

FURTHER DATA ON THE SUSCEPTIBILITY OF RUTACEOUS PLANTS TO CITRUS-CANKER¹

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INTRODUCTION

In the present paper results are given of field observations and inoculations with *Pseudomonas citri* upon plants belonging to genera more or less related to Citrus. These results show a wide range of hosts for Citrus-canker, and the possibility of lesions upon plants other than *Citrus* spp. serving as sources of new infection becomes emphasized in Citrus-canker eradication work.

In the present investigation the findings of Jehle² as to the susceptibility of *Chalcas (Murraya) exotica* Millsp., were corroborated and 23 other species representing 20 genera of the Rutaceae were studied.

It seems inadvisable to present the inoculation data here, since over 2,000 inoculations were made. Table I presents the data in a very much condensed form, and the illustrations show a few of the positive results. To anyone interested the complete inoculation data are available at the Bureau of Plant Industry, Washington, D. C. The inoculations and the controls were dried as herbarium specimens and will also be available for examination.

In making the inoculations an infusion of the organism was painted upon the leaf blade, midrib, petiole, or stem, as the case might be, with a small camel's-hair brush, and then the tissue was punctured through the coating of infusion with a needle. The inoculated twig was maintained in a moist condition by wrapping it in paraffin paper, including

¹ The investigations here outlined have been carried on largely at the Linao Experiment Station of the Division of Plant Industry of the Philippine Bureau of Agriculture. Thanks are due to Mr. A. M. Burton, former Chief, and to Mr. S. Apostol, present Chief of this Division, as well as to Mr. F. G. Galang, Superintendent of the Linao station. The Citrus collection of the College of Agriculture at Los Banos was also placed at the use of the writer through the courtesy of Dr. C. F. Baker, Dean of the College.

Many of the plants studied, belonging to genera closely related to Citrus are growing in the experimental plots of Mr. W. T. Swingle, Physiologist in Charge of Crop Physiology and Breeding Investigations, Bureau of Plant Industry, United States Department of Agriculture, for use in the breeding of canker-resistant Citrus fruits and canker-resistant stocks. Permission to use this material has greatly facilitated the work. Thanks are also due to Mr. Swingle for many helpful suggestions. Many plants related to Citrus grow wild in the Philippine Islands. Prof. E. D. Merrill, Botanist of the Bureau of Science, made helpful suggestions as to such plants and identified many of them. His help has been of the greatest value, and is hereby gratefully acknowledged.

It would have been difficult, if not impossible, to carry on this work without the extensive laboratory facilities of the Bureau of Science so freely made available through the courtesy of Dr. A. J. Cox, Director.

² JEHLÉ, R. A. SUSCEPTIBILITY OF NON-CITRUS PLANTS TO BACTERIUM CITRI. *In* Phytopathology, v. 7, no. 5, p. 339-344, 3 fig. 1917.

with the twig also a small piece of moistened cotton. Control needle punctures with tap water were made for each host plant, and the moist condition was also maintained with paraffin paper and moist cotton. Unless otherwise noted, the positive results observed here occurred only at needle punctures.

