A YEAR'S EXPERIENCE WITH THE COTTONY CUSHION SCALE IN PUERTO RICO *

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The most complete yet succinct account of the Cottony Cushion Scale, or as it was earlier generally called, the Fluted Scale, and its accidental introduction into California, is that written almost a generation ago by Dr. C. L. Marlatt(1). This is quoted below entire, with one interpelating quotation from Dr. L. O. Howard, as it gives a picture of how the scale and its control were regarded and how this affected the then pioneering industry of citrus fruit production in California.

"Of all the scale insects attacking citrus plants, this species, (*Icerya purchasi* Maskell) is perhaps the most notable, not so much from the damage now occasioned by it as from the problems of control which it has brought to the front and the international character of the work which it has occasioned.

"The facts indicate that Australia is undoubtedly its original home, from whence it was introduced on Australian plants into New Zealand, Cape Town, South Africa, and California at about the same time. The evidence points to its introduction into California about the year 1868 on *Acacia latifolia.* It is a very hardy insect, will live for some time without food, and thrives on a great number of food plants. In California it spread rather rapidly, and by 1886 had become the most destructive of orange scale pests. The damage occasioned by it was of such a serious character as to threaten the entire citrus industry of the Pacific coast. The nature and habits of this insect made it almost impervious to any insecticide washes, and the orange growers of California were rapidly losing heart.

"In 1889 however, through the agency of Mr. Albert Koebele, an assistant of this office (the U. S. Bureau of Entomology), the natural

* Some of the observations on which this paper is based were made by one writer, some by the other, but in most cases they were made jointly by both at the same time. All of the rearing work, of the scale and of the lady-beetles, has been conducted by the junior author. For the past year, the senior author has been in charge of the work and the MS was written by him.

ladybird enemy of the fluted scale was discovered in Australia and imported into California. This ladybird *Novius (Vedalia) cardinalis,* multiplied prodigiously, and in a very short time practically exterminated the fluted scale, saved the State of California annual damage amounting to hundreds of thousands of dollars, and removed this scale insect from the roll of dreaded injurious species."(1) Dr. Howard has thus evaluated this accomplishment: "This dramatic and extremely useful bit of work was a great thing for scientific economic entomology. So striking a success may probably never again be achieved in this country."(2)

"The beneficial results derived from this ladybird have not been confined to California. Through the agency of this Department (the U. S. Bureau of Entomolgy), and in cooperation with the California State authorities, this ladybird has been sent to South Africa, Egypt, Portugal, and Italy, and in each of these countries its introduction has been followed by similar beneficial results in the control of the fluted scale.

"While the fluted scale, at the time or soon after its injurious record in California, gained access to several foreign countries, very fortunately Florida and the Gulf districts remained long free from it.

"The first and presumably only introduction of this insect into Florida was an intentional one, though not malicious, and illustrates the risk run in importations of beneficial insects undertaken by persons unfamiliar with the subject. A nurseryman of Hillsboro County, Fla., hoping to duplicate against the common Florida scale insects the wonderful work of the imported Australian ladybird against the fluted scale in California and, ignorant of the fact that the ladybird in question did not feed on any of the armored scales which he especially wished to have controlled by it, got one of the county horticultural commissioners of California to ship him a lot of these ladybirds, together with some of the fluted scale as food. The whole lot was liberated on his premises and resulted, naturally enough, in stocking some of his trees very thoroughly with the fluted scale. The infestation coming to his attention, he sent, in June, 1894, specimens to the Division of Entomology and they were promply determined as the dreaded California scale pest. Fortunately, the nurseryman in question realized the enormity of his offense and took, at Dr. Howard's earnest suggestion, immediate and active measures to exterminate the fluted scale on his premises, ultimately taking out and burning the trees.

"It was hoped that extermination has been effected, but four years later (1898) the fluted scale was again received from the same dis-

trict. In view of its quite general spread, as reported, in the immediate region, it seemed improbable that it could be easily exterminated, and the introduction of the Australian ladybird was urgently advised. During the spring and summer of 1899 the ladybird in question was successfully colonized in Florida by Mr. Gossard, with the assistance of Mr. Craw.

"The fluted scale in Florida evidently does not multiply as rapidly as it does in California. Furthermore, as shown by Mr. Gossard, it is attacked by a fungous disease which appears suddenly in July and results in the death of from 25 to 70 per cent of the partly grown scales. We may hope that with the aid of this disease, and by means of the prompt introduction of its natural enemy, the fluted scales will never play the role in Florida which it originally did in California.

"The habits and transformations of the fluted scale closely parallel those of the species of *Lecanium* already described. The general appearance of the insect, however, is strikingly dissimilar, owing to the waxy excretions from the ventral plate of the adult female insect. There are ribbed, or fluted, from whence the insect takes it name, and become the receptacle of a vast number of eggs, a single female being the possible parent of more than a thousand young. The waxy material constituting the egg sac issues from countless pores on the under side of the body, especially along the posterior and lateral edges. As this secretion accumulates the body is lifted, so that ultimately the insect appears to be standing almost on its head, or nearly at right angles to the bark. The eggs are laid in the waxy secretion as it is formed, the waxy fluted mass often becoming from two to two and one-half times as long as the insect itself. The young are of reddish color, very active, and spread by their own efforts and by the agency of the winds, birds, and other insects. The female insect is, for the most part, a reddish orange, more or less spotted with white or lemon.

"The early stages of the male are similar to the corresponding stages of the female. Before appearing as an adult, the male insect secretes itself in some crack in the bark, or in the ground, and exudes a waxy covering, which forms a sort of cocoon, in which the transformations are undergone, first into the pupa and then into the adult insect. The winged male is rather large for a coccid, and has a reddish body with smoky wings.

"The rate of growth of the fluted scale is comparatively slow, and it does not normally have more than three generations annually.

This insect is quite active, the female traveling and moving about very freely nearly up to the time when she finally settles for egg-laying. The male is active up to the time when it settles down to makes its cocoon.

"The fluted scale exudes a great quantity of honeydew, and trees badly attacked by it are covered with the sooty fungus, characteristic of the black scale and the white fly.

"The remedy for this scale insect is always and emphatically to secure at once its natural and efficient enemy, the *Novius cardinalis*. Where this insect can not readily be secured, the scale may be kept in check by frequent sprayings with the kerosene or resin washes. Fumigation is comparatively ineffective against it, because the eggs are not destroyed by this treatment. Spraying is, for the same reason, effective only when it is repeated sufficiently often to destroy the young as they hatch."(1)

The above account of the cottony cushion scale and of its spectacular control in California has been reprinted here to indicate how generally it is considered that the problem of control of this pest is thoroly and completely solved. Yet upon examining the more recent publications from California, one discovers that control by the lady-beetle *Novius, Vedalia*, or *Rodolia cardinalis*, as it is now called, is by no means as effective as the earlier statements would lead one to suppose.

