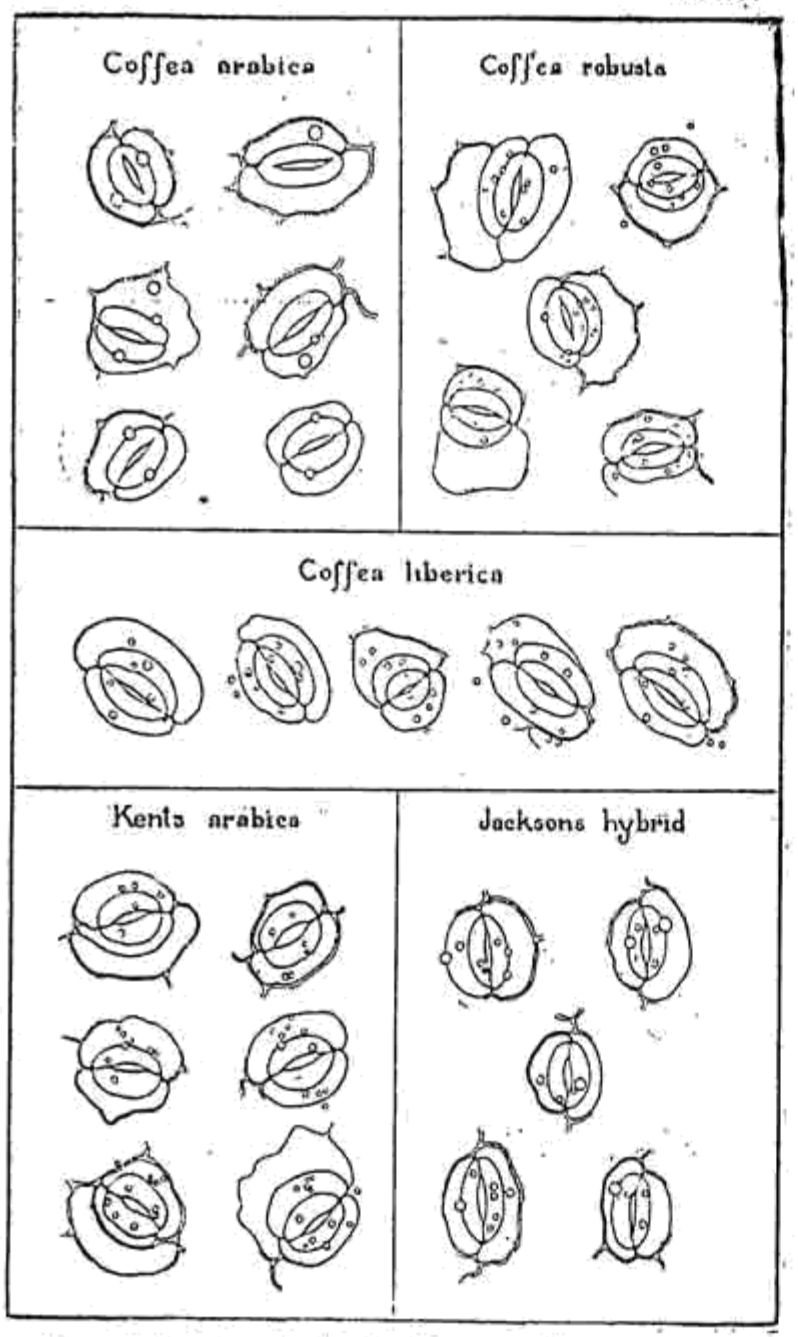
(4) In the resistant varieties, namely, Robusta, Liberica, Kent's and Hall's, the small globules are far more numerous than in the susceptible varieties.

(5) In the resistant varieties, the fusion of small globules is observed in the fourth and the fifth pair of leaves (counted from the distal end of a twig), that is, they fuse at a very late stage in the growth of the leaf, while in the susceptible varieties fusion is observed as early as in the second pair. In other words, fusion of the globules takes place at a very early stage in the development of the leaves of the susceptible varieties, while the small globules remain as such for a longer period and fusion begins at a comparatively later period in the resistant varieties.

