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NATURAL PARASITISM BY *TRICHOGRAMMA MINUTUM* OF THE EGGS OF THE SUGAR-CANE MOTH BORER, *DIATRAEA SACCHARALIS*, IN THE CANE FIELDS OF PUERTO RICO

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THE STATUS OF *Diatraea*

The insect pest causing greatest injury to sugar-cane in Puerto Rico at the present time is the lesser moth borer, *Diatraea saccharalis* F. This was not true even a few years ago, when white grubs chewing into the root-stalks were much more seriously injurious, but since the giant Surinam toad, *Bufo marinus* L., was introduced and became abundant feeding on the adults of the white grubs, these insects have generally become so scarce as to be of minor importance at present. The weevil root-stalk borer, *Diaprepes abbreviatus* L., is also to some extent reduced in numbers by the introduced toad, and the injury caused by this insect alone (unaccompanied by that of white grubs) is rarely sufficiently noticeable to be observed by the cane grower. For a series of years following the introduction and planting of varieties of sugar-cane immune or resistant to mosaic disease, the yellow aphid, *Sipha flava* Forbes, became a serious pest on these varieties of cane, and often spread from them to adjacent fields of other varieities. In the last few years, however, further changes in the varieties of sugar-cane extensively grown have reacted so unfavorably on the yellow aphid that it now seems to be usually controlled naturally by rainfall and its predaceous and parasitic enemies. This leaves the moth borer as the only remaining serious pest of sugar-cane in Puerto Rico not subject to more or less effective commercial control by natural factors.

The lesser moth borer occurs as a pest of sugar-cane not only in Puerto Rico, but also in all of the other West Indies (including all of the Lesser Antilles in which sugar-cane is grown), in Louisiana, Mexico, Brazil, Perú and Argentina, and is known to have been present in all these countries almost since the beginning of sugar-cane cultivation. Naturally it has been the subject of extensive studies, but without the discovery of any really effective control anywhere. A very partial control is obtained in Puerto Rico by the extensive adoption of the practice of not burning cane trash, before, during or after the harvesting of the cane stalks: excellent so far as it goes, but after all, not as effective as might be wished, and often erratic in its results. The lack of any effective artificial method of control has necessarily resulted in a very careful consideration of the use and value of the natural enemies of the moth borer.

Parasites of the Larva

Considering the natural enemies already present in Puerto Rico in the inverse order of their importance, it should be noted that the fungus attacking the caterpillars, *Cordyceps* (*Isaria*) *barberi* Giard, altho reported as being rather common in some of the other West Indies, is normally so scarce in Puerto Rico as to be valueless in control.

In examining the stomach contents of Puerto Rican lizards to determine what they had eaten, Wolcott (1924) noted that all of the common smaller species present in or near cane fields, *Anolis pulchellus, Anolis krugii, Anolis stratulus* and *Anolis cristatellus,* had eaten moth borer caterpillars, but in too small an amount to form a very considerable factor in control.

Concerning the Tachinid fly which attacks *Diatraea* caterpillars, Box (1928 a) states that "*Lixophaga diatraea* Townsend is the only larval parasite of any importance in Porto Rico." He found that the average parasitism during February-March 1925 was 12%, and during October-November 1926 was 37% (between Río Piedras and Trujillo Alto), but his conclusion as to how the value of this parasite might be increased for Puerto Rico is distinctly discouraging. "The writer does not think that the efficiency of *Lixophaga* can be artificially increased in any way, as it seems that this parasite has reached its maximum effectiveness." More recently, Dr. K. A. Bartlett (Anon. 1939), incidental to his work on rearing imported parasites of *Diatraea,* has collected extensive data on *Lixophaga.*

"The highest parasitism recorded for this species was 31.9 percent at Hormigueros, while the average for all collections was 9.6 percent. In view of the high infestation of cane by the moth borer, which was found to be as high as 96 percent in some fields on the south coast, it can be readily appreciated that on the whole this native parasite plays only a small part in the biological control of the borer. In some localities, however, under certain favorable conditions, it is of economic importance"

Introduced Parasites

The introduction from other countries into Puerto Rico of natural parasites of the moth borer not already occurring here was initiated by Mr. Harold E. Box (1924), when he brought from British Guiana in cold storage numerous cocoons of two Braconid wasps which attack the caterpillars: *Microdus diatraeae* Turner (now called *Bassus stigmaterus* Cresson) and *Ipobracon grenadensis* Ashmead. The former species became established here, for he recovered it in small numbers in 1925 and 1926 at Aguirre, where the releases were made, and it has since been found at Hormigueros by Dr. K. A. Bartlett in 1936, and by the writers at Isabela in 1938. It is by no means abundant in the other countries where it occurs, and presumably it is hardly to be expected that it will become sufficiently abundant in Puerto Rico to be an important factor in control. Despite the larger number of *Ipobracon grenadensis* later sent by Mr. Box (1928) and Mr. Luis A. Catoni from Venezuela, this species apparently did not become established here (Seín 1929), or at least it has not since been recovered in the field.

In 1935, additional shipments of *Bassus stigmaterus* Cresson were made from British Guiana by Mr. S. M. Dohanian (1937), altho his efforts there were largely devoted to obtaining large numbers of the so-called "Amazon Fly", *Metagonistylum minense* Townsend, for release in Puerto Rico. In 1936, Mr. Dohanian sent large numbers of *Ipobracon rimac* Wolcott from Peru to Puerto Rico, but none has since been recovered here in the field. The Amazon Tachinid fly apparently did not become established at this time, and later Dr. Bartlett made additional shipments of the Amazon fly from British Guiana and reared large numbers in captivity in Puerto Rico for release here, but with no field recoveries. In 1939, Dr. Bartlett collected in Sao Paulo, Brazil, an abundance of material of a physiological strain of the Amazon fly occurring under comparatively dry conditions, which, it was thought, might be better adapted to the dryer regions of Puerto Rico. This strain has been reared in Puerto

Rico and large releases made, with field recoveries (Anon 1940) at some localities.

Of the natural enemies, native and introduced, of the *Diatraea* caterpillar, one may summarize the prospect in Puerto Rico for the control of the moth borer, that (1) the fungus is of negligible value. (2) the lizards which eat the caterpillars are a minor factor, (3) the native Tachinid fly, which is unquestionably a considerable factor at times, can not be increased in abundance or efficiency by anything that can be done by man, (4) the one introduced parasite which has become established here is scarce, and, being of little importance elsewhere, may be presumed to be of little more value present or prospective in Puerto Rico, and (5) the status of the Amazon fly is still uncertain.

Parasites of Pupa and Adult

Specific parasites of the pupa of *Diatraea saccharalis* are unknown. One can only surmise as to natural enemies of the adult, for flight of the moths is almost entirely nocturnal, and, for practical purposes, is confined to the cane field. Lizards may possibly eat resting adults in the daytime, or at night those coming to rest around lights. No nocturnal birds occur in Puerto Rican cane fields, but possibly swallows at twilight might catch some of the moths. There is a distinct possibility that bats might catch and eat considerable numbers, but cane fields adjacent to bat caves give no indication of this by the smaller number of eggs laid on the leaves, or less stalk injury caused by the caterpillars. Indeed, the prospect of control of the moth borer by its natural enemies during the pupal and adult stages is by no means bright, leaving the egg stage as the one remaining point of attack.

The Eggs of *Diatraea*

The individual eggs of *Diatraea saccharalis* are oval and quite flat, being lenticular in cross-section, and are normally deposited in clusters consisting of rows usually paralleling the veins of the cane leaf, regularly overlapping like fish-scales, on either the upper or the lower side of the cane leaf. The junior writer found that less than 2% of all clusters collected over a period of some months are deposited close to the margin of the leaf; 31% were on the midrib of the upper surface of the leaf; 23% were beside the midrib on the under side of the leaf, and 45% were between the midrib and the outer margin of the leaf. The number of eggs in a cluster varies considerably, but four-fifths of the clusters contain between 8 and 36, altho large clusters containing between fifty and seventy are sometimes found, as are also individual eggs, or clusters of only two or three.

When first laid, the eggs are very light yellow, deepening somewhat in color for the next few days, becoming spotted with orange on the next to the last day, and showing the black head and the segmentation of the caterpillar thru the thin egg-shell by the final day before hatching. During extremely hot weather, incubation of eggs in the field may require as little as five days, but under ordinary conditions in the tropics, hatching takes place on the sixth or seventh day. Thus, for an entire week one stage of the borer is in plain sight on the cane leaves, where it can be readily attacked by any predaceous or parasitic animal interested in such a minute bit of concentrated nourishment.