For instance, Prof. H. J. Quayle states that:

"While the cottony cushion scale is at present a pest of comparatively little consequence, it is still one of the commonest insects inquired about throughout the entire length of the State where citrus trees are grown. While the *cardinalis* is pretty well distributed over the State, and often appears unaided in an infestation of cottony cushion scale, yet in many cases it does not occur, and neither does the scale become very abundant. The checking of the scale in such cases must be accounted for through some other factors. Sometimes, too, the beetle is slow in getting the scale under control. On the station grounds at Riverside fifty or seventy-five orange trees have been infested with the cottony cushion scale, as bad as occurred when the insect was at its height, for at least four years. During this time also the ladybird beetle has been present. The scale becomes very abundant each spring when the *cardinalis* begins work and effectively checks them. The beetles are present in April, May, and June, and disappear in July. Some young scales are left and those have a chance to multiply and severely infest the trees again

before the *cardinalis* appears in the spring. This has been the history of the infestation for the past four years."(3)

Nor is the relative value of the parasites introduced by Koebele finally settled, for, to quote from a recent book by Dr. E. O. Essig: "The dipterous parasite of the cottony cushion scale, *Cryptochaetum iceryae* (Williston), was one of the natural enemies of *Icerya purchasi* Mask., introduced by F. S. Crawford and Albert Koebele from Australia into California in 1888–9. The adults are 1.5 mm. long, the head and the thorax metallic dark blue, and the abdomen iridescent green. They are rather slow in movement, crawling slowly over the cottony cushion scale inserting one to several minute, oblong, oval, smooth, pearly white eggs preferably in the half grown hosts. It is thought that a single female may lay as many as 200 eggs. The young larvae are curious, semitransparent elongated maggots with black mouth hooks, the anterior half of the body bare, the posterior half ciliated and with two long tail-like processes often twice the length of the body. The full-grown larvae are quite different. The body becomes pear-shaped with two horn-like tracheae and the tail-like processes extended to four or five times the length of the body. The color becomes reddish from the contents in the alimentary canal. The larvae live freely within the body cavity of the host feeding on the body fluids and apparently not seriously inconveniencing it; upon reaching maturity, however, the host is eventually killed. Several larvae may occur in a single scale insect. Pupation occurs within the dead body of the host. The puparia are yellow or reddish brown, oval, 2 mm. long, with two horn-like projections. There are five or six generations a year. This parasite is often the most important natural check on the cottony cushion scale, but because of its small size and the concealed manner of attack, it has not been given due credit for its efficiency. In the San Francisco Bay region it persists where the vedalia has long since passed away and keeps the scale insect under almost perfect control. Practically every lot of the scale sent to the University for examination shows the work of the fly and it is with great difficulty that living specimens of this once common and abundant scale insect can be secured for student study. In Southern California too this parasite has done much of the work claimed for the vedalia."(4)

Indeed, the whole problem of the cottony cushion scale, which was at one time thought to be finally settled and decided, is in fact still very much of a problem. If this is the condition in California, where the insect has been present for so long, and investigators have

been working on it ever since it first appeared, one may anticipate that its status in a new and entirely different environment may be even more subject to unusual and unexpected conditions.

The first published record of the cottony cushion scale in Puerto Rico is a note by Dr. W. A. Hoffman (5), of the School of Tropical Medicine in San Juan, who first observed it on a hedge of casuarina or Australian pine, *Casuarina equisetifolia,* in the patio of the School, later noting it generally on this host elsewhere in San Juan. (See Pl. XV.) This was not the first known occurrence, however, for it had previously been collected on rose bushes in Santurce, a suburb of San Juan, over a year previously, and determined by Dr. Harold Morrison of the U. S. National Museum at Washington. This record was not published until July, 1932(6), and then without special comment among hundreds of others, mostly of common or well-known insects. The early developments in the story of the cottony cushion scale in Puerto Rico are best told in an unpublished MS prepared by Dr. M. D. Leonard, at that time Chief of the Department of Entomology at the Insular Station. He said,—

"On October 21, 1931, Edmundo Martínez of the Insular Forest Service brought a small twig of Casuarina to the Station bearing two specimens of the cottony cushion scale. These had been brought to his Station by some woman of unknown name and address in Santurce, for identification. The extent of the infestation was not known. I sent these two specimens to Dr. Morrison under date of October 21, 1931 (the same day) for determination since I was not sure but that this might be *Icerya montserratensis.* I told Mr. Martínez at the time, however, that this was probably *purchasi,* the injurious citrus species, and urged that he and the other foresters be on the lookout for it on casuarina. I myself had often looked at the casuarina at the Forestal in Río Piedras but had seen no evidence of infestation by this or any other insect.

"On February 16 or 17, 1932, I received from Dr. Morrison a letter dated February 5, confirming my determination of the casuarina specimens as *I. purchasi.* I saw Mr. Martínez a day or two later at the Post Office in Río Piedras and told him of this and asked again that the foresters be on the lookout for it.

"At about the same time I told Mr. Faxon, Chief of the Federal Plant Quarantine Office, of this determination and asked that he and his inspectors be on the lookout for *purchasi* on both casuarina and citrus during their regular grove inspections.

"From then on I personally examined a number of casuarina trees and hedges around Santurce but saw none until the first week

in March when in company with Mr. C. E. Pemberton, Chief Entomologist of the Hawaiian Sugar Planters' Experiment Station, a light infestation was found on a few casuarina trees next to the Clínica Miramar at Stop 10, in Santurce. These were for the most part unhealthy looking insects and a considerable proportion of the few there had been eaten out by something.

"At this time I told Mr. Pemberton of the occurrence of *purchasi* here on roses and casuarina (both determined by Dr. Morrison) and concluded that it was so scarce and so restricted that nothing be done about control at that time.

"When Dr. Wolcott was in San Juan on March 4 and 5 to attend the International Sugar Cane Technologists' Congress, the infestation on the casuarina hedge at the Clínica Miramar had not yet been noticed. I next saw him on March 11 during the trip of the Technologists around the Island and on the 12th at Guánica told him of the occurrence of *purchasi* on roses and casuarina (3 infestations total only observed to date) and we examined many casuarinas in company with Dr. Pemberton. I still did not think it worth while to give this any publicity.

"I examined casuarinas at all stops in the Island tour between that date and March 15 but with negative results.