TABLE I.—Summary of results of inoculations on plants of Rutaceae

No.	Genus and species.	Inoculation No. for reference.	Result.	Remarks.
SUBFAMILY CITRATAE. (Not of tribe Citreae.)				
1	<i>Claucaena lansium</i>	1046-1050....	Positive.....	Negative for leaves, but positive on petioles and stems; inoculations slow in maturing.
2	<i>Chalcas exotica</i>	876-880....	Weakly positive.	Negative for leaves but positive on petioles and stems. Susceptibility only evidenced by slight swelling not evidenced in controls.
TRIBE CITREAE. SUBTRIBE FERONINAE.				
3	<i>Feronia limonia</i>	41-50.....	Positive.....	Leaves as well as stems show positive results. Reaction takes place slowly.
4	<i>Feroniella lucida</i> SUBTRIBE AEGLINAE.	1361-1370....do.....	Results obtained only for stem. Positive results obtained very readily.
5	<i>Aegle marmelos</i>	811-816....	Negative.....	Inoculation attempts made repeatedly on all parts of plants; all negative; believed to be immune.
6	<i>Chaetosperrum glutinosa</i>	61-70; 831..	Positive.....	Results obtained very readily in 5 days. Many naturally occurring infections (Pl. 6c).
7	<i>Balsamocitrus gabonensis</i> SUBTRIBE LAVANGINAE.	1341-1350....	Negative.....	This species is believed to be immune.
8	<i>Hesperethusa crenulata</i>	1291-1310....	Positive.....	Results obtained quickly and readily for both leaves and stems (Pl. 61, A).
9	<i>Triphasia trifolia</i>	1071-1808....	Negative.....	Stems and leaves negative.
10	<i>Paramignya longipedunculata</i>	771-790....	Positive.....	Tissue yellow, with oily appearance around punctures, not raised; no such coloration around control; true both for leaves and stems (Pl. 61, B).
11	<i>Severinia buxifolia</i>	1381-1390....	Negative.....	Believed to be immune; inoculated repeatedly under same conditions which gave positive results on other genera.
SUBTRIBE CITRINAE.				
12	<i>Citropsis schweinfurthii</i>	1371-1380....	Positive.....	Readily positive both leaves and stem.
13	<i>Atalantia citrioides</i>	1331-1335....do.....	Positive for leaves, causing a watery dark discoloration of tissue but no excrescence. Weakly positive on stem (Pl. 62, A).
14	<i>Atalantia disticha</i>	936-950....	Weakly positive.	Stem inoculations slightly swollen, not the case with controls. Leaf inoculations slightly discolored, not the case with controls. Very resistant at least.
15	<i>Eremocitrus glauca</i>	1416-1420....do.....	Stem inoculations slowly positive.
16	<i>Fortunella hindsii</i>	1271-1280....	Positive.....	Quickly positive on both leaves and stem (Pl. 62, B).
17	<i>Fortunella japonica</i>	1031-1040....	Weakly positive.	Leaf blade inoculations definitely negative; inoculations in midrib weakly positive and inoculations in stems slowly but clearly positive. Believed to be highly resistant.
18	<i>Microcitrus australis</i>	486-505....	Positive.....	Quickly positive; cankers definite but much smaller than on <i>Citrus</i> spp.
19	<i>Microcitrus australasica</i>	1326-1330....do.....	Stem inoculations show cankers; much smaller than on <i>Citrus</i> spp., however.

TABLE I.—Summary of results of inoculations on plants of Rutaceae—Continued

No.	Genus and species.	Inoculation No. for reference.	Result.	Remarks.
RUTACEAE OTHER THAN CITRATAE.				
20	<i>Toddalia asiatica</i>	1401-1410....	Positive.....	Leaves show no excrescences, but a yellowing of tissue not found in control punctures. Stem inoculations are swollen and the tissue is blackened.
21	<i>Xanthoxylum rhetsa</i>	631-690.....	Negative.....	Leaves, petioles, and stems negative.
22	<i>Evodia ridleyi</i>	2113-2127....	Positive.....	Both leaves and stem produce light brown eruptions very definite and similar to those on <i>Citrus</i> spp. (Pl. 63). There is also evidence that stomatal infections took place.
23	<i>Evodia latifolia</i>	291-300.....	do.....	Leaves clearly negative but stem tissues show excrescences of a brown color similar to those produced on <i>Citrus</i> spp.; lesions very large.
24	<i>Melicope triphylla</i>	1526-1540....	do.....	Leaves clearly negative; stem tissue shows excrescences of brown color similar to those produced on <i>Citrus</i> spp.

Field observations corroborating these inoculation data have been made in many cases. Thus, in South China *Severinia buxifolia* occurs naturally, exposed in a number of instances to infection from Citrus-canker in near-by orchards. In no instances were lesions in any way resembling those of Citrus-canker found. *Aegle marmelos* and *Triphasia trifolia* are cultivated at Lamao in the Philippine Islands, surrounded by nursery rows of Citrus trees heavily infected with canker. In no case have lesions similar to those of canker been found on these hosts.

Chalcas exotica is a commonly-grown ornamental in Manila; nothing at all resembling Citrus-canker has ever been found occurring naturally upon it, although sources of infection are in some cases closely present.

Xanthoxylum rhetsa and *Atalantia disticha* occur naturally at Lamao in places where infection with Citrus-canker would be easily possible. No lesions similar to canker have been found on these plants.