Trichogramma

The eggs of many different kinds of moths and butterflies in many tropical and temperate zone countries are attacked by a minute cosmopolitan wasp, *Trichogramma minutum* Riley. This Chalcid wasp has pink eyes, a yellow body, darker abdomen and clear, irridescent wings, and despite its minute size, is generally so abundant that entomologists, at least, often see it in the field parasitizing some moth or butterfly egg. It is so minute as to find ample nourishment for the complete development of one individual (and sometimes of two or more) to adult within the shell of a single moth or butterfly egg. It attacks the eggs of *Diatraea saccharalis,* and is so omnipresent as to constitute one of the most important factors in borer control. It is to favor this parasite that the non-burning of cane trash is advocated. Furthermore, as a more positive measure in increasing the abundance of this parasite in cane fields at the time when its presence is most essential, the release of large numbers of individuals artificially reared in the laboratory has been practiced for a considerable number of years in several cane-producing countries. To determine the value for Puerto Rico, under local conditions, of adopting this practice of artificially rearing *Trichogramma* wasps and releasing them in borer-infested fields, an investigation was started in the late summer of 1936 by the Division of Entomology of the Agricultural Experiment Station at Río Piedras.

History of the Investigation

For the first year, it was planned to make a preliminary survey of the conditions as they occur naturally and normally, before any releases of *Trichogramma* were made, and with this as a basis, to commence releases in the second year. The reason for this preliminary survey was to determine if the cycle of host egg abundance and parasitism was the same in Puerto Rico as had been reported in other countries, to properly time the releases in the second year as to season, or time of year, or rainfall, or whatever factor might appear to be of most influence. In retrospect it appears that conditions observed in the first year were hardly typical in some regions, thus the releases made in the second year were successful (to the extent that they were successful) only by accident. Obviously, further field observations on natural conditions were essential, and no releases were made during the third year, but more time was devoted to the problem, with a reduction in the time period between observations. The problem had not been solved at the end of the third year, but enough data had accumulated to plan releases with some degree of certainty in the fourth year and to confirm them in the fifth year, while observations on natural conditions were continued during the entire period until field work was discontinued late in 1941.

The results reported in the present paper are for five years of continuous observations on the abundance or scarcity of the egg-clusters of *Diatraea saccharalis,* and on natural parasitism by *Trichogramma minutum,* in most of the important cane-growing regions of Puerto Rico. The results of the releases of artificially reared *Trichogramma* have been presented elsewhere, and do not affect these observations on natural parasitism. At the localities where releases were being made, only the check fields are here noted. As releases were usually repeated each week for a series of weeks in a region, however, the records of normal conditions at these points are available at shorter periods than elsewhere.

REGIONS

As originally planned, the observations were to be made for one week in the region between San Juan and Arecibo, for another week in the Isabela region, a third week in the Guánica to Ponce region, a fourth along the south coast east of Ponce, and a final week in the northeastern corner of the Island. (Because of the foreign parasite introduction work being conducted at the Federal Experiment Station at Mayagüez, many of the releases of which, it was thought, might be made in the cane regions adjacent to Mayagüez and thus affect the moth borer in that region, no observations were made at Rincón, Añasco, Mayaguez and Hormigueros, and very few at San Germán.) As the investigation developed, it became clear that these regional units were too large, while individual records showed too much variation to be considered separately. Scattered observations anywhere in the region were eliminated, as were those far distant from a point where a co-operative observer of the Weather Bureau recorded rainfall and temperature. Eventually, observations were restricted to the localities given in the accompanying table (Table No. 1), which are arranged beginning at the southwestern corner of the Island, proceeding thence along the south, east and north coasts to the northwestern corner. That a clearer mental picture may be obtained of these regions, the average annual rainfall for the period September 1936 to August 1941, inclusive, and the maximum and minimum temperatures recorded at any time during this period are given for all localities for which records are available. It should be understood that these are extreme temperatures for the five years, not normal for the greater part of the time.

TABLE NO. 1

Coastal Cane-Growing Regions of Puerto Rico

AVERAGE ANNUAL RAINFALL	LOCALITY	TEMPERATURES MAXIMUM AND MINIMUM	
33.43 in	Guánica to Yauco	92°F.	53°F.
		(after December 1939)	
29.02 in.	Guayanilla and Tallaboa		
35.51 in.	Ponce	98°F.	57°F.
32.77 in.	Santa Isabel and Juana Díaz	93°F.	62°F.
		(after February 1940)	
38.59 in.	Salinas and Aguirre	96°F.	60°F.
56.33 in.	Guayama and Arroyo	96°F.	60°F.
89.21 in.	Patillas, Maunabo and Yabucoa	99°F.	61°F.
87.40 in.	Humacao and Naguabo	95°F.	54°F.
61.80 in.	Ceiba, Fajardo, Luquillo and Mameyes	93°F.	61°F.
75.65 in.	Río Grande, Loíza and Canóvanas	95°F.	56°F.
65.25 in.	Toa Baja and Dorado	99°F.	61°F.
66.68 in.	Manatí	98°F.	57°F.
54.29 in.	Arecibo	96°F.	58°F.
56.23 in.	Quebradillas		
66.06 in.	Isabela	94°F.	59°F.
83.59 in.	Coloso	98°F.	58°F.

The grouping into regions on the north coast was comparatively simple, with fields on each river valley naturally grouped together. Indeed, all field observations in the entire northwestern corner of Puerto Rico are so nearly the same at one time that, despite their being divided under the headings of Coloso, Isabela, Quebradillas, Arecibo, (and in some years, Manatí, Dorado and Toa Baja), for practical purposes they may be considered as forming one large region. Despite the diversity of soil, elevation, contour and rainfall, *Diatraea* and *Trichogramma* appear to find conditions essentially similar in this geographically diversified region, which constitutes possibly a fifth of the cane-growing area of the Island.

Just the opposite condition occurs on the south coast, which in soil, elevation, contour and rainfall from Ponce to Guayama is remarkably uniform. It would appear to be but a single environment, with practically unbroken cane fields, all under irrigation, extending in a narrow belt along the coast. From the standpoint of *Diatraea* and *Trichogramma,* however, there is no uniformity. Here occur the most tremendous variations in abundance, most often affecting all fields in a region, but sometimes only individual fields or those of a restricted area. Temperature and rainfall in the Santa Isabel and Juana Díaz region are so similar to that of Ponce on the west and Salinas on the east, with no natural geographic break or division, that the apparently arbitrary one here made is adopted solely because of the reactions of the insects as shown by our observations.

Selection of Fields

Under optimum conditions, a locality record consists of the totals of from five to eight (or more) typical fields, non-adjacent, but not too far distant from the point at which the rainfall and temperature records are made. In the latter years of the investigation, such locality records were the rule, and were often made at three week intervals, but earlier, such optimum conditions were only approximated at some localities, and the time interval between records was four or five weeks, and sometimes longer. When an abundance of fields was available for inspection, the results as reported might to some extent depend upon the particular fields selected for observation. Since the purpose of the investigation was primarily to determine the abundance of *Trichogramma,* what seemed to us to be the least desirable fields were not inspected if better fields were available. Whether our standards were the same as those of the insects is a question which the available evidence does not answer. When no choice of fields was possible, the field which seemed least desirable to us rarely had as many egg-clusters as the others, and often had none. On the contrary, when many fields were available, often one would be far below the average, and an additional half hour spent in examination (on the possibility that the piece selected for examination was a sub-normal sample) failed to materially change the result. Such sub-normal fields must be included in the records for a region, even if no egg-clusters were found. Quite often, however, if one apparently optimum field (by our standards) had few or no egg-clusters, that would prove to be the rule for the region at that time. Averaging such apparently negative results was held to indicate the culmination of unfavorable conditions for *Diatraea* oviposition, and to present just as true a picture as the average of fields with an abundance of egg-clusters at some other time.

For the most part, the fields examined were those most readily available along the main highway. Thus in some cases, the region as examined was miles long and only a few fields wide, and was of more logical shape only when parallel roads, or a triangle of roads, made the examination of a greater width possible. Large fields were preferred for inspection, and usually were examined clear across from one side to the other at about the middle. If the rows ran parallel to the road, the observer went part way up one side to avoid the end rows, which are often sub-normal if shaded by roadside trees. When a choice was possible, fields of uneven contour were avoided, as earlier examinations of such fields had sometimes shown marked concentration of egg-masses, as at the brow of a hill in humid regions, or in a swampy part, or along a small permanent stream in xerophytic regions. Comparable uneven distribution of egg-masses might occur in certain parts of a field apparently no different from any other part of the field, but more often the collection made crossing the field approximated that made on the return, and sometimes was exactly the same.

PERSONNEL

For making the field observations, the junior writer was employed specifically and exclusively, while the senior writer accompanied him when possible. Thus the bulk of the notes for the first part of the investigation is the joint product of their observations. Later, to reduce the time between observations, the work was divided so that the junior writer made most of the observations on the south coast, the senior writer those on the north coast, and those of the east coast and in the Isabela region usually made jointly. While the egg-counts of individual fields as thus made are sometimes subject to wide variation from other fields of the region on the same day, or from previous or subsequent observations in the same field, it is believed that such deviations actually represent conditions as they were in the region at the time, subject to minor error in the selection of the sample, and are not due to the personal, subjective difference of the observers. Of course the personal element can not be entirely ignored, but when both observers were collecting in the same field, wide variations in their results only occurred when egg-clusters were scarce and what each one found was largely a matter of chance. When abundance of egg-clusters largely eliminated the factor of chance, collections were nearly identical. It should also be noted that what looks like a major variation when reported of only a few egg-clusters (due to chance, or personality of the observer, or selection of the field, or the rows in the field) really matters very little. When eggs are abundant, no such major error is likely to occur, and from a statistical standpoint, can not occur.