"On March 24, I believe it was, Dr. Wolcott wrote Commissioner Colón advising him, on my say-so, of the presence of *purchasi* in Puerto Rico and advised immediate extermination. I did not know this had been done however, until March 29. On this date I visited Mr. Barbour, Chief of the Insular Forest Service, to tell him that we had just recently discovered that the casuarina hedge in the Parque Muñoz Rivera in San Juan was generally infested and that light infestations occurred on one or two other hedges near the Union Club in Santurce. We also examined again carefully all the casuarina seedlings and larger trees at the Forestal with negative results. Mr. Barbour showed me a letter from Dr. Wolcott under date of March 19 urging that he watch carefully his casuarina seedlings in the nursery and saying that he had officially notified the Commissioner of the presence of *purchasi*.

"About this time Mr. Seín stated that he had found a rather bad infestation of what he had taken to be *Orthesia insignis* on the large casuarina hedge of the Colegio Puertorriqueño at Stop 15 in Santurce. The date was on February 26. This was now determined however as *I. purchasi*. He had recommended nicotine sulphate and soap. Some "gallego" plants, *Polysias Guilfoylei*, were also infested there.

"Based on Dr. Wolcott's notice of March 24th to the Commissioner, a meeting of the Insular Plant Quarantine Board was called on March 31 to consider possible measures to be taken against the cottony cushion scale. The history to-date in Puerto Rico was briefly reviewed and a resolution was made by Mr. López Domínguez and adopted to make a more thoro survey than had already been made of citrus and of casuarina especially in the vicinity of citrus groves as soon as practical and to determine, if possible, what agents may be holding the pest wherever it occurs.

"The next day, April 1, I visited Mr. Luciano's home in Santurce since Mr. Luciano had written me the day before that he had just observed parasites of the cottony cushion scale working there. There were present besides myself and Mr. Luciano, Messrs. Pemberton, and Anderson and Mills of the U. S. Plant Quarantine and Control Administration Office. A dipterous maggot was found working in the hollowed-out egg-sacks of the scale on the rose bushes and in some cases 3 or 4 puparia present in one empty egg-sack. Mr. Luciano stated that he had observed these rose bushes infested for about 2 years now and that the infestation was lighter now than formerly. There was no infestation on a number of casuarinas present in his garden. Two or three days later several small Phorid flies emerged from specimens of infested scales. This may possibly be *Syneura cocciphila* described from *I. purchasi* in 1895, from Mexico. Specimens were sent for determination to Washington thru Mr. Faxon's office by the boat of April 7.

"On April 2, Mr. Pemberton and I found that a number of scales in the lightly infested casuarina hedge alongside of the Olimpo Court Apartments at Stop 10, Santurce, were parasitized by the Phorid fly.

"Upon arrival at the Station Mr. K. M. Fletcher was there with a badly infested branch from his grapefruit grove at Palo Seco. He said a number of trees were infested, several badly so. Messrs. Pemberton and Seín and myself at once visited his grove and found that at least a dozen or fifteen trees had some branches badly encrusted with the insects and a number of other trees were lightly infested. Most of the trouble occurred on the first two rows next to a large bamboo windbreak along the road. A number of pigeon pea bushes next to the first row were also considerably infested. Mr. Fletcher stated that he had noticed this infestation over a month ago but it had just lately become much worse. He claims to have seen this insect present in his grove off and on in small numbers for the last

20 years. He had already scrubbed with brushes the larger branches of several trees previously, he said, badly infested.

"I recommended an oil or nicotine and soap spray at once and the immediate introduction of the Australian ladybird beetle.

"*April 4, 1932.* In the morning I went with Mr. Fletcher and Mr. Wildman (of the Isabela grove adjoining Mr. Fletcher's place) to see Commissioner Colón, and recommended introduction of the Vedalia beetles. I prepared a cable at once to the Florida State Plant Board requesting a prompt shipment of the beetles by air-mail.

"In the afternoon Fletcher's grove was again examined in company with representatives of the Insular and Federal Quarantine Services, Mr. Pemberton and Mr. Sims of the Nitrates Agencies.

"During the next few days I told several of the leading citrus growers about the infestation at Fletcher's and showed them specimens of the insect.

"On April 8, in company with Messrs. Anderson and Mills, of the Federal Plant Quarantine Office, we looked over Mr. John Kohn's (at Bayamón) casuarina windbreak and adjoining grape fruit trees as well as a number of rose bushes. Farther along the same road we found a light infestation on several trees in a large long casuarina windbreak and several grape fruit trees adjoining these as far as one tree in the 4th row from the windbreak lightly infested also. The Manager could not be located that afternoon.

"By previous arrangement I received from the Post Office in San Juan that night the shipment of 150 Vedalia puparia from Florida. They left Gainesville on the afternoon of the 5th.

"*April 9, 1932.* I had arranged to distribute the Vedalias in Mr. Fletcher's grove the first thing in the morning but was instructed by the Director to await the arrival of Dr. Wolcott who had been put in charge of the cottony cushion scale campaign by order of the Commissioner.

"*April 10, 1932.* The Director, Dr. Wolcott and I, released most of the Vedalias in Fletcher's grove in the morning—twelve boxes of them. Two boxes were put out on infested trees recently discovered in the adjoining Isabela grove and two were taken back to the Station. We then visited Mr. John Kohn and later arranged with the Manager of the Guildermeister grove nearby to start spraying with oil at once."

All the known occurrences of the cottony cushion scale in Puerto Rico up to that time were in San Juan and Santurce, or in citrus groves a few miles west along the coast, and widely separated by swampy marsh land, pasture or cane fields from the main citrus

producing section of the Island. The area was so limited in extent that for a time it seemed possible that the insect might be absolutely exterminated, if effective measures could be brought to bear upon it. The real difficulty was to determine what measures would actually be effective in extermination. A study of available literature showed only control measures, not extermination. By general admission, the lady-beetle *Rodolia* was only relatively effective, always leaving a few scales after cleaning up major infestations. Spraying was admittedly ineffective, and recommendations as to what to spray were vague and unsatisfactory. All that one could be sure of was that pruning of infested branches and destruction by fire of infested hosts would certainly eliminate those scales at least. Such treatment was quite practical in some cases, but hardly applicable generally in Isabela Grove, the largest single citrus property on the Island. As a matter of fact, however, the infestation in this grove was soon found to be so general that both spraying and pruning were generally adopted, and temporarily held the pest in check. In the adjoining grove, Mr. Fletcher had had little success in spraying with prepared oil sprays, consequently the old fashioned "cold-stirred" emulsion, with an excess of whale oil soap, was used in Isabela Grove.