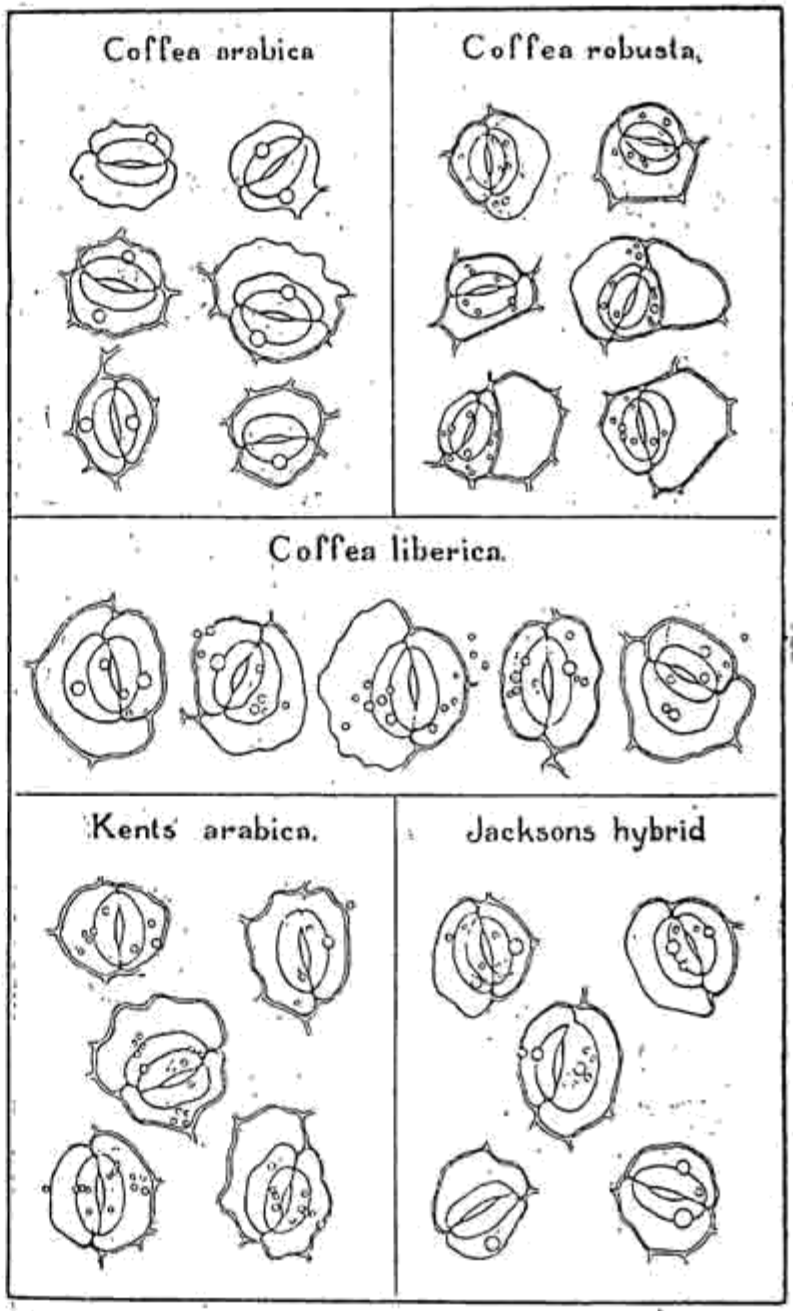
Conclusions. From the study of the leaf anatomy of five varieties of Coffee, it is apparent that a correlation exists between Rust resistance and the number, distribution and period of fusion of the oil globules found on the lower epidermis. The fact that these globules are present also in the mesophyll of the leaves suggest that the amount of oil or wax on the epidermis bears a direct relation to the amount present in the Parenchyma cells. Even if this contention cannot be proved, the amount of oil or wax on the lower epidermis appears to be a determining factor in the extent of resistance to 'Rust.' How it is brought about, it is at present impossible to say, but it is possible that the wax or oil on the leaf renders it water-proof and perhaps functions as a toxin on the promycelium in its efforts to make an entry, particularly during the early stages in the development of the leaf when it is otherwise susceptible to infection.