Man - Hours

After the first few experimental months, most of the observations were of only one man-hour, altho at first an earnest effort had been made to find at least ten egg-clusters before leaving the field. Theoretically, the use such a subjective unit as the man-hour may appear undesirable,, yet experience indicates that this is the most useful and practical for this particular problem. To be sure, from it one can not calculate the number of eggs per acre, for the ease of walking thru fields with such different systems of cultivation as are used in Puerto Rico and of different heights of cane and varied weather conditions, varies considerably. Even less possible is any estimate of the number of egg-clusters for the area examined, for, except for those indicated by chlorotic spots, half of the egg-clusters, being on the other side of the leaf, can not possibly be seen, and some also escape observation because of the wind shaking the leaves, or sunlight reflected from them, even tho they are apparently in plain sight. The man-hour merely indicates the number of egg-masses collected by one man in one hour walking naturally thru the field and collecting those which can be found without stopping to turn the leaves, or to examine the plants with extreme care.

Other Spots

In searching for the egg-clusters of *Diatraea saccharalis,* the observer must look for a small object of indeterminate shape and size; of a color

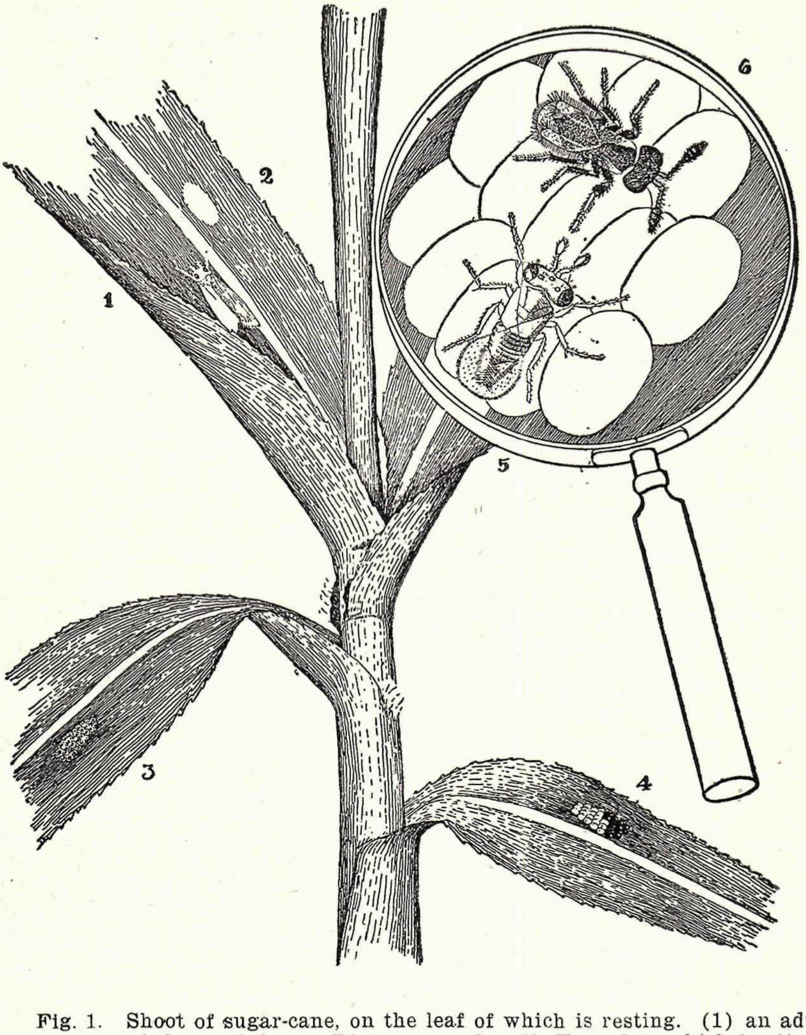

Fig. 1. Shoot of sugar-cane, on the leaf of which is resting. (1) an adult of the moth borer, *Diatraea saccharalis* F., and to which is attached (2) a fresh cluster of *Diatraea eggs*, (3) an egg-cluster which has been eaten by ants, and is as hard to represent in a drawing as it is to see in the field, (4) a partly parasitized egg-cluster and, greatly magnified under the lens, a fresh egg-cluster on which is resting (5) an adult of *Trichogramma minutum* Riley and (6) an adult of *Prophanurus alecto* Crawford. (Original, drawn by G. N. Wolcott).

which may be creamy white (eggs just laid), light yellow (a few days later), spotted with orange or red (next to last day before hatching), opalescent grey (recently parasitized), blue-black (parasitized), mottled grey (parasites emerged) and promptly differentiate it from other spots of similar shapes, sizes and colors. Furthermore, if the egg-cluster has been eaten by ants, often the lower layer of egg-shell that attached the eggs to the leaf is all that remains, and sometimes no more than the merest ring of chorion outlining the original shape of the cluster. (Fig. 1).

The mere presence of a moth-borer egg-mass on the cane leaf also sometimes (in reality, not very often) causes the eventual appearance underneath or above it of a chlorotic spot in the leaf-tissue, which of course is also visible on the other side of the leaf. The spot itself remains after the egg-cluster has fallen off normally, but in the present investigation, no chlorotic spot was counted unless some bit of the egg-shell remained to prove that an egg-mass had previously rested there. Nevertheless, all chlorotic spots of the shape and size of a *Diatraea* egg-cluster had to be examined, on both sides of the leaf.

Besides chlorotic spots which might be due to other causes than the actual or previous presence on the leaf of an egg-cluster, the observer must also promptly differentiate and mentally discard the following things or spots on cane leaves: split places in the leaf, or holes eaten into or thru the leaf, or the shadow of such a hole on the leaf below; lizard excrement or bird excrement, or mistletoe seeds, or other seeds of fruit scattered by birds; black shiny spots of what looks like crank-case oil, thick black hard shiny masses, granular white, yellow orange, brown or black masses; individual dew or raindrops (which look like "eaten" egg clusters); mechanical abrasions and points where the midrib has been broken; fertilizer and soot from the mill; fungus leaf spots; masses of spider silk; fresh or hatched egg-masses of *Laphygma frugiperda* S. & A.; hatched egg-masses of *Diaprepes abbreviatus* L., which often turn the leaf-tissue underneath reddish brown; egg-masses of the leafhopper *Kolla similis* Walker, which are light green when first laid in the leaf-tissue, often becoming reddish brown later; egg-masses of the Fulgorid, *Saccharosydne saccharivora* Westwood, which are often yellow or brown on the other side of the cane leaf or midrib in which they are deposited; adults of the Fulgorid, *Oliarus franciscanus* Stal, which are grey, and adults of the Ortalid fly, *Euxesta thomae* Loew, which are barred with shining black and white. To be sure, many of the mentioned spots or objects may seem to be most improbable of confusion with *Diatraea* egg-masses, and in most cases they are immediately recognized for what they are, but each such spot or object must be noted and promptly identified before the attention can be redirected in further search.

Summarization of Data

At the conclusion of the field work, copies of the field notes were made on smaller cards, measuring two by three inches, which could be readily arranged and re-arranged without disturbing the chronological arrangement of the numbered field notes retained in their booklets of fifty for reference in the files. From these little cards, shuffled and re-arranged as one desired according to any particular factor, or group of factors, it was possible, without danger of missing any records, to obtain exact data in summarized form on fields, man-hours, percentage of parasitism and on each class of egg-clusters by month, locality, plant or ratoon, trash burned of ratoon cane or not burned, and on height of cane.

Classification

All egg-clusters collected were retained at least for careful re-examination when recording the data at the end of the inspection. For recording, they were grouped under six headings: fresh, eaten by ants, hatched, parasitized, partly parasitized and parasites emerged. These groupings seem sufficiently definite, but a small number of egg-clusters was collected which could not be thus readily classified, part of the egg-cluster assigning it to one group, the other part to another. Of course it was possible to note the exact condition of such egg-clusters, but this only complicates the final consolidation of data. In practise, one placed the egg-cluster in question in one classification, and noted its possible inclusion in the other. Fortunately, the number of such egg-clusters was so small that it could be ignored without materially affecting the final results. The total number of egg-clusters collected in five years from the 4,595 fields (not including those in which releases were made, and twelve at scattered locations) was 45,430, or an average of almost ten per man-hour.