Thru the co-operation of Mr. Fletcher and Mr. Kohn, a power sprayer was made available for immediate use by the Department of Agriculture in spraying casuarinas in San Juan, and as soon as funds were made available in the next fiscal year, a new power sprayer was purchased for this work. The conduct of spraying operations was under the supervision of Mr. Adolfo Mayoral, who previously had considerable orchard-spraying experience. He carried on extensive experiments to determine the relative merit of various sprays, and as a result, later sprayings were confined to the use of "Kerecide", a local preparation of standard composition which used fusel oil as stabilizer. His experiments showed that no spray is of much value during showery or rainy weather; but during dry weather, this heavy oil spray gives close to 100 per cent control. San Juan is an island, and most of the infestations in Santurce are close to the ocean, in some cases the casuarina trees being actually on the beach. It is under such conditions that the heavy oils give best results. Little is known about the effectiveness of this or other sprays under inland conditions, for up to the present no similarly extensive inland infestations have been available for experimentation.

Spraying and pruning operations having been gotten under way in localities where infestations were known to exist, the next step was to determine, if possible, all infestations. All available means

of publicity were used. Dr. Jaime Bagué, Sub-Commissioner of Agriculture, made announcements over the local radio broadcasting station. He also supervised the preparation of a poster, showing by reproductions of photographs of the insect on casuarina, what the insect looked like and requesting that all suspicious material be submitted for inspection. The text of the poster is as follows:

GRAVE PELIGRO PARA NUESTRA AGRICULTURA

La Cochinilla Blanca ha aparecido recientemente en los pinos australianos, rosales y toronjales de San Juan y sus cercanías.

Esta plaga es sumamente peligrosa; pues en una época casi acabó con los naranjos en el Estado de California.

Si usted encuentra dicho insecto en su jardín o en su huerto, ponga varios ejemplares en un frasco y envíelo a la Estación Experimental Insular, Río Piedras, P. R.

Coopere con nosotros a salvar la industria de toronjas de Puerto Rico que representa millones de dólares para el país.

A short descriptive article was circulated by both the fruit-growers' organizations, and write-ups appeared in San Juan newspapers. The aid of the Boy Scouts of the San Juan region was enlisted. Regional meetings of the Agricultural Agents were held in Río Piedras, Isabela, Ponce and Guayama, at which they were shown photographs of the insect (no live material was carried around the Island), and instructed to be on the constant look-out for infestations. While en route between these meetings, the senior writer inspected many casuarina trees, especially along the east and northeast coast. Later, a special inspection was made of the casuarinas and orange trees along the beach east from San Juan as far as Río Grande, the results being entirely negative.

The immediate returns from this publicity were encouragingly meagre. A few spider webs on casuarina needles were submitted by one anxious citrus grower, for these webs in size and color at least superficially resemble mature scales. Mr. Mariano Mari, in charge of the Demonstration Farm near Arecibo, noted an extensive infestation of the native cottony scale, *Icerya montserratensis* Riley & Howard, on orange, which he thought might be mixed with *Icerya purchasi* because many of the scales lacked the long waxy projections secreted by the native species. (See Plate XVI.) His suspicion was shown to be justified, when, a few days later, another infestation of *Icerya montserratensis,* on a single citrus tree at the Poultry Sub-Station at Pueblo Viejo, was discovered to be mixed with the Australian species. Several other large infestations were soon afterwards found in Pueblo Viejo, and a number of infestations in the

main Bayamón citrus district. A suburban resident on the Trujillo Alto road reported some scale on a rose bush which had been presented to him by a friend in Santurce. Scales were also found on the casuarinas besides the Las Monjas racetrack between Río Piedras and Santurce. All of these new records, however, were in the immediate vicinity of San Juan, and except in the one case where the scale had obviously been carried on the host, were to the west and southwest. No infestations were found to the east or far to the south, indicating that normal dispersion was resulting from the prevailing winds (from the east and northeast), and that this was by far the most important single factor in dispersion. (See Plate XVII.)

Even before the results of the publicity campaign were beginning to come in, Dr. Hoffman reported another infestation on causarina and citrus, west of Dorado, ten or twelve miles in an airline from San Juan and seven or eight miles west of Isabela Grove. At first this seemed to be an isolated outbreak, but later and more careful observations in this region disclosed an infestation in a few citrus trees just outside of Dorado. That only two infestations were discovered in this region is largely due to the scarcity of appropriate hosts, most of this region being in cane, pasture or coconuts. Their presence, however, and the complete absence of infestation east of San Juan, despite an abundance of suitable hosts, confirms the original observations on the importance of the prevailing wind as an agent in dispersion.

Farther west of Dorado than Dorado is west from San Juan, a small infestation was much later discovered on a windbreak of casuarinas in the hills back of Barceloneta, on the Florida road. This might have resulted from the scale being carried on an automobile, for the casuarinas were close to the main road into the grove, but it seems more likely that this infestation represents another chance wind infestation, a jump of at least twenty miles from the nearest other known infestation.#

Just as the prevailing wind is the most important factor in natural dispersion of the cottony cushion scale, so humidity is the most important factor determining abundance. The north coast of Puerto Rico, where all known infestations of cottony cushion scale occur, has an annual rainfall of from 50 to 90 inches. The distribution of the rainfall is by no means uniform thruout the year, and in general the late winter and the spring months are the dryest. The cottony cushion scale has unquestionably been present for several years in Puerto Rico, but it appeared in noticeable and distinctive

#- This infestation is now (October, 1933) known to have been of Icerya montserratensis, N O T

abundance only during the exceptionally dry spring of 1932. As the spring advanced, new infestations were discovered every few days, and despite a strenuous campaign of spraying and pruning, new areas of even denser infestation were constantly appearing in unsprayed parts of groves. The limited numbers of the Australian lady-beetles that could be released seemed quite unable to make an impression in the unsprayed areas where they had been released. During February, March and the first three weeks in April, 1932, less than an inch of rain per month fell anywhere in the infested area, and it was towards the end of this prolonged drought that the scales became most numerous.

The situation changed in May, 1932, when the average rainfall for the region was nearly 13 inches, and during June, July and August, averaged over 7 inches per month. For periods of four or five days at a time, rainfall would be almost continuous, and humidity would remain high, even when rain was not actually falling. Temperatures were also high during most of this period, not only during the day but all night long. It was a most uncomfortably hot and humid summer for people living in and near San Juan, and it was deadly for the cottony cushion scale. In citrus groves well protected by windbreaks, humidity remained high at all times, and, fortunately for the growers, most of the infestations were in windbreak-protected blocks. Isabela Grove, despite its proximity to the ocean, is exceptionally well protected, for the citrus trees were originally planted in clearings thru primeaval forest, and this natural windbreak has been constantly reinforced since. When the grove was examined in July, not a single live scale could be found. When one considers that thousands of trees in this extensive property had been infested only two and a half months previously, and new outbreaks were constantly being discovered on unsprayed trees so fast than all the spraying equipment available could not treat them, the contrast was amazing. A few lady-beetles had been released in this grove, but not a trace of them could be found in July, and their presence at any time could have been only a very minor factor in the elimination of the scale. Practically all of the infestations were found covered with a greyish-white fungus, never before observed in Puerto Rico. Thru the courtesy of Miss Vera K. Charles, this fungus was identified as *Spicaria* sp, and Mr. E. West of the Florida Station states that it is identical with what they call *Spicaria javanica*.

