ON THE HAWAIIAN WORK IN INTRODUCING BENEFICIAL INSECTS

By L. O. HOWARD

There have been several efforts in the past few years to bring together some account of the experiments in different parts of the world with the practical use of the natural enemies of injurious insects. Probably the first of these was contained in the writer's paper on "The Economic Status of Insects as a Class," the address of the retiring President of the Biological Society of Washington, January 18, 1899, afterwards published in *Science*, new series, IX, No. 216, pp. 233-247, February 17, 1899, and afterwards republished in the Annual Report of the Smithsonian Institution for 1898, pp. 551-569 (Washington, 1900). The second was probably the writer's paper presented before the Massachusetts Horticultural Society January 13, 1906, and published in the Transactions of that Society for 1906, Part I, pp. 11-19 (author's abstract, Boston, October, 1896).

In 1907 was published Paul Marchal's important paper entitled "Utilisation des Insectes Auxiliaires Entomophages dans la Lutte contre les Insectes nuisibles à l'Agriculture," which appeared in the *Annals* of the National Agronomical Institution (Superior School of Agriculture), Part II, Vol. VI of the Second Series, pp. 281-354. The writer translated this paper, and it was published in *Popular Science Monthly*, Vol. LXXII, April and May, 1908, pp. 352-370 and 406-419. In this admirable summary, Marchal mentioned the work of the importation of the natural enemies of the sugar cane leafhopper by the Sugar Planters' Association of Hawaii, but was apparently uninformed at that time as to the success or non-success of the work.

In the following year, 1908, Dr. F. Silvestri visited the United States and Hawaii, and in 1909 published in the *Bulletin* of the Society of Italian Agriculturists another important summary, included in his account of his investigations, under the title "Sguardo allo Stato attuale dell'Entomologia Agraria negli Stati-Uniti del Nord America e Ammæstramenti che possono derivarne per L'Agricoltura Italiana." A translation of a large portion of this will be found in the *Hawaiian Forester and Agriculturist* for August, 1909 (Vol. VII, No. 8). Having spent a month on the Hawaiian Islands in intimate association with the entomologists at the Sugar Planters' station, Silvestri was able to give a rather full account of the work done there, and praised it highly.

A later general summary of the world work of this kind will be found in the first 46 pages of Bulletin 91 of the Bureau of Entomology,

"The Importation into the United States of the Parasites of the Gipsy Moth and Brown-tail Moth: A Report of Progress with some Consideration of Previous and Concurrent Efforts of this Kind," by L. O. Howard and W. F. Fiske (Washington, 1911). In this account some space is devoted to the search for parasites of the sugar cane leaf-hoppers in Hawaii, with the final statement that "The practical results of these importations seem to have been excellent. There seems no doubt that the parasites have been the controlling factor in the reduction of the leaf-hoppers."

The latest to be published is the chapter entitled "Die biologische Bekämpfung," in K. Escherich's book, "Die angewandte Entomologie in den Vereinigten Staaten," published by Paul Parey in Berlin, 1913; but in this account the Hawaiian work is not mentioned.

The Hawaiians themselves have not bragged about their achievements. They have published bare statements of facts with technical descriptions of imported species, but have shown themselves aggrieved by statements made by Froggatt in his account of his journey around the world during which he spent a month on the islands and they have published, as just indicated, a translation of a large, part of Silvestri's commendatory paper. Recently, however, they have seemed to be more inclined to tell the world exactly what they have done and to welcome the favorable and even enthusiastic comment which must necessarily follow a widespread knowledge of their achievements. Mr. O. H. Swezey, for example, in an excellent, straightforward, and at the same time modest paper which he read before the meeting of the Association of Economic Entomologists at Berkeley, California, during the first week of last August (published in the JOURNAL OF ECONOMIC ENTOMOLOGY, Vol. 8, No. 5, October, 1915), has put the entomologists of the world in possession of many new facts which were unknown to them before.

But still, enough has not yet been said, and the writer satisfied himself by a visit during August, last, to Oahu, by observation, and by interviews with the scientific men of the island and with the practical men of affairs, that Hawaii has seen a most extraordinary series of successful experiments in the introduction of beneficial insects which has in toto far excelled anything of the kind that has been done elsewhere in the world and which has resulted in an immense monetary saving. There can be no doubt of it.

THE SUGAR CANE LEAF-HOPPER AND ITS IMPORTED PARASITES

The sugar cane leaf-hopper of Hawaii (*Perkinsiella saccharicida* Kirkaldy) appears to have been introduced with seed from Australia about 1898.