"Emerged"

As used for these records, the heading "emerged" indicates that parasites had emerged from the egg-cluster previous to its collection, and not caterpillars. 5,391 egg-clusters were collected from which parasites had emerged, or 12% of the total number, and slightly less than half as many as were found parasitized. The finding of many emerged egg-clusters in a field or a region should indicate the close approach of the end of the cycle of parasitism which started with an abundance of fresh egg-clusters, culminated in an abundance of parasitized egg-clusters, and ends with a preponderence of emerged egg-clusters. This is true in general, and would be more obvious if such egg-clusters had better adhesion and did not drop off, or disappear out of sight under fresh leaves as soon as their mission is accomplished. The ratio between 5,391 emerged and 11,433 parasitized presumably indicates the length of time that the egg-masses remain attached to the leaves after the parasites have emerged, expressed in terms of the period from the appearance of parasitism to emergence of the wasps. Actually, one finds emerged egg-clusters in some fields long before the cycle is that far along in other fields of the same region, thus the graph drawn for the averages of a region may show many emerged egg-clusters while parasitism is still increasing. In practice, the number of emerged egg-clusters is added to that of partly parasitized and parasitized to obtain total apparent parasitism.

"Partly parasitised"

The term "partly parasitized" as here used indicates that more than two eggs in the clusters had been attacked by *Trichogramma,* but that the remainder were fresh, had hatched, or had been eaten by ants. If only one or two eggs had not been parasitized, the egg-cluster was considered so nearly entirely parasitized as to be included under that heading, while if only one or two eggs in the cluster had been parasitized, this small amount of parasitism was ignored, the two conditions thus canceling eachother out so far as our records are concerned. It is presumed that most of the failure of *Trichogramma* to parasitize all the eggs in a cluster is due to cold weather, even tho minimum temperatures in the middle of the day in Puerto Rico are rarely low enough to affect its activities. At many localities, most of the partly parasitized egg-clusters were found during the cooler months of the year, especially on plant cane, but with numerous exceptions. The totals for all localities show four times as many in December as in June and July, and five times as many as in August or September, but with differences between other months less pronounced. Actually, the grouping has little importance in Puerto Rico, the recorded total of 638 being only about 4% of all parasitized, or 1.2% of all egg-clusters. At no locality was 3% of the total number of egg-clusters thus partly parasitized, and nowhere on the south coast more than 1%. Indeed, the figures for partly parasitized are so small that when the consolidated data for a locality were being represented in a graph, they were combined with emerged to be seen at all.

"PARASITIZED"

The time-lag after *Diatraea* eggs are parasitized by *Trichogramma* waps before they begin to show the effect of parasitism by turning black is between one and two days. As used for these records, the term "parasitized" is only for those egg-clusters unquestionably attacked as indicated by at least the beginning of change in color. Somewhat inconsistently, however, all egg-clusters collected while they were being attacked were also counted as "parasitized", even tho there would be no indication of this for a day or two, once the wasps had flown away. By this definition, the number of parasitized egg-clusters collected was 11,433, or 25% of the total of all egg-clusters. To obtain the figure of total parasitism, to this is added the 638 of partly parasitized and 5,391 emerged, which gives 17,462, or 38% of all egg-clusters.

Of all the axioms of parasitism, the one most universally assumed is that abundance of the host implies subsequent abundance of the parasite, either immediately or closely folowing. The egg stage of *Diatraea* and the entire life-cycle of *Trichogramma* each occupy such a very short time that one would expect abundance of egg-clusters to practically coincide with percentage of parasitism. Of all the results obtained in this investigation, no other set of figures is so uniformly consistent as that giving for each locality the percentages of parasitism and abundance of egg-clusters. Even where, as at some north coast localities, the percentage of parasitism began at 25% or 26% when only one or two egg-clusters were collected per man-hour, the next higher division of from 3 to 6 egg-clusters per man-hour showed some increase in parasitism, going up rapidly to the classes of greatest abundance: 31 to 62, and 63 and over, with parasitisms of 66% and 73%. At Santa Isabel, starting with no parasitism in the 1 to 2 egg-cluster class, parasitism goes up rapidly and reaches 68% in the 63 egg-cluster or over class. At some localities, parasitism goes up more slowly, as at Guánica, starting at 5% and ending at 33%, but in every case the trend is consistently upward paralleling the increasing number of egg-clusters. Averaging all localities: 1 to 2 egg-clusters are 13% parasitized; 3 to 6 are 19% parasitized; 7 to 14, 30% parasitized; 15 to 30, 42%, and 31 to 62 and 63 and over both 53%. It should be especially noted that these are average figures, smoothing over many exceptions, but that the averages are so consistent would indicate the truth of the axiom for this particular instance of parasitism.

"EATEN BY ANTS"

The heading "eaten" was originally intended to include all egg-clusters in any stage of development which had been fed upon by any predator. Especially in those cases where part of the eggs were still uninjured, the status of those remaining was of more importance for the purpose of this investigation for including under the heading of parasitized or fresh than the fact that part of them had been eaten. Empty egg-shells were also sometimes eaten by ants, and in such cases, the fact that the caterpillars had hatched out of the egg-cluster was of greater importance for this investigation than that the egg-cluster had later been disturbed by ants. In all of these cases, the egg-cluster in question was invariably listed under the other heading, rather than as "eaten". Indeed, no space for eaten was provided in the first provisional card blanks, but the common occurrence of such egg-clusters required that a space be made in the re-designed card blanks used after the first months.

Despite the wide variation in the character of "eaten" egg-clusters, however, varying from complete consumption of everything except the rim around the edge of the cluster, making any assumption as to the original character of the cluster impossible, to partial consumption of some fresh or parasitized eggs, or merely messing up of empty egg-shells, it is believed that all of these cases are due to a single cause. A small black ant, *Monomorium carbonarium ebeninum* Forel, as determined by Dr. M. R. Smith, has repeatedly been found in the field feeding on both fresh and parasitized egg-clusters, as well as on the egg-shells of hatched and emerged egg-clusters. No other ant, or other insect or small animal has been found in Puerto Rico feeding on *Diatraea* egg-clusters. As nearly one-sixth of all egg-clusters collected are recorded as having been eaten, *Monomorium ebeninum* would be a factor of very considerable importance in the control of the moth borer if it were more discriminating in its choice of the character of eggs eaten, and avoided those parasitized by *Trichograma*. In many instances, however, when *Trichogramma* is not present at all, or is very scarce, one gets the impression that the ants eat more of the egg-masses than when the parasite is present in abundance. This is especially marked at Guánica and Ponce, but sometimes the reverse is true elsewhere. It is so often true, however, that this ant may be considered as largely beneficial in aiding in the control of *Diatraea*. A total of 7,377 egg-clusters completely eaten by ants is recorded or 7,724 counting those partly eaten, and those also counted under another heading, but not empty egg-shells bitten into and messed up. This is 17% of all egg-clusters collected.

At Guánica this little black ant is an especially important factor in natural control of *Diatraea*, for 23% of all egg-clusters had been eaten by ants here, as compared with 27% total apparent parasitism by *Trichogramma*. Ants were of least importance in the northwestern corner of the Island, and at Santa Isabel on the south coast, accounting for only 10% of all egg-clusters at these points; elsewhere they ate from a fifth to an eighth.

"HATCHED"

The heading "hatched" is used for indicating egg-clusters from which caterpillars hatched, as opposed to those from which parasites emerged. The original purpose in including the records of hatched and emerged was to obtain a cross-section of conditions as they were a week ago, as well as those at the time of inspection. Actually, all that is possible is to obtain a cross-section of present conditions, for the data on hatched and emerged egg-clusters are not comparable. *Trichogramma* requires approximately twice as long for its development to adult in the host egg as does the embryo of the moth borer for its development to caterpillar. Thus, some parasitized eggs are of the same age as some hatched egg-clusters, and there is no way of judging the age of egg-clusters from which caterpillars have hatched. Nevertheless, the data on hatched egg-clusters are most important as indicating beyond a question of doubt how many egg-clusters actually did escape natural control, even if the length of the period during which they remain attached to the leaves is of uncertain duration. A total of 12,635 hatched egg-clusters was collected in five years, or 28% of all found.

In plant cane, the number of egg-clusters found hatched varied from somewhat over two and a half egg-clusters per man-hour at most points on the north coast, thru nearly four per man-hour from Ponce to Guánica and Loíza to Humacao, with a high of over six egg-clusters per man-hour at Salinas, Guayama and Yabucoa. The extremes are even more marked in ratoon cane: one and a half egg-clusters per man-hour on the north coast, around four or over from Guayanilla to Yabucoa, with an outstanding high of 8.2 egg-clusters at Salinas. As will later be explained, to show how large is the number of eggs escaping natural control, to this also must be added a part of the apparently fresh egg-clusters, the part naturally being largest where most hatched egg-clusters are found, and smallest where natural control is most effective and most fresh egg-clusters become parasitized or are eaten by ants.