Very heavy infestations of limited extent on citrus trees in pockets in the hills around Bayamón showed even more beautiful examples

of complete and very recent destruction of the scales by this fungus. Its distribution was not extensive at first, however, and on one scale infestation discovered at this time on a citrus grove in Pueblo Viejo which had shortly previously been sprayed with Bordeaux, none of the fungus was to be observed. The owner brought leaves and twigs covered with fungus-killed scale from Isabela Grove, and placed them in one tree, otherwise untreated, between others which he sprayed with kerosene emulsion. Two weeks later, all the scale had been killed on the tree where the fungus had been introduced, while many scales were still alive on the sprayed trees. Naturally the owner was enthusiastic about the value of the fungus, and he was rapidly placing leaves with fungus-killed scale in all parts of his grove. Fortunately for the success of his experiment, humidity remained high for several weeks thereafter, and when examined a month later, not a single live scale could be found in his grove. Another report of scale infestation, which could not be examined immediately, was later found to have been completely eliminated by the fungus.

Continuously high humidity for several days is absolutely essential for the successful use of *Spicaria.* This was abundantly demonstrated in one grove where the scale infestation extended from a knoll-protected hollow to the top of a wind-swept hill. Within a few weeks, not a scale was to be found in the hollow, but as one went up the hill, infestations increased in intensity. The citrus grove at Dorado was very imperfectly protected from the wind, and here the fungus never appeared. Its requirements of humidity are more exacting than of a similar entomogenous fungus, *Cephalosporium lecanii,* which in the nursery at Dorado killed many hemispherical scales, *Saisettia hemispherica* Targioni, and green scales, *Coccus viridis* Green, on young seedlings also infested with cottony cushion scale. Experimentally, smears of its spores rubbed on scales on casuarina trees by Dr. Mel. T. Cook, of this Station, gave entirely negative results in control. Apparently casuarina trees, generally planted as windbreaks, retain with their needle-like leaves too little humidity on themselves to permit of this fungus being of much value for killing scales on them. Temperature is not so important, for even at minimum winter (tropical) temperatures, *Spicaria* is at least partially effective, as was later indicated in a grove at Bayamón, observed in January 1933, with many freshly killed scales.

The entomogenous fungus, *Spicaria javanica,* is by far the most important factor in control of cottony cushion scale during rainy weather and under generally humid conditions. It is, however, not the only agency attacking the scale in addition to the introduced

lady-beetles. Mention has already been made, in Dr. Leonard's MS report, of the discovery of Phorid flies attacking and developing within mature scales, and his tentative determination of these flies was later confirmed by Messrs. C. T. Green and J. R. Malloch as *Syneura cocciphila* Coquillet.

"The next most important natural enemy in Puerto Rico is the lace-wing fly, *Chrysopa collaris* Schneider. The trash-carrying larvae were usually found feeding in colonies of the scale, often commonly so, and a number of adults were reared. The pupal period occupied only 5 or 6 days.

"The common lady-beetle, *Cycloneda sanguinea* L., was frequently found feeding both as adult and larvae on the scales and the larva of a moth, undoubtedly *Ereuntis minuscula* Wlsm. was several times observed making heavy inroads where the scales were thickly encrusting twigs or small branches."(**7**)

Even more interesting was the discovery by the junior author, who was handling all the rearing work of the lady-beetles, that, among the scales brought in from Dorado as food for them, a few much smaller lady-beetle larvae were already present. They pupated when less than half the size of *Rodolia* larvae, the adults emerging being small, light red beetles, quite different from *Rodolia cardinalis* in size and color markings, and indeed differing from anything in the Station collection. They were entirely light red in color, except for black eyes, a black spot on each elytron, and a black margin at the base of the elytra and extending for a short distance along the sutural margin. The first specimens reared were sent to Washington for determination and Dr. Chapin replied that they were a new species. Later, additional immature material was collected at Dorado, which, together with other adults, was sent to the National Museum, where technical descriptions have been prepared by Drs. Chapin and Böving (**8** and **9**), the insect being named *Decadiomus pictus* Chapin.

A minute wasp parasite, *Cheiloneurus pulvinariae* Dozier, as determined by Mr. C. F. W. Meusebeck, was reared from cottony cushion scale by the junior writer in May, 1932. This parasite was originally described by Dr. Dozier from material reared from a soft scale of sugar-cane, *Pulvinaria icerya* Newstead, but which he considered as being "a hyperparasite on the primary parasite of this scale, *Aphycus flavus,* with which it is always reared."(**10**)

The original host in Puerto Rico of both this and the other recently discovered insects predaceous and parasitic on cottony cushion scale is the not very common native cottony scale, *Icerya montserra-*

lensis R. & H. The larvae and adults of *Rodolia* will also feed on this native scale, at least in captivity and indeed a few of them have been reared on this scale when a sufficient supply of the Australian species was not available. The Phorid fly, *Syneura cocciphila* was originally, according to a letter from Dr. Aldrich, "collected from *Icerya purchasi* at Victoria, Mexico, October 16, 1894; Magdalena, Sonora, Mexico, September 26, 1894; Tamaulipas, Mexico, November 30, 1894. These are records from the type material. Other specimens (in the National Museum collection) are from Sao Paulo, Brazil, collected by A. Hempel, January 1899, from *Icerya brasiliensis.*" To this is now added the rearing record from the native scale. One parasite which has been reared only from the native scale is a small yellow Braconid wasp, of which the antennae, eyes and wing veins are black, determined by Mr. C. F. W. Muesebeck as *Rhyssalus brunneiventris* Ashmead.