It was first found harmful to sugar in 1902. It spread rapidly, and in 1903 damaged the crop to the extent of three millions of dollars. That year Koebele came to the United States to look for parasites.

In 1904 Koebele and Perkins went to Australia; got more than one hundred species of parasites of leaf-hoppers, and although failing with their first consignment sent in cold storage from Cairns, later shipments from Bundaberg were successful. They were reared in confinement and liberated in cane fields.

The year 1904 showed enormous loss from the leaf-hopper on many plantations. In 1906 certain of the parasites began to multiply very rapidly.

In 1907 one very large plantation, owned by the Hawaiian Agricultural Company, whose crop had dropped from 10,954 tons in 1904 to 1,620 tons in 1905 and to 826 tons in 1906, made the next year 11,630 tons almost entirely as the result of the parasite introduction.

Silvestri visited the islands in 1908 and reported with enthusiasm on the results of the introductions.

During August, last, the situation with regard to the sugar cane leaf-hopper on the island of Oahu was almost perfect. The canes were not damaged in any respect so far as I could see. The leaf-hoppers were still present, but in insignificant numbers; where they had oviposited their eggs were almost invariably parasitized either by *Paranagrus* or *Ootetrastichus*.

I was told that there is an occasional reviving of the leaf-hoppers in numbers, following the destruction of parasites by trash-burning, and that, at that time, on one large plantation on the island of Hawaii, 1,000 acres was so badly infested that a yield of only one-half a normal crop was expected; but these recrudescences are and probably will be fugitive.

No other leaf-hopper parasites were seen. Some of the parasites of the adults, notably *Haplogonatopus* (a Dryinid), I was informed, still exist on the islands.

THE SUGAR CANE BORER AND ITS PARASITES

The sugar cane weevil borer, *Rhabdocnemis* (*Sphenophorus*) *obscurus*, has been a pest on the islands for very many years.

After the success of the egg parasites of the leaf-hopper in 1904-5, the Planters' Association began to search for parasites of the weevil. F. Muir started on an exploring trip, and in 1908 found a Tachinid fly (*Ceromasia sphenophori* Villeneuve) at Amboina in the East Indies parasitizing a weevil infesting sago palms, sometimes destroying 90 per cent of the borers, the weevil being probably only a geographic variety of the sugar cane species.

During the summer of 1908 efforts were made to send this tachinid to Hawaii by means of a relay breeding station at Hong Kong, but failed. Later, in British New Guinea, Muir found the same tachinid destroying a borer in sugar cane, identical with the Hawaiian species, and destroying a high percentage. He succeeded in breeding it in cages. He was taken down with typhoid, and on arriving at Brisbane, Australia, was forced to go to a hospital. His parasite cages were sent on to Honolulu, but, wanting proper care, the parasites died.

After his recovery he met J. C. Kershaw, an entomologist whom he had previously met at Macao, China, at Brisbane in January, 1910. Kershaw prepared cages at Moresby, North Queensland, and Muir went to New Guinea where he collected puparia of the tachinid and sent them to Kershaw. The latter placed these in cages containing the prepared sugar canes containing numerous borer larvæ.

Muir continued to send puparia until Kershaw had the tachinids satisfactorily breeding, when he joined him, and, taking fresh puparia from the cages, went to Fiji where another breeding station was established. When this was successfully done, Kershaw abandoned the cages in Queensland and went to Fiji with more puparia. When he arrived, Muir went to Honolulu with tachinids, leaving Kershaw in Fiji where he remained a few more weeks and then came on to Honolulu with additional parasites.

Muir arrived in Honolulu with living parasites in August, 1910, and Kershaw arrived the following month. Part of the parasites were liberated and others retained in breeding cages.

The breeding continued for two years in the cages; the colonies were liberated on sugar plantations as rapidly as they were available. They bred continuously, each generation requiring about six weeks, and there were about six generations a year.

After six months they were found established and increasing in plantations where the first liberations were made, and in a year spread to all parts of these plantations, sometimes over a distance of five miles.

In 1914 Swezey reported (*JOURNAL OF ECONOMIC ENTOMOLOGY*, December 14, 1914) that they were established almost entirely throughout the sugar cane districts of the islands.

Prior to the introduction of parasites, hand collecting had been practiced on some plantations. On one plantation, in 1913, 27,010 ounces were collected; in 1914, on the same plantation, only 3,440 ounces were collected, showing a reduction of over 87 per cent.

In August, 1915, I found the borer rare on Oahu. In no case did I find a living larva. Mr. Swezey and Mr. Osborn found for me a number of burrows, but in every case when they were opened the larva had been destroyed and the puparia of the tachinid were present.