The apparently negative evidence of finding only a few hatched egg-clusters in a field is very definite proof of how unfavorable conditions had been in that field for the days and weeks immediately preceeding for *Diatraea* oviposition and *Trichogramma* parasitization. Finding an abundance of only hatched egg-clusters just as surely indicates a period of a few days, a week or more ago, most favorable for *Diatraea* oviposition, but developing so rapidly that control by *Trichogramma* could not take place. The first condition is common everywhere on the Island; the second is less often noted, being too late a discovery of conditions that did offer ideal conditions for the release of laboratory-reared parasites a few days previously. How to find such fields in time to take advantage of the opportunity presented, or rather, how to predict their occurrence some time in advance, is the key to successful *Trichogramma* liberations.

"Fresh"

The heading "fresh" is merely the shortest term under which to group all the egg-clusters which were unhatched at the time of collection, and were apparently unparasitized. It includes all egg-clusters varying in freshness and depth of coloration from the light cream to those plainly showing the curled-up caterpillar within. Thus the actual time difference between an egg-cluster listed as fresh and one entered as hatched may be a matter of a day, or only a few hours. This seems somewhat arbitrary, but in reality is vital, for the hatching of the egg-cluster eliminates the possibility of its being parasitized or eaten by ants. For this investigation, all those eggs which were in fact parasitized, but showed no sign of it at the time of collection, were also listed as "fresh".

It must be remembered, therefore, in interpreting the percentages of parasitism as given, that parasitism, if it occurred at all, was presumably somewhat higher than indicated, and might be very considerably more. For some months, all the so-called fresh egg-clusters were retained until their true status was obvious, and from a third to nearly two-thirds were found to be parasitized in fact. As the bulk of the fresh eggs retained were from fields where the observed parasitism was low, it would indicate nearly total parasitism of the smaller number of apparently fresh eggs collected in fields where parasitism was high. To this must be added the parasitism which would have resulted in the actually fresh egg-clusters at the time of collection had they remained undisturbed in the field, which naturally is also a greater chance of being parasitized where most of the egg-clusters are also parasitized and the parasites are abundant. Constructing a somewhat arbitrary table with allowance for both of these factors, no increase in actual parasitism is anticipated if observed parasitism is 30% or less; 50% increase in parasitism is presumed due to these two factors if observed parasitism is 50%; total parasitism if observed parasitism is 70% or more. Possibly some correction should be made for the effect of abundance of egg-clusters on parasitism, also for natural control by ants if the clusters had been left in the field, but this makes the table so complicated as to be unworkable in practise.

The total number of fresh egg-clusters was 7,956, or 18% of the total. Had they not been collected, three possible fates awaited these apparently fresh egg-clusters: (1) they might escape all perils and hatch normally, (2) they might be eaten by ants, or (3) they might be parasitized by *Trichogramma*. These three possibilities are not probable in exactly the proportion that the egg-clusters collected by us actually did suffer these fates. As Dr. G. W. Kenrick, Professor of Physics at the University of Puerto Rico, points out: consumption by ants or parasitization by wasps might happen at any time after they were laid and during most or all of the incubation period following, while hatching could occur only at the end of these days of peril. It is apparent, therefore, that many parasitized or eaten by ants have already been subtracted from those recorded under the heading "fresh", and none under the heading "hatched", thus a proportionately greater number of them will hatch. To obtain a really exact answer requires more exact biological data than is available, but using various approximations from the total data figures reported for the whole period, Dr. Kenrick, solving the problem by two very different approaches, by either obtains approximately the same answer. He finds that the number of fresh eggs which will survive to hatch if left in the field is somewhat more than half of those collected, rather than the one-third indicated by the percentage noted of the actual collections. There is only an apparent conflict here with the high probability of fresh eggs becoming parasitized when numerous in fields where some or most other eggs are parasitized, for such cases occur comparatively rarely. Dividing up the "fresh" eggs according to their presumed fate and adding it to those actually collected indicates that 38% of the eggs actually do hatch, and by difference, a total destruction due entirely to natural causes of 62%. That is, for Puerto Rico as a whole, for all seasons and times of year, at all localities and without distinction as to whether the cane is plant or ratoon, nearly two-thirds of all *Diatraea* eggs are destroyed naturally, without any effort on the part of the grower to produce such a condition.

HEIGHT OF CANE

That the data as collected might be comparable in as many factors as possible, all observations were made in cane of a height that could be readily examined as one walked thru the field. In practice, this meant that cane less than a foot high was normally not considered worth the time necessary for examination. A few weeks later, the cane is of just the right height for easiest examination: eighteen inches to two feet. Ordinarily, if a field is examined once, the tendency was to continue examinations in the same field as long as such were possible. Often one, and sometimes two following examinations were made, and during periods when growth was slow, or when fields were being used as checks on others in which releases had been made, this might mean four or five consecutive examinations in the same field in one crop season, as well as examination in preceding and suceeding years. In some cases, considerable differences appeared in the number and character of the eggs found in successive examinations, suggesting that the difference might be due to the height of the cane. However, when a greater number of data of this character were available, it at once became apparent that the outstanding differences in different fields canceled out. Indeed, when all the data for each locality for each month are arranged according to height of cane, the result is surprising uniformity at all heights. Consolidating all data from all localities eliminates slight inequalities due to inadequacy of number of observations at the extreme heights. All the variations from normal in the final consolidation are within the limits of statistical error, and not only for the total number of egg-clusters, but also for each kind of egg-cluster: fresh, hatched, eaten by ants, parasitized and emerged.

The ants climb the higher cane to eat eggs just as readilly, and *Trichogramma* recognizes no difference between high and low cane. Thus one may state without reservations that between eighteen inches and four feet in height, the height of the cane has no effect on the number and character of *Diatraea* egg-clusters present on the leaves. This is of the very greatest importance in this investigation, for it at once eliminates one possible cause of variation that one might have to consider in explaining results. The statement is limited to the height of the cane examined, but presumably it applies to all cane of whatever height. As regards oviposition by *Diatraea* moths, and parasitism by *Trichogramma*, the canopy of cane leaves would seem to be the same whether it is two feet or twenty feet above the surface of the ground.

Concentrating observations on cane from eighteen inches to three or four feet in height is quite different from the practise of other investigators working on the same problem in other countries, who have followed the same cane thru the season until it was harvested. No other course was possible in some of these other countries, but since cane of practically all heights is present during every month of the year in Puerto Rico, it seemed desirable to take advantage of this condition and eliminate the differences which might be due to the mechanical difficulties of making observations in high cane.

Variety of Cane

The variety of cane has a very definite effect on the amount of borer injury to the stalk, as the varieties with the hardest rind and the most cellulose or fiber are so discouraging to caterpillars attempting to eat them that fewer survive than in the softer, sweeter canes. So far as oviposition by moths is concerned, this factor does not operate, or, if it occurs, is obscured by other factors. The variety B H (10) 12 is so generally grown on the south, POJ 2878 on the north coast, with scattered fields of M 28 in the northwest, and Fajardo seedlings in the northeast as to give little scope for comparison. In the one or two variety experiments examined, no apparent difference in oviposition was noted, but the paucity of comparable data makes a conclusive statement impossible.

Environment

In addition to spaces for noting the character and number of the egg-clusters, their total and the percentage of parasitism, the field note blank forms as finally designed for use in recording the presumably pertinent data in this *Diatraea* egg-cluster survey, also had spaces for the number of the record, the numbers of previous and subsequent observations in the same field, the date and exact time of day, the man-hours, the locality, the name of the owner of the field or the name of the Hacienda and the piece or tablón number, and its exact location (if on the main road) by the kilometer-hectometer post, whether the cane was plant or ratoon, and, if the latter, if the trash had been burned or not, the height or age of the cane at the time of observation, the soil and contour, the rainfall (annual, for the previous week and for each of the preceeding six weeks), and the environment on all four sides: north, east, south and west.

The extensive notes on environment were primarily for noting any possible effect on abundance of egg-clusters. Incidentally, it was of the greatest value in noting on which side of the main road was the field examined, which, together with the kilometer-hectometer post, enabled one to identify the field exactly, and later correlate with observations in previous or subsequent years of the same field. Subtracting such incidental notes as those of "main road", "dirt road", "cane road", and "railroad", which can hardly have any effect on borer eggs, leaves 20,587 items in the environment of the total of 4,707 fields (including those in which releases were made, and a few at localities later eliminated) which were examined. Obviously, some fields had more than one factor on one or more sides, but this was the exception. Aside from the factor of "main road", one might think of the factors of environment as here given as possibly describing the typical Puerto Rico cane field, altho practically all of the fields were selected for suitability for examination and availability from the main road, and, to this extent at least, may not have been typical or average.