The high humidity of the late spring and early summer of 1932 was not only highly destructive of cottony cushion scale, but it also made the artificial rearing of the predaceous *Rodolia* lady-beetles extremely difficult. In all discussion of the rearing work, it must be kept in mind that no infestation of cottony cushion scale occurs within several miles of the Experiment Station at Río Piedras, and it was not considered a desirable policy to establish colonies there in the open, while facilities for rearing large supplies of food for the lady-beetles were not available under cover. Consequently, scales had to be brought in from elsewhere to feed the beetles, and often most of the scales collected at this time were either dead or dying from fungus attack, or became infected immediately they were brought to the insectary. In this emergency, the casuarina hedge in the patio of the School of Tropical Medicine, where Dr. Hoffman had first observed the scale, and where it was still abundant, proved of great value in keeping a supply of the beetles alive. Only a few pairs were released there originally, but they throve to such an extent that their progeny soon spread to adjacent scale-infested casuarina trees of the grounds around the U. S. Army barracks. By the middle of September, hundreds of pupae could be collected here, and releases of beetles were made in all citrus groves where infestations of the scale still existed. The combination of fungus in windbreak protected groves, with ladybeetles in those where protection from the wind was less perfect, had by the middle of September 1932, reduced infestations in citrus groves to insignificant numbers. Indeed, it was rapidly becoming difficult to find places where beetles could be released to advantage, for the supply of food in sight for them was

so limited. Had such conditions continued for only a short period longer, absolute extermination, which seemed so visionary six months previous, might have become a fact.

In certain groves, the destruction of cottony cushion scale by *Spicaria javanica,* not only approached, but actually was 100 per cent perfect. If such conditions had been general, the problem would have been solved. In reality, however, certain parts of infested groves were so poorly protected by windbreaks that the fungus had little effect, and on the casuarina trees and hedges of San Juan and Santurce, none at all. In a very few cases the *Rodolia* beetles destroyed every scale insect present, but in most cases a few scales would be found even where beetles were repeatedly released. It was apparent that there was not enough food present to feed many lady-beetles or their larvae, but they usually failed to eat up even that little. Where only a few scales were left on a small tree, these could be destroyed by hand-picking; but to care for other infestations on larger hosts, or widely scattered in a grove, some other means must be used. The statement of Prof. Essig regarding the relative efficiency of the Agromyzid fly, *Cryptochaetum iceryae,* and *Rodolia* (already quoted), was so unequivocal that it seemed desirable to attempt the introduction of this parasite into Puerto Rico, and see if it would clean up what the beetles left. Mr. S. A. Rohwer, Acting Chief of the U. S. Bureau of Entomology, referred the request for a shipment of these flies to Dr. Stanley E. Flanders of the Citrus Experiment Station, Riverside, California, for favorable action.

This was the picture in the latter part of September, 1932: cottony cushion scale absolutely eliminated in some groves where it had previously been very abundant, and greatly reduced everywhere else thru the activities of the lady-beetles, of which an over-abundant supply was available for release and distribution. Even had the beetles failed, we knew what spray would give greatest effectiveness in control under local conditions, and an adequate sprayer and a trained spraying crew was available for any emergency. In addition, a shipment of the Agromyzid parasite, *Crytochaetum iceryae,* was confidently expected in the near future. To be sure the distribution of the scale was quite extensive, but the situation was entirely under control and only time and a continuance of well organized activities were needed to successfully complete the campaign.

During the night of September 26–27, 1932, the hurricane of San Ciprián swept the northern coast of Puerto Rico and entirely changed the status of the cottony cushion scale. As was reported by the senior writer immediately afterwards, the hurricane had but little ef-

fect on soil insects, or on those living where they were well protected against its onslaught, but scale insects of all kinds suffered greatly. "The trunks and branches of trees exposed to the full force of the wind are smoothed of rough bark and all projections in a most surprising manner. Of course some scales persist in the crotches and on the petioles of leaves, but the breaking off of leaves, twigs and larger branches causes an immediate decrease in their numbers only exceeded by the mortality caused by the direct action of the wind and rain in rubbing the insects from their host."(**11**) Not only such large, fluffy and easily dislodged scales as *Icerya purchasi* were blown off of their host, but those with a tough, hard scale, closely appressed to the host, were also carried away. It was the rule, and not the exception, that 95 to 99 per cent of all the purple scales, *Lepidosaphes beckii* Newman, on citrus trees in the region affected by the hurricane, were removed overnight. In the next few weeks after the hurricane, no sign of cottony cushion scale could be found, even on hosts known to have been infested before the hurricane. Of course not every egg and every crawler had been destroyed, but it was a matter of months before the few surviving individuals could be found.

So far as can be determined from observations made in the following six months, the hurricane did not extend the distribution of the scale at all. No new infestations have been found since the hurricane, and apparently its actual effect it to destroy all those blown off the host, and not to carry them uninjured to a new host, miles away. The force of the hurricane wind is too great, and is destructive, rather than dispersive, of these soft, fluffy insects.

Just a month after the hurricane, a shipment of scales heavily infested with *Cryptochaetum iceryae* was received. This shipment was mailed at Riverside, California on October 18th, 1932, and was delivered at the Station in Río Piedras on the 25th, having been sent by air-plane mail. Thirty flies had already emerged en route, and these were released on the date of receipt in two, protected casuarina hedges in Santurce where a very few large cottony cushion scales had survived the hurricane. For the next weeks, releases were made of twenty or thirty flies every other day in every place where scales were known to have been present before the hurricane, even tho none could be found at the time of release of the parasite. A few weeks later, when scales were more apparent, daily hand collection was organized in San Juan and Santurce, but not a fly emerged from any of this material collected where the releases had been made. Nor were any flies reared from scales collected in citrus groves where releases had been made, and it appears probable that the introduction

was a failure, largely because the sending was received at a time when so few scales were available to be parasitized.

This imported Agromyzid fly was not the only insect dependant on cottony cushion scale, of which greater numbers were present immediately after the hurricane than could be fed. Because of lack of food for them, or any means of obtaining it, all the live *Rodolia* beetles at the Station had to be released in a citrus grove in Bayamón which before the hurricane represented the heaviest infestation of scale known at that time. Besides these beetles in captivity, some in the open also survived the hurricane. That casuarina hedge in the patio of the School of Tropical Medicine, on which Dr. Hoffman had first observed the scale on this host, and on which *Rodolia* was breeding at the time of the hurricane, was so well protected against the force of the wind by the three story building of the school as to be practically undisturbed. On October 6th, ten days after the hurricane, about thirty fresh (unemerged) beetle pupae were noted on this hedge. They were not collected for release of the beetles elsewhere, for scanty as was the prospective supply of food for them on this hedge, just then it represented more of large scales than was present is all the rest of Puerto Rico. These few *Rodolia* beetles were all that survived the hurricane, and practically all of their progeny perished soon after from lack of food.

So far as is known, *Rodolia* beetles survived the post-hurricane scarcity of food in only one place. In January 1933, a single beetle was noted by Mr. Richard Faxon on some scale infested pigeon pea bushes growing across the street from his office in the Ochoa Building, possibly a mile to the west of the School of Tropical Medicine. In the next few weeks, a number of fresh (unemerged) pupae were collected here, to form the nucleus of renewed breeding operations at the Station.