As the result of this importation, there has been a very great increase in the sugar yield per acre. The gain runs into the hundreds of thousands of dollars.

The adult tachinid places her eggs at openings in the rind of the cane where the borer larvæ feeding inside have come to the surface. The maggots find the borer larvæ in the channels, penetrate the body and kill the host when it is about ready to pupate. From one to a dozen maggots may thrive in one borer larva, but one is sufficient to kill it. The puparia are found in the fibrous cocoon made by the full-grown borer larva. The flies on issuing make their way through the cocoon and out of the cane through the hole which the borer larva had previously made.

THE MEDITERRANEAN FRUIT-FLY AND ITS INTRODUCED PARASITES

The Mediterranean fruit-fly has been present in Hawaii since some time prior to 1910, and has practically stopped the growing of fruit except pineapples and bananas, although some sound mangoes and alligator pears are still raised.

On account of the occurrence of enormous quantities of wild guava bushes all over the mountains, the extermination of the fly or even its great reduction in numbers seems to be impossible. The destruction of the fallen fruit afforded little relief. Poisoning experiments, although somewhat successful, could not control, on account of the enormous wild supply.

Silvestri, by his favorable report on the work of the Sugar Planters' Association in the introduction of parasites of the leaf-hopper, achieved the good will and admiration of the Hawaiian people, notably Mr. W. M. Giffard, Chairman of the Entomological Committee of the Sugar Planters' Association and President of the Hawaiian Board of Agriculture and Forestry. He therefore asked Silvestri to search for parasites of the fruit-fly and to introduce them into Hawaii. Silvestri started July 25, 1912, and visited the Canary Islands, Senegal, French Guinea, Southern Nigeria, Gold Coast, Dahomey, Congo, Angola, and South Africa; then, by way of Australia, he went to Honolulu, arriving May 16, 1913.

He brought with him from West Africa, having continuously reared them through the journey, 300 specimens of *Galesus silvestrii* Kieffer, 500 specimens of *Dirhinus giffardi* Silvestri, 12 specimens of *Opius perproximus* Silvestri, 5 specimens of *Opius humilis* Silvestri, and 4 females and 3 males of *Diachasma tryoni* Cameron. The rearing of these was begun by Mr. D. T. Fullaway until September 30, and then by Mr. J. C. Bridwell from October 1 to December 31, 1913. It was found not very difficult to rear some of them in confinement. The

Galesus and the Dirhinus, both pupa-parasites and received in the greatest numbers, have not yet become established. They have been put out in quantity but have not been recovered in the open. Whether the character of the soil is the trouble, or whether they are all destroyed by the fire ant is a question.

The Braconids were discouraging from the start. *Opius perproximus* failed. *Opius humilis* and *Diachasma tryoni* were divided. Four females of *Diachasma* and three females of *Opius* were liberated in the district of Kona. Those retained in breeding cages were lost.

Now comes the extraordinary thing. From the insignificant number of seven females of the *Diachasma* and *Opius* liberated in Kona, both species have become established! Both are larva-parasites, and were rediscovered by Mr. Giffard and Doctor Back. An examination made by Back and Pemberton in the summer of 1914 indicates percentages of parasitism as high as 85 in larvæ from coffee berries grown in the Kona district, 97.8 per cent in larvæ from coffee berries at Lanihau and high percentages in other fruits at other places.

THE EARLIER INTRODUCTIONS

The earlier introductions of parasites and beneficial insects against injurious insects, made by Kœbele before the outbreak of the sugar cane leaf-hopper; have been rather fully considered in Mr. Swezey's paper and elsewhere. Very many of them undoubtedly did excellent work. In spite, however, of the large numbers of enemies of mealy-bugs that were introduced at that time, outbreaks are frequent though not serious; and, although efficient parasites were introduced for leaf-rollers and the latter are not now very injurious, outbreaks occasionally occur. This, however, is quite to be expected, and in any consideration of the value of imported parasites we must never expect extermination but a reduction to comparatively non-injurious numbers with an occasional increase to some extent.

In the case of none of these early introductions was there sufficient study made of the intimate biology of the species introduced, and in fact the most careful study should be made now of the intimate life-history of the recently introduced parasites, and especially of those which are still coming in from Mr. Fullaway. Some of this work I hope Mr. Timberlake will be able to do.