Fortunella japonica occurs in orchards at Lamao and also at Los Banos, Philippine Islands. No naturally-occurring cankers have ever been seen on this host. Wolf¹ reports Citrus-canker on kumquats, but does not mention what species were under observation. Swingle² also reports canker on kumquats in Japan.

Fortunella japonica, although susceptible to Citrus-canker under the most optimum conditions, should nevertheless be regarded as highly resistant, closely approaching immunity.

On the other hand, *Fortunella hindsii* occurring naturally in South China has been observed frequently with heavy canker infection. Plants

¹ WOLF, Frederick A. CITRUS-CANKER. In Jour. Agr. Research, v. 6, no. 2, p. 70. 1916.

² U. S. DEPARTMENT OF AGRICULTURE. CITRUS CANKER IN PHILIPPINES. In U. S. Dept. Agr. Dept. Circ., v. 1, no. 1, p. 8. 1915.

of this species were found by Prof. G. W. Groff and the writer near the summits of mountains in Kwangtung Province at an altitude of about 1,500 feet. These mountains are heavily eroded and peculiar in having their sides barren and almost entirely free from growth. Plants of *F. hindsii* at the tops of these mountains were therefore very much isolated from commercial Citrus plantings and other sources of canker infection; nevertheless, in almost all cases the species was heavily infected with Citrus-canker. The writer later found plants of the same species upon Victoria Peak, Hongkong, a mountain of very similar type. It is possible that further facts may show that this plant is an original wild host from which Citrus-canker has spread to cultivated species.

Chaetospermum glutinosa occurs both naturally and cultivated at Lamao, and naturally occurring cankers are abundant upon such plants. The susceptibility of *C. glutinosa* to canker is easily greater than that of the sweet orange (*Citrus sinensis*) in the Philippines.

Glycosmis pentaphylla occurs naturally in Kwangtung Province, China, in places where infection from Citrus-canker would be easily possible. No naturally occurring cankers were observed.

Of the positive results obtained in the foregoing tabulated species, *Pseudomonas citri* has been reisolated from *Claucaena lansium*, *Feronia limonia*, *Feroniella lucida*, *Chaetospermum glutinosa*, *Hesperethusa crenulata*, *Paramignya longipedunculata*, *Citropsis schweinfurthii*, *Atalantia citrioides*, *Fortunella hindsii*, *Microcitrus australasica*, *M. australis*, *Toddalia asiatica*, and *Evodia ridleyei*. Such isolations have been reinoculated on foliage of *Citrus grandis*, and have given positive results in each case. In those positive results not listed as having the organism reisolated the material was collected and dried in the field, where laboratory facilities were not available.

The statements made above as to immunity, since they are based on lack of infection after inoculation with a dense infusion of the causal organism under the most favorable conditions for infection, are probably more substantial than claims made for absence of infection under natural conditions.

The most noteworthy feature of the inoculations is the susceptibility of such very distant relatives as *Evodia ridleyei*, *E. latifolia*, and *Melicope triphylla*. In these cases the cankers are by no means weakly produced, but form quickly, with a decided swelling of the tissue, which later erupts as on species of Citrus. On *E. ridleyei* the results were evident in two weeks. *Pseudomonas citri*, therefore, is not closely limited to *Citrus* spp., but has a very wide range of host plants within the family Rutaceae.

Severinia buxifolia, *Aegle marmelos*, and *Balsamocitrus gabonensis* produce no reaction whatever when inoculated with *Pseudomonas citri*. It is believed that these species may be safely called immune to Citrus-canker; this is especially noteworthy, since they are all close relatives of the genus Citrus.

The evidence is that *Xanthoxylum rhetsa* and *Triphasia trifolia* are immune, while *Chalcas (Murraya) exotica*, *Atalantia disticha*, and *Fortunella (Citrus) japonica* show positive results only under the most favorable circumstances for infection.

It is noteworthy that some of the immune and highly resistant species possess thick, coriaceous brittle leaves—for example, *Severinia buxifolia*, *Atalantia disticha*, *Fortunella japonica*, and *Chalcas exotica*. This suggests the possibility that resistance to Citrus-canker may be influenced in some measure by histological or morphological differences.

SUMMARY

(1) Inoculation tests with *Pseudomonas citri* upon 24 species representing 20 genera of the family Rutaceae show that 19 of the species are susceptible in greater or less degree. It thus appears that Citrus-canker is not closely limited to the genus Citrus, but has a wide range of hosts among the Rutaceae.