The investigations recorded in this paper do not lay claim to completeness, and more work has to be done before other factors governing Rust-resistance are accounted. However, the results of the studies are presented with the hope that other workers on Coffee, and on disease-resistance of crops in general, may make helpful criticisms which would help further progress in this line of work.

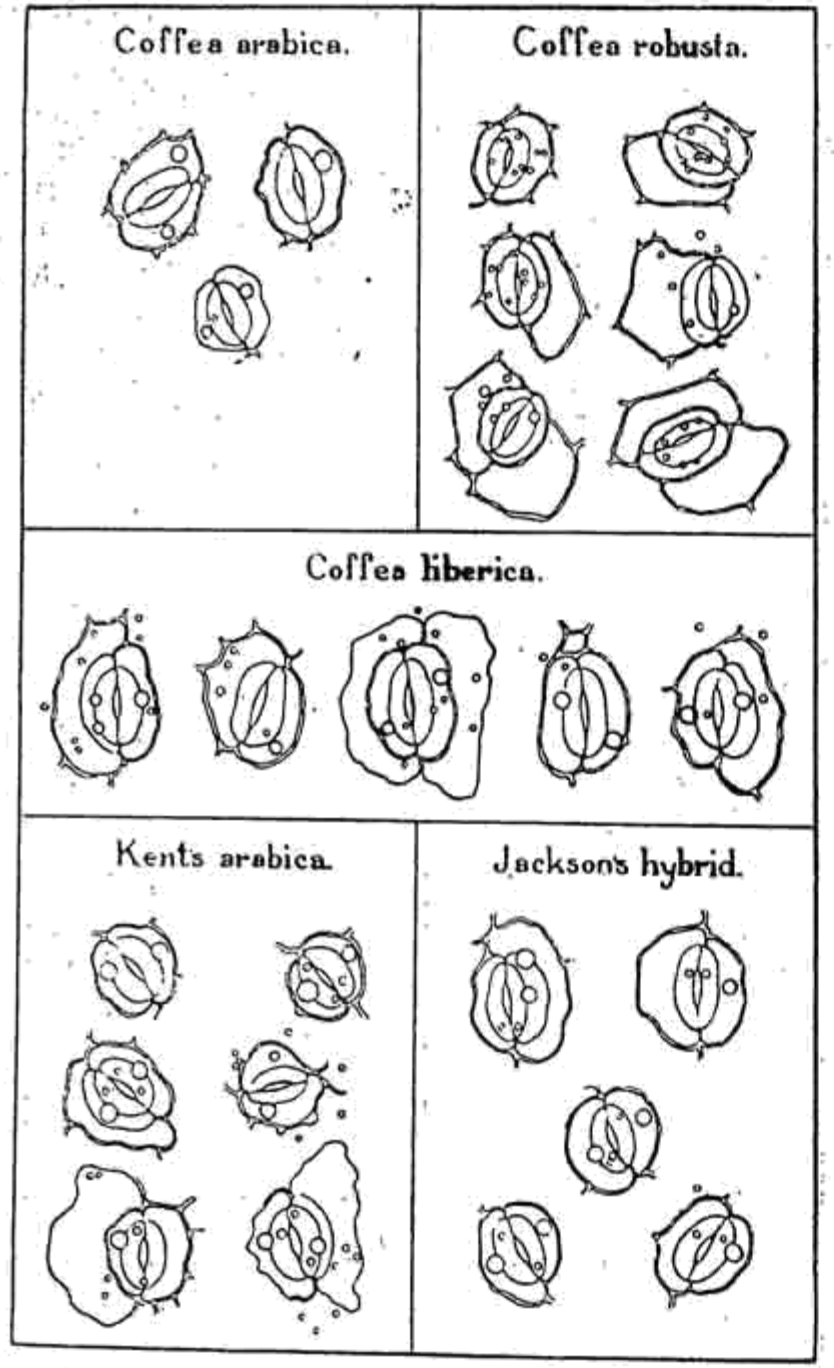
From what has been observed, a study of the number, distribution and period of fusion of the oil globules on the lower epidermis of four successive pairs of developed leaves constitute a