Just why they have been able to accomplish so much is at first glance rather hard to understand. As early as 1897 Mr. R. C. L. Perkins, writing in *Nature* (Vol. 55, No. 1430, March 25, 1897), and referring to the successes of the importations of many species by Kœbele for the purpose of destroying various crop pests, wrote as follows:

It becomes natural to ask why the success of the imported beneficial insects has been so pronounced here, while in other countries it has been attained in a comparatively small measure. The reason, I think, is sufficiently obvious. The same causes which have led to the rapid spread and excessive multiplication of injurious introductions, have operated equally on the beneficial ones that prey upon them. The remote position of the islands, and the consequently limited fauna, giving free scope for increase to new arrivals, the general absence of creatures injurious to the introduced beneficial species, and the equability of the climate, allowing of almost continual breeding, may well afford results which could hardly be attained elsewhere on the globe. The keen struggle for existence of continental lands is comparatively non-existent, and, so far as it exists, is rather brought about by the introduced fauna than by the native one.

In commenting upon Mr. Perkins's paper, the writer, in his address on "The Spread of Land Species by the Agency of Man," said: "Mr. Perkins's reasons are all good, but he has not mentioned one prime reason of success, and that is that the most successful of the imported species have come from another portion of the same great faunal region, while others have been received from the region most closely allied, viz. the oriental." This was in connection with a discussion as to the chances of acclimatization of insects brought from different life zones.

In connection with this discussion, by the way, I concluded: "It is on the degree of simplicity of its life—the degree of simplicity of its natural environment as a whole—that the capacity of a species for transportation and acclimatization, even in a parallel life zone, depends." Mr. H. S. Smith recently, in a letter in which he quotes this sentence, very aptly writes: "It seems to me that the degree of simplicity of the new environment is quite as important. If the species introduced into Hawaii had encountered the complex relation that *Apanteles fulvipes* did in New England, where it was attacked by eighteen different species of secondaries as well as several predators during the first generation, there might have been a different tale to tell!"

It must be pointed out in conclusion that while conditions in Hawaii are extremely favorable for the reasons which Dr. Perkins formulated so early in the game, the men in control of the work were fortunate in themselves in the first place, and in having Mr. Giffard among them, and fortunate in being able to financially support any promising measure; and were fortunate, also, in having Mr. Kœbele and Dr. Perkins at hand; and were fortunate later in being able to add to their forces such men as Swezey, Muir, Silvestri, and Osborn, and now Fullaway; and at the present moment Timberlake, with his admirable technique and broad knowledge, is on the Pacific on his way to take up parasite work under the combined auspices of the Sugar Planters' Association

and the Territorial Board of Agriculture. All the possible requirements for successful work have thus been filled, namely the most favorable climate (permitting continuous breeding throughout the year), the most favorable conditions of cultivation, a small number of crops, a restricted and simple fauna, a highly intelligent body of men in control, with plenty of means, and an altogether admirable force of scientifically trained employees. As the French would say, *Que voulez vous encore?*

What we shall want later is a complete account of the whole work from Mr. Giffard or Dr. Perkins or Mr. Muir or Mr. Swezey. The work has been most notable and should have its written history available to all.

FURTHER NOTES ON PROSPALTELLA BERLESEI HOW.

By L. O. HOWARD

The little Aphelinine parasite known as *Prospaltella berlesei* has become a creature of much international and practical importance, and its name in various combinations, not only as a noun but as a verb as well, has made its entrance into the Italian and Spanish languages, and bids ultimately in these same combinations to enter the English language.

Originally found by Berlese in Florence, issuing from lilac twigs infested by *Diaspis pentagona* sent from Washington by Marlatt at the writer's request in May, 1906, this parasite was sent back to the writer in Washington, was found to be new, and was described by him as *Prospaltella berlesei* in an article on the parasites of *Diaspis pentagona* in *Redia*, Vol. III, part 2, and in the *Entomological News* for October, 1906, pp. 292-293. Sendings of parasitized scales from Washington to Florence were continued during 1906, 1907 and 1908.

Berlese's continuous success in rearing and colonizing this parasite on mulberry trees affected by the scale has been reported from time to time, notably in an article in the *JOURNAL OF ECONOMIC ENTOMOLOGY* for August, 1912, pp. 325-328, translated by the writer from a French abstract of Berlese's report drawn up by Dr. Caterina Samsonoff.

During the past year Professor Berlese has published in a long article in *Redia* (X, Parts 1 and 2, May 20, 1915, pp. 151-218) a summary account of the warfare in Italy against *Diaspis pentagona* which at the beginning of the present century threatened the extinction of the silk industry of Italy through the destruction of the mulberry, of the early laws enacted to enforce the mechanical and chemical fight