The factors of the environment as recorded for 4,707 cane fields in Puerto Rico observed during five years, are as follows:

high cane	8,372	houses	981
cane being cut	502	town	154
young ratoon	3,370	cemetery	37
young plant cane	939	cane-hoist	39
abandoned cane	136	Central	45
		stables	19
sugar-cane	13,319	dipping vat	20
		bridge	17
malojillo meadow	13		
corn	85	structures	1,312
other *Diatraea* hosts	98	pasture	2,797
		plowed land	463
bananas	63	airport	22
pineapples	19	batéy	20
tobacco	33	ocean	79

cotton	15
sweet potatoes	21
minor crops	143
pigeon peas	19
cowpeas	13
alfalfa	4
crops	330
coconuts	137
grapefruit	48
coffee	9
trees	408
casuarinas	8
windbreak	28
mangrove swamp	78
caña brava	31
forested mogote hills	777
trees	1,525

creek or river	550
reservoir or lake	82
geographic	4,013
main road	4,347
dirt road	361
cane road	796
railroad	691
roads	6,195

TOTALS

sugar-cane	13,319
other *Diatraea* hosts	98
crops	330
trees	1,525
structures	1,312
geographic	4,013
roads	6,195
	26,792

Eliminating from consideration the various kinds of roads, nearly half of the environment was high cane, and sugar-cane in some stage of growth was almost exactly two-thirds of all environments. Obviously, the isolated cane field is exceptional, and only a single instance was noted of the isolation of the fields affecting the number of borer eggs. A field of young plant cane between Manatí and Vega Baja, surrounded on all sides by pasture, or forest and brush-covered mogote hills, had practically no egg-clusters the first year that it was examined, yet in the following year as ratoon cane, when time had allowed some chance for infestation, the number of egg-clusters was comparable to other fields in the same region. This shows the temporary advantage of seed selection, and also how temporary is such an advantage in Puerto Rico, where isolation from other fields is so difficult. Fields with the Atlantic Ocean or mangrove swamp to the north and east (from which the prevailing winds blow on the north coast) showed no advantage over those with cane on all sides, altho possibly they might have done so when plant cane. On the other hand, fields with just cut cane or young ratoon cane to the leeward in no case had a noticeably greater abundance of eggs, due to moths flying out of the cane recently cut to oviposit in the young cane to the windward, than the average of others in the same region. Since we were anticipating such a difference, and looking for it in every case where these special conditions of environment occurred, that no such difference was found would indicate that every instance is a special case, and the result might not be due to the anticipated factor. Indeed, except in a very few individual cases, the data on environment would seem to be interesting rather than significant. A careful and detailed statistical treatment might indicate results not anticipated, but it must be remembered that the people actually making the observations saw no such possible clue when in the field.

Other Parasites

The environment of the cane field in Puerto Rico plays no role comparable to that reported in some other countries, of serving as a reservoir of hibernating eggs of other kinds of moths and butterflies for *Trichogramma* during the winter. Indeed, as sugar-cane is generally grown in Puerto Rico, in large solid blocks, usually carefully weeded and with a minimum of other plants on which the eggs of other moths and butterflies might be laid, *Trichogramma* is in fact largely restricted to the eggs of *Diatraea saccharalis*. Not only that, but another dark race of *Trichogramma* is also present in cane fields, attacking the eggs of the Hesperiid butterflies, *Prenes nero* F. and *Prenes ares* Felder, but according to our observations, not those of the Crambid moth, *Diatraea saccharalis*. This dark race of *Trichogramma* is not to be confused with another black egg-parasite of the sugar-cane *Prenes*: an Encyrtid which Mr. A. B. Gahan identifies as a species of *Oöencyrtus*.

Nor should this dark *Trichogramma* be confused with the black Scelionid wasp, *Prophanurus alecto* Crawford, first reared in Puerto Rico from the eggs of *Diatraea saccharalis* at Río Piedras and Toa Baja in 1921 (Wolcott 1922). Until 1938, this parasite was not again found in Puerto Rico (Wolcott 1939), but in October of that year it was the only parasite attacking egg-clusters of *Diatraea* at Isabela (determination confirmed by Mr. C. F. W. Muesebeck) and mingled with *Trichogramma* at Quebradillas and Coloso. A month later it had disappeared in the Isabela region, but was responsible for seventy or eighty percent parasitism of *Diatraea* eggs at Guánica (and thoroly disorganizing the *Trichogramma* release experiment there), where it had never before been collected. By the next month it was gone at Guánica, but had appeared at Patillas and Arroyo, where it had disappeared by the next observation. It was very abundant at Las Piedras in April 1939, and noted at Isabela, and again in December at Quebradillas, but has not since been recorded from anywhere in Puerto Rico.

Plant or Ratoon

One of the most obvious and really fundamental differences between the various fields of a region is that some are of plant cane and others are ratoon. On the assumption that this might have an effect on oviposition by *Diatraea,* we were constantly on the look-out for such a difference between plant and ratoon fields. Yet rarely did we find a pair of truly comparable fields showing an apparent effect in one way that it was not promptly duplicated by a similar pair showing the supposed effect in the other direction. Averaging a sufficiently large number of fields, however, such as all those examined in the same month for five years at one locality, or all of those from one locality, or all those for one month, gives a very definite but not very consistent difference. Ratoon fields at Coloso, Isabela and Arecibo average twice as many egg-clusters as do fields of plant cane at these localities, and at Santa Isabel, Salinas, Dorado and Manatí, the difference is pronounced, (see Table No. 2). At other localities, the difference is not significant, and at Guayama, Yabucoa, Fajardo and Loíza there is no difference. Twice as many egg-clusters were found in ratoon fields in May and July, and almost twice as many in April and June, as in plant cane, but in December, February and March the collections averaged practically the same.

Parasitism of egg-clusters in ratoon cane averages double that in plant cane at Guánica, Ponce, Santa Isabel, Fajardo, Dorado and Manatí, and even more in all localities in the northwestern corner of the Island. The months of May and June also have ratoon cane with twice the parasitism of that found in plant cane, and with significant differences in all other months. The differences in abundance of egg-clusters and parasitism are all in the same direction, and en masse are unquestionably significant, even tho they rarely parallel each other at the same locality.

The total number of fields of plant cane examined was 2,343, which had 22,064 egg-clustuers, or 11.5 per man-hour, and the percentage of parasitism was 27%. The total number of fields of ratoon cane in which the trash had not been burned was 2,144, which had 22,468 egg-clusters.

TABLE NO. 2

EGG-CLUSTERS PER MAN-HOUR

LOCALITY	MAXIMA		AVERAGE TEN HIGHEST		AVERAGE		MINIMA		PERCENT PARASITISM	
	PLANT	RATOON	PLANT	RATOON	PLANT	RATOON	PLANT	RATOON	PLANT	RATOON
GUANICA	160	112	78	55	11.8	13.7	10 zeros	3 zeros	20%	39%
GUAYANILLA	36	36	28	28	9.3	12.	7 zeros	2 zeros	21%	33%
PONCE	88	88	57	58	12.5	14.7	4 zeros	2	23%	41%
SANTA ISABEL	90	140	65	88	17.4	27.3	2	1 zero	31%	63%
SALINAS	132	112	88	67	18.3	22.9	1	1	27%	34%
GUAYAMA	84	84	63	68	15.6	15.8	3 zeros	3 zeros	28%	42%
YABUCOA	96	172	50	68	16.3	16.	4 zeros	1 zero	33%	50%
HUMACAO	52	56	33	43	11.7	13.7	4 zeros	1 zero	30%	44%
FAJARDO	42	42	28	28	7.6	8.4	20 zeros	22 zeros	18%	32%
LOIZA	50	56	31	33	9.4	8.3	14 zeros	13 zeros	25%	37%
DORADO	70	114	37	63	9.	14.5	18 zeros	16 zeros	29%	52%
MANATI	93	136	44	79	10.	18.1	28 zeros	9 zeros	37%	68%
ARECIBO	48	66	24	45	7.1	14.2	8 zeros	8 zeros	24%	62%
QUEBRADILLAS	50	66	32	49	10.9	12.9	4 zeros	7 zeros	32%	65%
ISABELA	72	78	32	51	8.1	16.3	8 zeros	5 zeros	24%	65%
COLOSO	56	60	24	41	6.9	11.1	10 zeros	8 zeros	25%	67%

or 14.8 per man-hour, with a percentage of parasitism of 50%. While the total of fields examined in each division was substantially the same, most of the plant cane was examined in the fall and winter, with mostly ratoon in spring and summer, and if the season had any effect, this (especially in the northwestern corner of the Island) might also show up as an apparent difference between plant and ratoon.

Burning of Trash

The burning of cane trash at the time the crop is harvested is generally practiced in most countries where cane is grown, but in Barbados and Puerto Rico it is the exception rather than the rule. Without attempting to evaluate its agricultural status, from the standpoint of natural control of insect pests the burning of cane trash can only be considered a calamity. When the non-burning of cane trash was first recommended for adoption in Puerto Rico, its effect only on moth borer and *Trichogramma* was considered, but now the destruction of toads, which rarely are able to escape from between cross-fires, is of even greater importance because of the role that they play in the control of white grubs.