Thru the courtesy of Dr. C. L. Marlatt, Chief of the Bureau of Entomology, a shipment of *Rodolia* beetles was received from the Cottony Cushion Scale Laboratory of the Bureau, at New Orleans, being mailed there by Mr. A. W. Cressman on February 7th, 1933, and received at the Station in Río Piedras on the morning of the 11th. This shipment contained 35 pupae when it left New Orleans, several of which transformed to adult en route, and all arrived alive and vigorous. Combined with the few beetles collected from the pigeon pea bushes opposite the Ochoa Building, this shipment gave the Station an ample supply for breeding, so that hundreds of beetles were ready for release by the middle of the spring of 1933.

The hurricane of San Ciprián unquestionably destroyed 99 per cent or more of all the cottony cushion scale alive in Puerto Rico on September 26, 1932, and for the first few weeks afterwards, no scale could be found. But a few individuals had survived, and in the succeeding months they were able to reproduce more rapidly than before because the hurricane had even more completely swept away their natural enemies, even including windbreaks. At first it seemed as tho it might be possible to destroy these few survivors, and a careful and intensive search was made in every place where the scale was known previously to have been present, and every individual discovered was collected or destroyed by hand. Young scales were found in various protected locations on the host, between petioles and twig, in crotches, and in greatest numbers at the edge of the callus growing over the wound where a branch had been sawed off. An obvious clue to their discovery on citrus trees was a line of the fire ant or "hormiga brava", *Solenopsis geminata* F., which had promptly adopted this Australian immigrant, and entered into even more active symbiosis with it than with most native soft scales and mealybugs. As a general rule, citrus trees with no ants are free from "honey-dew" producing mealybugs or soft scales. Where ants were present, young colonies of cottony cushion scale (or some other soft scale, or mealybug) were almost invariably present also. The hurricane had doubtless destroyed much of the usual food of the fire ant, and they were in consequence especially solicitous to preserve and care for any insect able to provide them with "honey-dew". In numerous cases they were observed to have built a structure of carton and earth over young colonies of cottony cushion scale located on callus margins of wounds, such structures being reminiscent of hurricane sheds, or "tormenteras", altho all were constructed after the hurricane, rather than before. Gradually, as the citrus trees put out new leaves, the scales began to appear exposed on the new leaves and on twigs, having left their pseudo-tormenteras and no longer receiving such intensive care from the ants.

During the remaining months of 1932, the numbers of the scale increased slowly, but with the beginning of dry weather in the early months of 1933, a very considerable increase in their numbers became apparent. In not a single place had the scale been entirely destroyed, despite constant watchfulness and hand collection. The earlier outbreaks on casuarinas in San Juan and Santurce were controlled by spraying, and by organizing a system of daily hand collections from a few trees which were not sprayed, an adequate supply of food was maintained to rear and have ready for general distribu-

tion hundreds of *Rodolia* beetles early in March. Because such an abundance of the beetles, lacking in 1932, was available and was released this year, no such tremendous increase in abundance of the scale as occurred in the spring of 1932, paralleling the practical absence of rainfall, was to be expected this year. Approximately three thousand beetles were released in March, April and May of 1933, effectually checking all incipient outbreaks and so thoroly cleaning up others as to almost approximate local extermination.

SUMMARY

1. The Cottony Cushion, or Fluted Scale of Australia, *Icerya purchasi* Maskell, is known to have been present on rosebushes in Puerto Rico since early in 1931, and presumably had been present for some time previously.

2. It first appeared in noticeable and destructive abundance on casuarinas (Australian pines) in San Juan and Santurce, and in citrus groves mostly less than ten miles to the west and southwest of San Juan, during the exceptionally dry spring of 1932.

3. Natural dispersion of the scale is by the prevailing north-east winds: from the original focus in San Juan and Santurce to the west and southwest.

4. In the citrus groves well protected by windbreaks, the scale was entirely eliminated by an entomogenous fungus, *Spicaria javanica,* never before recorded from Puerto Rico, which attacked it during the extremely wet weather of May 1932, and persisted during the following humid summer months.

5. The Australian lady beetle, *Rodolia (Novius) cardinalis* Mulsant, brought to Puerto Rico by airplane from Florida and later from New Orleans, is reasonably efficient in cleaning up scale infestations in less humid locations, such as exposed citrus groves, and on casuarinas growing close to the ocean or planted to serve as windbreaks.

6. Of native parasites, the most important is a Phorid fly, *Syneura cocciphila* Coquillet, originally described from Mexico, and never before found in Puerto Rico. The scale is also attacked by a wasp, *Cheiloneurus pulvinariae* Dozier, described from Puerto Rico, and by a small lady-beetle, *Decadiomus pictus* Chapin, a new and previously undescribed species.

7. During dry weather, almost perfect control is obtained by spraying with a standard heavy engine oil-fish oil soap emulsion, of which fusel oil is the stabilizer.

8. Except in special instances where especially well protected by

high buildings, all the large scales and practically all the small scales were carried away and destroyed by the hurricane of San Ciprián, September 26–27, 1932. A few scales in protected locations on their hosts escaped destruction and were later able to increase rapidly in abundance because the hurricane had been even more destructive of their natural enemies.

9. So far as can be determined, the hurricane had no effect in the dispersion of the scale.

List of Illustrations:

PLATE XV

The Cottony Cushion Scale, *Icerya purchasi* Maskell, on Casuarina or Australian Pine, *Casuarina equisetifolia*. Natural Size. (Photograph by Guillermo Rodríguez.)

PLATE XVI

The Cottony Cushion Scale, *Icerya purchasi* Maskell, (left) and a native cottony scale, *Icerya montserratensis* Riley & Howard, (right) on Casuarina or Australian Pine, *Casuarina equisetifolia*. Twice natural size. (Photograph by Guillermo Rodríguez.)

PLATE XVII

The Known Infestations of the Cottony Cushion Scale, *Icerya purchasi* Maskell, in Puerto Rico, before the Hurricane of San Ciprián, September 26–27, 1932:

Smaller cities and towns referred to in the text indicated by circles; infestations by solid black areas. (Original.)

PLATE XVIII

Outline map of Puerto Rico showing by Dots the Extreme Limits of Dispersion of the Cottony Cushion Scale, *Icerya purchasi* Maskell. For details of exact location of infestations, see Pl. XVII. (Original.)

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PLATE XV.

PLATE XVI.