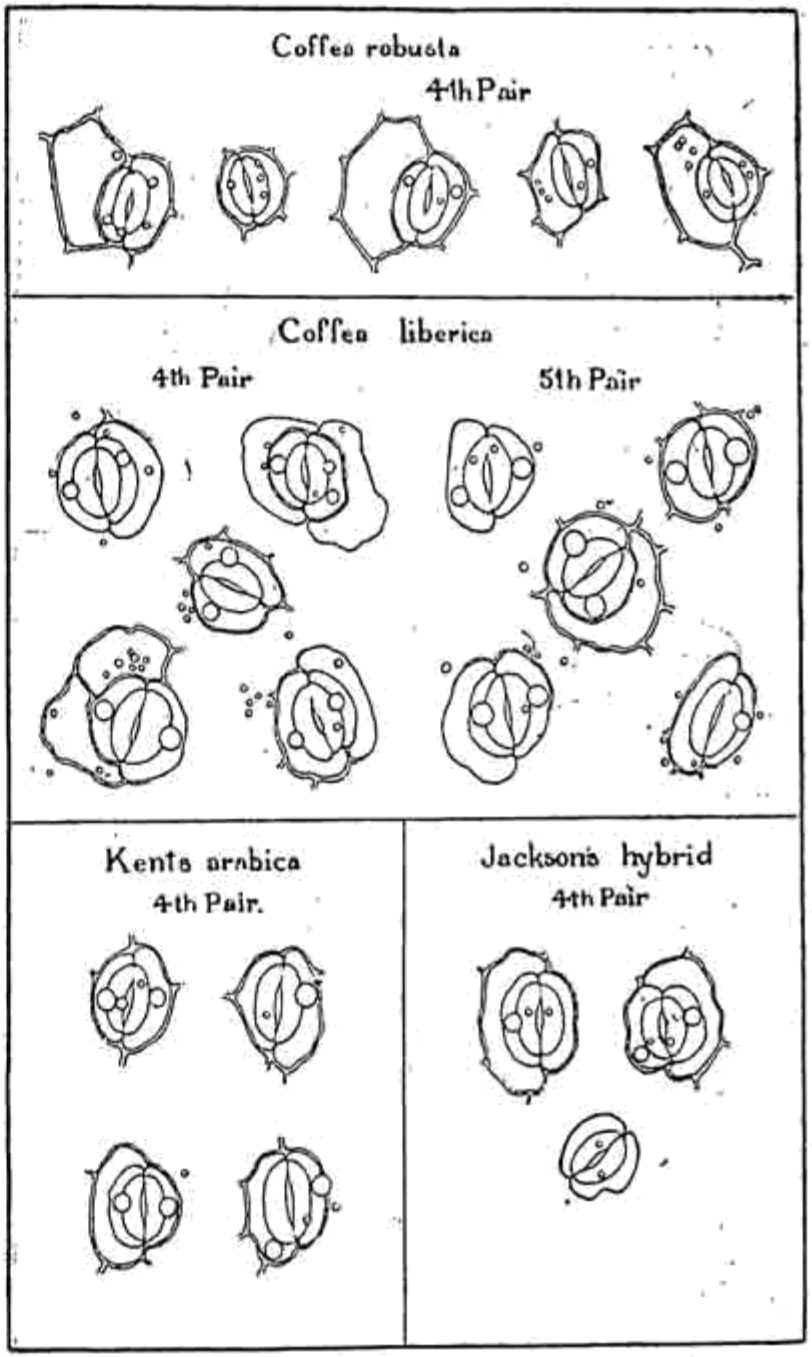
Stomata from the *first* pair of developed leaves from the growing point. × 300. Note the globules.



Stomata from the *second* pair of developed leaves from the growing point. × 300. Note the fusion of [illegible]



Stomata from the *third* pair of developed leaves from the growing point. × 300.



Stomata from the *fourth* pair of developed leaves from the growing point. × 300.

simple test by which Rust-resistance of individual plants could be gauged with a certain amount of precision; and this fact may be utilized in the laboratory to test new selections and strains of Coffee for Rust-resistance, before resorting to elaborate field tests. To the breeder, it may prove valuable for preliminary comparative tests when the material available is scanty.

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