The non-burning of cane trash has been so generally adopted in Puerto Rico (Wolcott 1933) that it is now difficult to find many fields in which the trash has been burned. No attempt to find such fields, or to avoid them, was made in the present investigation, and it is largely accidental that 110 fields out of the total of 4,597 were of this character. This is a rather small number from which to draw conclusions, but their average of 10.3 egg-clusters per man-hour and parasitism of 31% is so similar to that of plant cane, rather than to ratoon cane of which the trash had not been burned, as to suggest that the burning of cane trash actually did have a definite effect.

Rainfall

As soon as data on the abundance and scarcity of *Diatraea* and *Trichogramma* had begun to accumulate, attempts were made at summarizing them so that trends could be observed and theories evolved and tested to determine what were the essential factors affecting these insects. On the assumption that rainfall would be found to be the decisive factor affecting the abundance of egg-clusters of *Diatraea,* as it unquestionably appears to be of larval injury to stalks (Wolcott 1915), primary attention was given to this factor.

In the first observations, the great variation in the number of egg-clusters collected in the wet and the dry parts of the Island seemed to indicate that total annual rainfall for each locality in which the observation was made would give the key to the number of egg-masses to be expected in the fields of that region. Later observations indicated that this assumption was quite incorrect, and led to a re-designing of the record card so that a space would be available for recording the rainfall of each of the seven weeks preceeding the date of observation, as well as the annual rainfall for that locality. The monthly summary of the local station of the Weather Bureau, published as "Climatological Data, West Indies and Caribbean Service," gives daily records of the rainfall at all points where we made field observations, and much time and energy was devoted to consolidating these daily records into weekly summaries for our field notes. At that time it was impossible to predict how much of the rainfall data was essential, but it seemed preferable to include space for too much, rather than too little. Even at that time it was obvious that the total amount of rainfall in the week gave only a very rough approximation of what should be known as to the conditions of humidity as they affected the emergence and oviposition by the female moth, and parasitization by *Trichogramma,* but no closer approximation is possible for extensive field observations.

So far as the *Diatraea* moth is concerned, several observations had indicated that a field otherwise dry, and capable of growing cane only as it was irrigated, had quite a different character if a small permanent stream flowed thru it, for all egg-clusters were found close to the banks of the stream. Such a modification of the micro-climate of that part of the field was obviously of much greater local importance than rainfall, and lacking any definite theory as to how humidity affected the *Diatraea* moth and the parasite of its eggs, the time of day or night when the rainfall came, and its distribution thru the week might prove to be of more importance than its actual amount.

In re-designing the record card, the character of the soil, as it might affect the micro-climate close to the ground, was considered to be of possible importance. In only a few specialized cases did this appear to be so, as in the xerophytic part of the Island, heavy clay soils, especially the "pollal" or poorly-drained phase of such soil, maintain a microclimate supposedly more suitable for the insects. Contour may have an appreciable effect when it separates the level swampy field from a higher slope, even tho rainfall is the same for all parts of the field. For such specialized cases, soil and contour may affect the results, but for the great bulk of the fields, all of our efforts to exactly locate the field on the soil survey map of the Island and record the name in our field notes appear to have been of little value.

The effort to obtain exact data on rainfall, and on soil and contour as it affects humidity in the field, is worth while only on the assumption that variations in tropical weather as normally experienced in Puerto Rico are vital to to cane insects. Sugar-cane is extensively grown, for instance, where the annual rainfall in some years is less than 30 inches. During 1939, at Central San Francisco, Guayanilla, the total annual rainfall was 18.82 inches; at Hda. Florida, Santa Isabel it was 22.07 inches; at Central Aguirre it was 24,32 inches; at Ponce it was 26.70 inches; and at Hda. Santa Rita, Guánica it was 29.82 inches. Of course the commercial growing of sugar-cane under such conditions of rainfall is possible only when it is abundantly supplemented by irrigation. Indirectly, irrigation is essential to *Diatraea* in assuring an abundant supply of food for its larval stage, but that gives no clue as to the direct effect on oviposition, if any. Our observations proved to be of little value in this connection, for we repeatedly found an abundance of egg-clusters on young cane so dry that the leaves had begun to curl, not only on the south coast, but also during drought on the north coast. Quite as often, one found only a few old hatched egg-clusters on drought-curled leaves, indicating that no eggs had been laid within weeks. If either one or the other condition only had been found, some conclusion might have been reached. Special efforts, immediately and one and two days after heavy rains in such regions, to determine if rain after drought did have a pronounced effect on oviposition, were also inconclusive.

Sugar-cane is commercially grown at several points where the annual rainfall averages close to 90 inches. Despite the high total annual rainfall, such regions often experience periods of drought weeks and sometimes months in length, and if the fields are reasonably level, the rainfall is supplemented by irrigation. Naturally, these are the best fields, and as such were those which we usually examined in a region. The net result was that most of the fields examined anywhere in the Island were those which received sufficient water for optimum growth: either mostly heavy rainfall supplemented by irrigation, or light rainfall supplemented by heavy irrigation. Thus the tremendous difference in annual reinfall, from less than 30 inches to nearly 90 inches in a year, had little effect on growth of cane, and also appears to have had no consistent effect on oviposition by *Diatraea*, at least in most of the fields which we examined.

As a most extreme example, one might cite the 16.17 inches of rainfall in the week ending January 2nd, 1937 at Loíza, which apparently eliminated parasitism temporarily, and somewhat decreased the total number of host eggs, but with complete recovery of abundance of host eggs and parasitism by the time the fields in this region were next examined. Fifty to sixty miles to the west, at Manatí, similar weather at this time and similar abundance of egg-clusters and parasitism paralleled those of the Loíza, Canóvanas and Río Grande region. Between Loíza and Manatí, in the Plata River valley, at Toa Baja and Dorado, the same weather had the same preliminary effect, but in the following weeks a tremendous increase in total number of eggs and parasitism developed, far greater than any other time until 1941. Some connection should exist between this heaviest rainfall in any one week at Dorado in the five year period, and the greatest number of egg-clusters and the highest parasitism recorded, yet the lack of any comparable result at the localities on either side, one having four inches more and the other four inches less of rainfall, would appear to indicate that it was nothing but a coincidence. Or, if not a coincidence, at least a result that has not been duplicated or paralleled at any time during the investigation at any other locality in any other part of the Island.

On the contrary, at other localities, one finds peaks of egg-clusters and parasitism developing just before heavy rains, in which case the supposed result comes before the cause. Or the exceptional rains have no apparent effect. After the exceptionally dry year of 1939 on the south coast, 1940 proved to be exceptionally wet, and at Ponce and at Santa Isabel, no peaks of egg-clusters appeared during the entire year of 1940. At Guánica, the highest peak of the five years came in the late winter of 1940, of which a very modest parasitism by *Trichogramma* was supplemented by an all-time high of 20 egg-clusters per man-hour "eaten by ants".

All of the cases cited are extremes of rainfall, or abundance of host egg-clusters, or parasitism, or "eaten by ants", and if these make no consistent pattern of cause and effect, it seems hopeless to expect minor variations of weather to produce an effect. Furthermore, if one can not be sure of the results of rainfall after all the records are in from all over the Island on a five year basis, it is apparent that any attempt to predict results in advance, based on rainfall, has no more than even chances of being correct.

TEMPERATURE

Aside from specific factors in an environment, those of most general importance to an organism are humidity and temperature. With rainfall, at least within the limits normally experienced in Puerto Rico, so modified by irrigation that humidity is apparently eliminated as decisive in affecting *Diatraea* oviposition and parasitization by *Trichogramma,* the factor of temperature remains to be considered. In temperate zone countries, temperature is often the deciding factor for all of the activities of an organism, but in the tropics, generally rainfall is of major importance to living things. When, as in the present investigation, irrigation upsets all this, the apperely minor factor of temperature must at least be evaluated. The generally lesser importance of the temperature factor is indicated by the absence of Weather Bureau records at some vital points where we made observations. When the effect of temperature on *Diatraea* oviposition began to be considered, recording thermographs were obtained, and thru the courtesy of the Centrals concerned, were operated for the remainder of the period at Hda. Santa Rita, Guánica, at Hda. Florida, Santa Isabel, and at Hda. Verdaguer and Hda. Olimpo, Guayama.

One can hardly think of a positive stimulus having a negative effect, but it is not so difficult to imagine a lack of stimulus having no effect. Fajardo has the least recorded variation between day and night temperatures,—by months, less than 20°F.— for the 1936-41 period, and also has the smallest number of *Diatraea* egg-clusters per man-hour, the least variation in their abundance, and the lowest parasitism by *Trichogramma.* If all of these negatives mean anything, then it seems possible that their opposites might be correlated. Thus we awaited results of the thermograph installed at Hda. Florida, Santa Isabel, for the fields in that region have the greatest variation in abundant of *Diatraea* egg-masses, the greatest abundance of eggs and the highest parasitism by *Trichogramma.* For the period during which the thermograph was operated, the variation between night and day was almost exactly the same as for the same period at Fajardo. Obviously, the apparent correlation at Fajardo was meaningless as applied to Santa Isabel, and the extremes of *Diatraea* oviposition at Santa Isabel are not to be explained on a temperature basis.