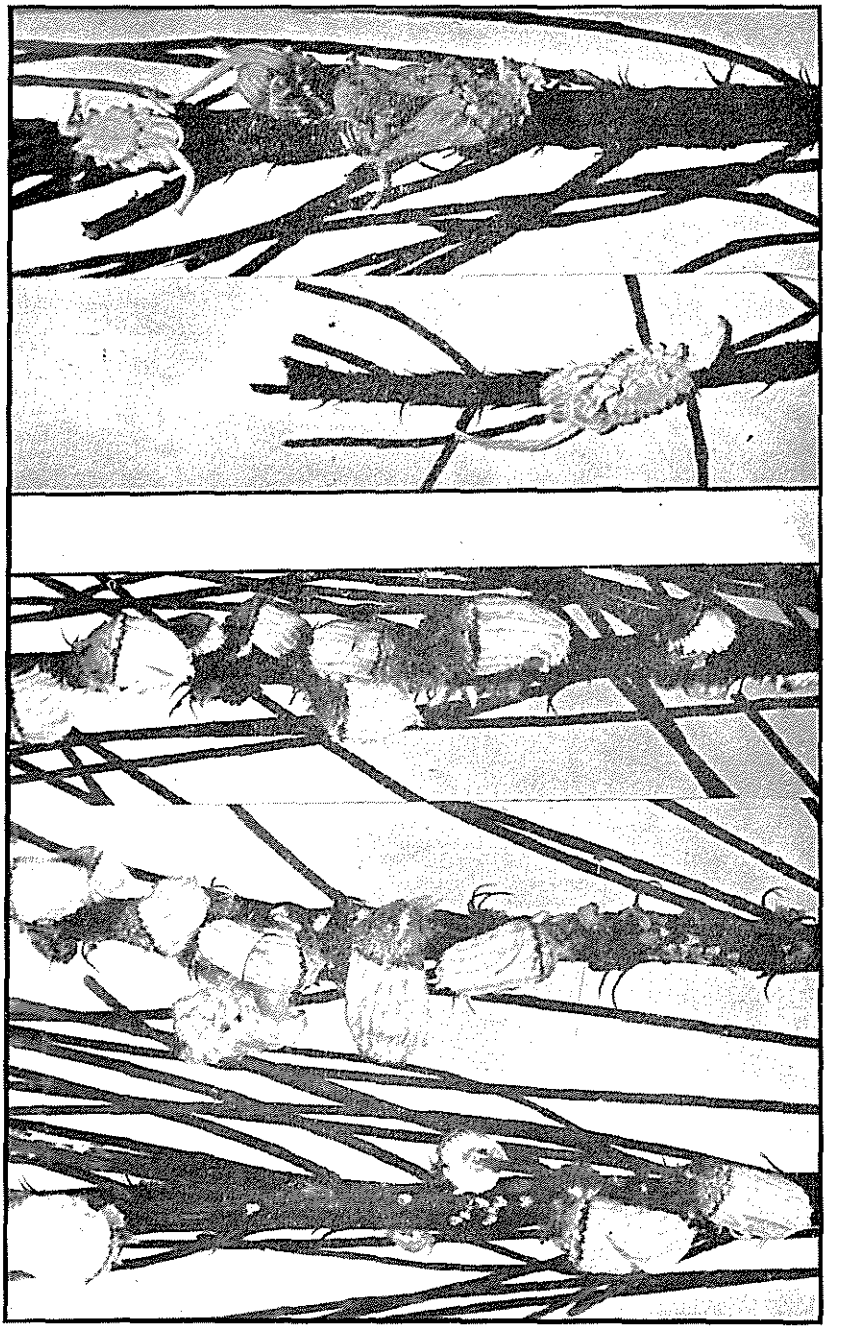

PLATE XVII.

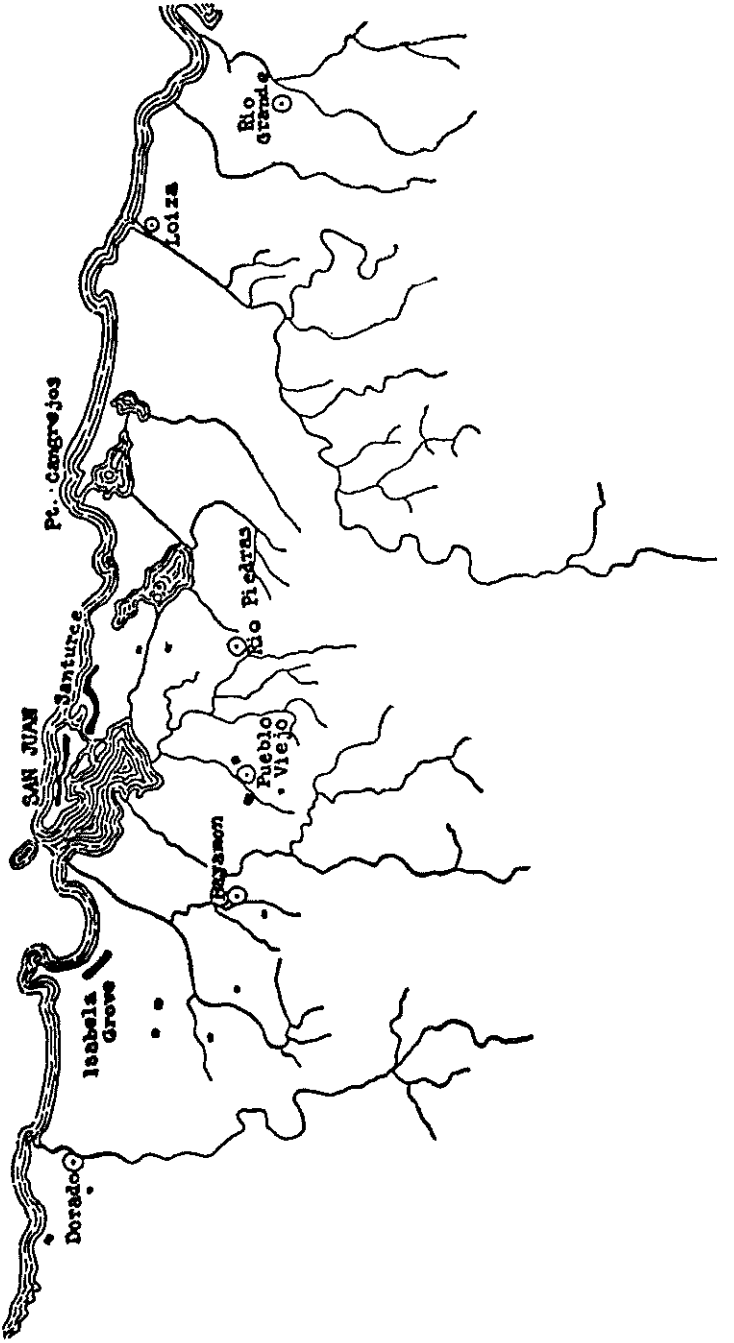
Rio grande
Loiza
Pt. Cangrejos
Santurce
SAN JUAN
Rio Piedras
Pueblo Viejo
Bayamon
Isabela Grove
Dorado

PLATE XVIII.