(2) *Severinia buxifolia*, *Aegle marmelos*, and *Balsamocitrus gabonensis*, all close relatives of Citrus, may safely be called immune to Citrus-canker. *Xanthoxylum rhetsa* and *Triphasia trifolia* seem to be immune.

(3) *Chalcas (Murraya) exotica*, *Atalantia disticha*, and *Fortunella (Citrus) japonica*, also closely related to the genus Citrus, are strongly resistant to Citrus-canker.

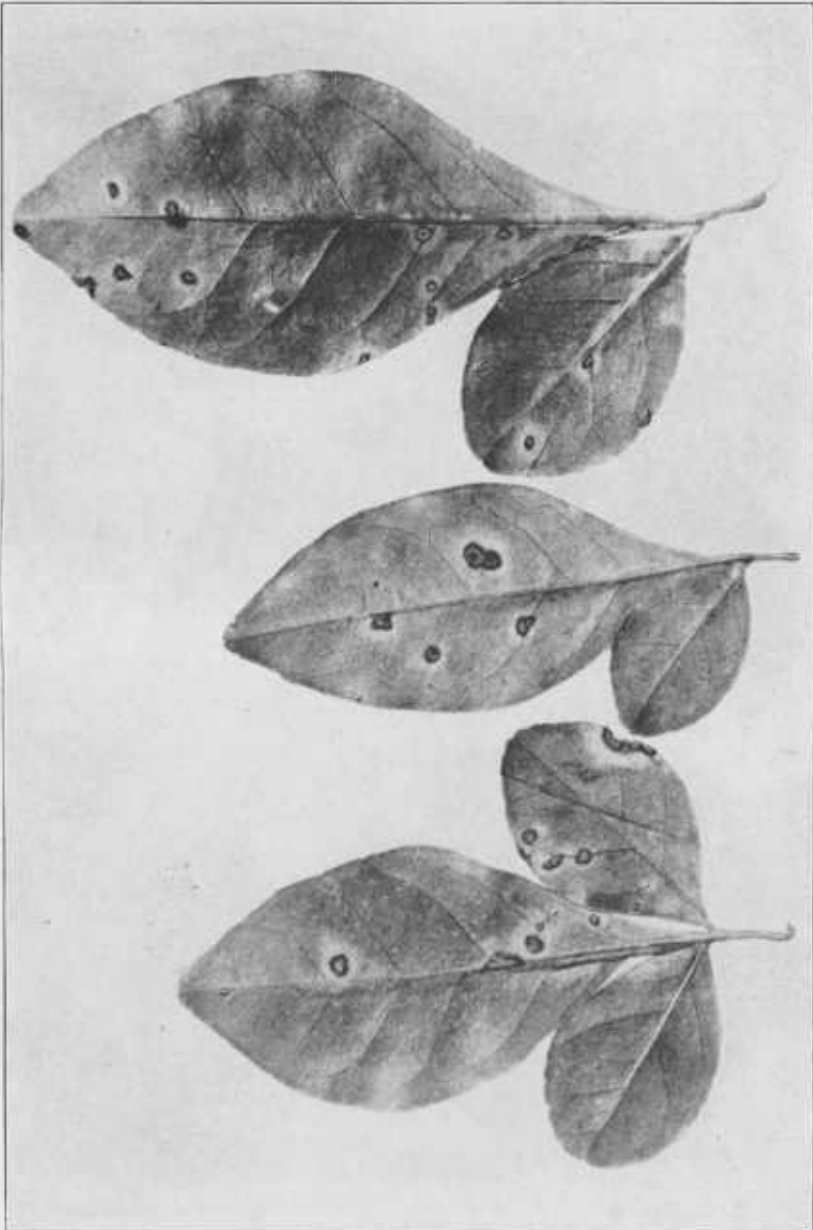
(4) *Claucaena lansium*, *Feronia limonia*, *Feroniella lucida*, *Chaetospermum glutinosa*, *Hesperethusa crenulata*, *Paramignya longipedunculata*, *Citropsis schweinfurthii*, *Atlantia citrioides*, *Eremocitrus glauca*, *Fortunella hindsii*, *Microcitrus australis*, *M. australasica*, *Toddalia asiatica*, *Evodia ridleyei*, *E. latifolia*, and *Melicope triphylla*, of different relationships to the genus Citrus, all produce positive results when inoculated with *Pseudomonas citri*, at needle punctures. Of these *Claucaena lansium* and *Feronia limonia* develop infection very slowly, the others fairly quickly.

(5) *Chaetospermum glutinosa* shows naturally occurring infections of Citrus-canker and in the Philippines its susceptibility is easily greater than that of the sweet orange (*Citrus sinensis*). *Fortunella hindsii* occurs naturally in South China, very much isolated from sources of Citrus-canker infection. The abundance of cankers found on such trees gives rise to the theory that this species may have been an original wild host from which Citrus-canker spread to cultivated species.

PLATE 6o

Naturally occurring Citrus-canker lesions on leaves of *Chaetospermum glutinosa*.
Natural size.

(666)



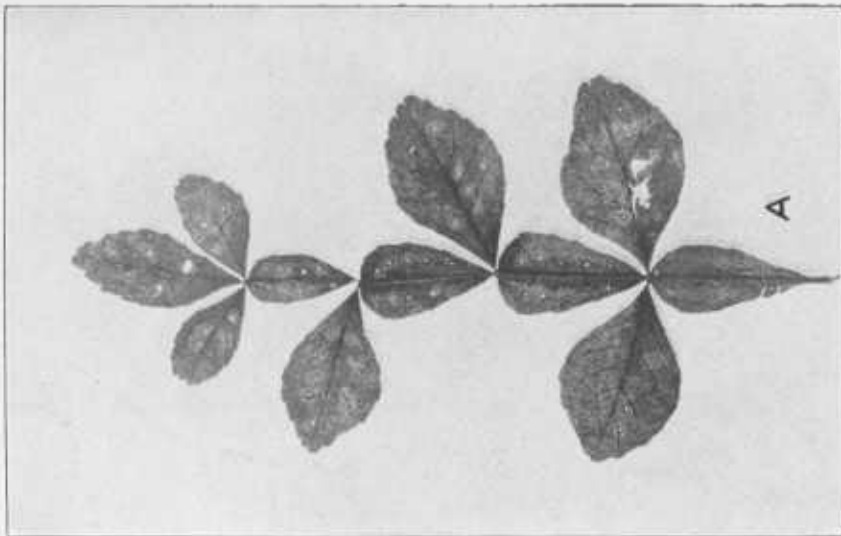
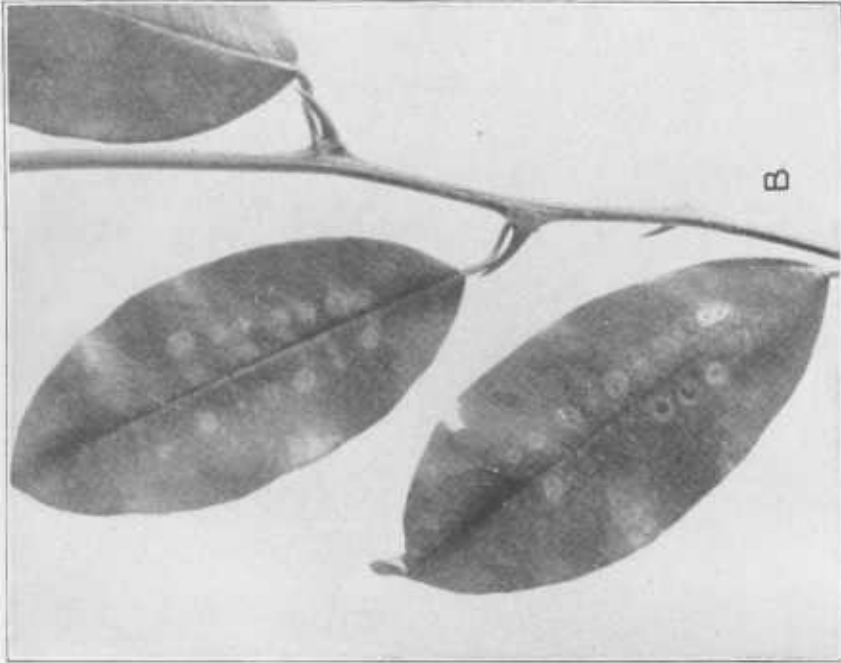


PLATE 61

A.—*Hesperethusa crenulata*, showing discolorations resulting from inoculations with *Pseudomonas citri*. Natural size.

B.—*Paramignya longipedunculata*, showing discolorations around punctures made with *P. citri* on leaves. Such discolorations did not develop at punctures made with river water. Natural size.

PLATE 62

A.—*Atalantia citrioides*, showing positive results following inoculation with *Pseudomonas citri*. Natural size.

B.—*Fortunella hindsii*, showing results of inoculation with rain water on leaves. Natural size.

C.—*Fortunella hindsii*, showing results of inoculation with *P. citri* on leaves. Natural size.

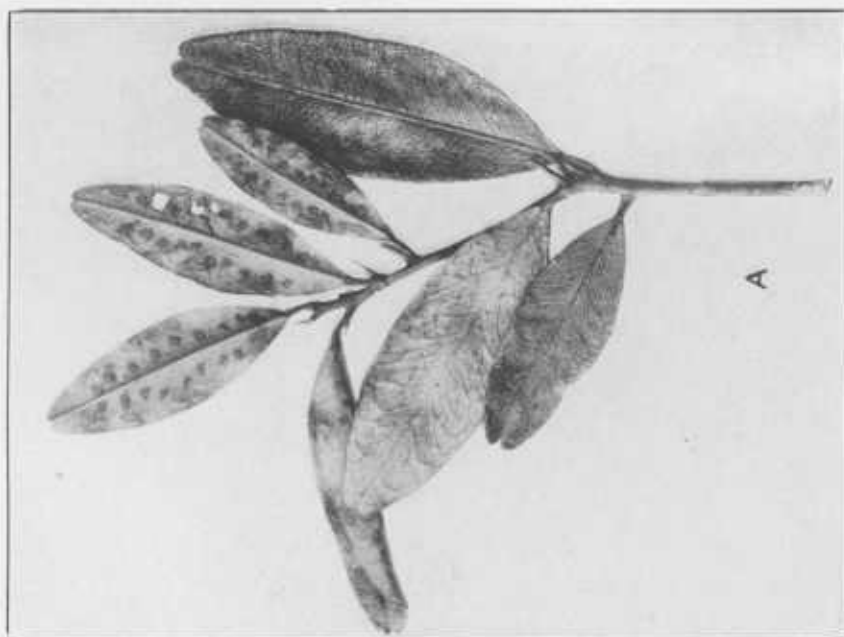
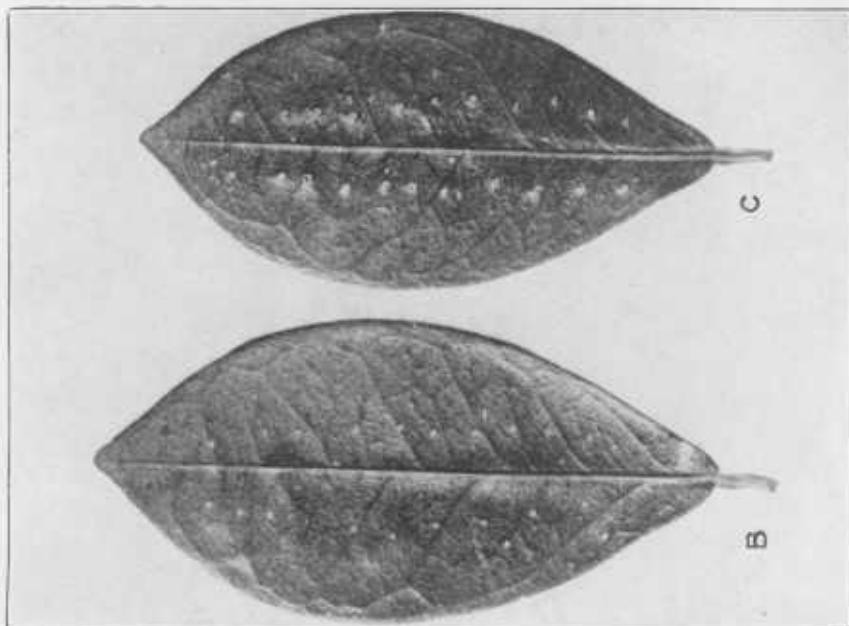




PLATE 63

Evodia ridleyi:

A.—Stem inoculated with tap water.

B, C.—Two twigs inoculated with *Pseudomonas citri*. Natural size.

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