Temperatures at Santa Isabel do not differ decisively, and often not at all, from those reported at Ponce and Aguirre, and certainly can not be considered as explaining the higher oviposition of *Diatraea* moths there as compared with adjacent localities to the east and the west.

At Santa Rita, Guánica, no two years of our observations exhibit a similarity of pattern of abundance of egg-clusters or attack by parasites or predators, and the records of temperature were obtained for too short a period to indicate anything.

During the third year of observations in the Guayama region, it was noted that an abundance of egg-clusters and acompanying high parasitism by *Trichogramma* developed first in the fields farthest away from the coast and closest up under the mountains, and, by going over the records of the previous years, it was possible to trace a similar occurrence during those years. It seemed possible that this might be an effect of temperature, thus two thermographs were installed in addition to the maximum-minumum thermometer records contributed by the office of the Irrigation Service at Guayama: one at Hda. Verdaguer, not far from the coast of the Caribbean, the other at Hda. Olimpo, up the Carite valley between the mountains. Most unfortunately, little difference in the time of appearance of abundance of egg-clusters was noted in the two final years for which comparative temperature records are available. The thermograph records show but minor variations from each other, or from the maximum-minimum thermometer readings in town.

If one finds an apparent correlation between *Diatraea* egg abundance and temperature at one locality, it can often be almost exactly duplicated in reverse at the same locality another year. Thus, the net result of all observations on temperature, including the special observations in addition to those furnished by the Weather Bureau, fails to indicate anything decisive. Indeed, one may state that: within the normal range of temperatures and humidities experienced in the coastal cane-growing regions of Puerto Rico, oviposition by *Diatraea saccharalis* F., and parasitization of its eggs by *Trichogramma minutum* Riley most of the time, depends on other facters than rainfall and temperature.

Locality Graphs

Shortly after the investigation reached the stage of establishing the boundaries of the regions that were to be observed, and restricting observations only to those localities, the construction of graphs for each locality was begun, to show graphically the conditions as they were observed. Begun in a small way, with horizontal spaces equivalent to weeks, as the investigation was continued from year to year, additional paper had to be pasted to the original sheets to continue to represent the accumulating data. Vertical spaces were egg-clusters per man-hour; the fresh and the hatched on one side of a central base line; the eaten by ants and the parasitized and the emerged (including partly parasitized) on the other side representing natural control. From the very beginning, rainfall by weeks was entered on what it was expected would continue to be blank space, and later the maximum and minimum temperatures by weeks. In this way, all pertinent data for each locality was kept graphically up to date by being entered on the graph just as soon as the field notes had been summarized and the weekly weather reports received.

Some of the more interesting of these graphs have been redrawn, and are here presented. In all these redrawn graphs, the central base line divides "fresh" egg-clusters into those above the line which were actually parasitized or would have become parasitized had they been left in the field, and those below the line which would have hatched had they been left in the field. Thus, everything above the central line represents egg-clusters subject to natural control; everything below the line represents surviving *Diatraea* caterpillars.

The first plate of graphs includes that for Coloso, typical of the northwestern corner of Puerto Rico, which accompanies that of Fajardo, of the northeastern corner, and that of Guánica of the southwestern corner: no two of which show any traces of similarity. The graphs of two north coast regions, Manatí and Dorado, show the general similarity of two adjacent regions and minor differences; the graphs of two similarly adjacent south coast localities, Ponce and Santa Isabel, are presented together for contrast.

Ideal graphs

The ideal curve of host abundance and control by parasitism would show these characteristics: starting from a scarcity of host, it should show a rapid rise in host abundance, followed by a parallel rise in parasitism which continues at almost total parasitism until fresh hosts almost completely disappear, which of course involves the coincident disappearance of the parasites. Applied to the graphs of *Diatraea* egg-abundance, the fit is almost perfect in 1938 at Coloso and intervening localities to Manatí and Dorado, and only a little short of perfect during the other years from Coloso to Arecibo. (It also describes with equal accuracy the major wave at Guánica in the winter and spring of 1940, but with ants playing the important role in control and *Trichogramma* of secondary importance). The recurrence of this wave each year at approximately the same time in northwestern Puerto Rico would appear to indicate that it is a seasonal phenomenon in its initiation at least, being accompanied by a more or less pronounced difference in rainfall and temperature in the spring. The more or less sudden drop before the end of summer, long before there is any difference in temperature or rainfall, would therefore appear to be due to the perfection of natural control, and not to a change in weather, for there is none at this time of year. The height of the wave, its continuance and its sudden break are all aspects of the near perfection of control by parasites, and it is the combination of seasonal initiation and natural control which forms an adequate explanation of the waves of abundance of *Diatraea saccharalis* in the northwestern corner of Puerto Rico.

Accuracy

The difficulty in explaining the locality graphs for the remaining four-fifths of Puerto Rico on any reasonable basis raises the question whether these graphs actually are an accurate representation of conditions in the cane fields. Of course, the same methods were used in the Coloso-Arecibo region as elsewhere, but there remains the possibility that methods sufficiently accurate there, fail to give adequate results elsewhere. It must be admitted that observations every month did not come often enough to correctly plot waves of short duration, and also the erratic character of the waves of abundance might be due in part at least to a change in the actual fields from month to month, as some became too high for ready examination and were replaced by others of much younger cane. It must be remembered, however, that "height of cane", as such, does not affect the result at all, for the summarized data of height of cane is statistically conclusive that there is no effect. Individual fields vary, and sometimes the variation is so extreme that there seems to be no similarity. Some fields may be in the trough of a wave when others are at the crest, the average of such fields producing such confusion as to obscure the pattern of each one. This will possibly explain how it is possible for waves of abundance of egg-clusters to appear in mid-winter at Manatí, just as one is sure that perfection of natural control should make any such thing impossible. It is impossible in the fields where it has been attained, but other fields now being examined completely change the picture, especially if the region is not a natural group.

A Single Field

It has been taken for granted that once *Trichogramma* becomes established in a field, it will continue to increase indefinitely until all eggs are parasitized. In Puerto Rico, this may not occur.

As an outstanding single example, one might cite the case of Santa

Rita No. 4 at Guánica, which as plant cane a month and a half old on December 7th, 1938 was observed with no egg-clusters, but twenty-two days later had 160 egg-clusters per man-hour and 51% parasitism. One should note that this happened in December, at a time too late for cutting seed cane for planting gran cultura, and too early for the regular grinding season, if it is thought that the moths flew in from some field of mature cane, disturbed when the cane was cut. By the ideal curve, parasitism should increase, and the number of egg-clusters decrease only when close to 100% parasitism had produced natural control. Instead, when examined three weeks later, both the number of egg-clusters and the percentage of parasitism was half what it had been before, with the situation practically unchanged when again examined at the end of another three week interval. Two weeks later, the number of egg-clusters was down to one-sixth of the peak, but of this decreased number parasitism had gone up to 40%. The peak of 160 egg-clusters per man-hour is the all time high for plant cane in Puerto Rico, and the field is an exception to that extent, but it is typical of many in that an unprecedented high of fresh egg-clusters to be parasitized actually was not attacked, for *Trichogramma* was absolutely and relatively much less abundant when the next two examinations were made, and absolutely least abundant at the final examination.

This field is like a poorly-planned drama, with all the interesting action happening off-stage between the first and second act. But with no egg-clusters collected at the first examination, how could anyone imagine that the next observation would show an all-time high? In other years, this field had shown no exceptional abundance of egg-clusters, and when last observed on June 3d, 1941, only four egg-clusters were found in an hour's search, while on June 16, 1937, only three egg-clusters had been found in an hour. Thus, we may be sure that a field which once has an abundance of egg-clusters doesn't always have an abundance, and apparently is as unpredictable as where lightning will strike. Yet the third examination in 1938-9 gives the second all-time high at Guánica for plant cane, and the fourth examination the third all-time high at Guánica. The decrease from the previous highs still o'ertopped all its neighbors for five years! Thus, altho there was a relative decrease in the number of eggs, this was an abundance subject to parasitism many more than in any other field in the region at the time. (In December 1938, the black egg-parasite, *Prophanurus alecto* Crawford, had just made its only recorded appearance at Guánica, and it had entirely disappeared in January, when *Trichogramma* was merely less abundant).

Unpredictability

If the locality graphs of northwestern Puerto Rico actually represent commercial control of *Diatraea* by its egg-parasite until the following spring, this requires four or five months of continued abundance of host eggs, as well as of the parasite, before it becomes effective. This is shown by the sudden drop in abundance of host eggs, approaching zero, and continued scarcity thru the remainder of autumn and winter until the following spring. By contrast, the sharp-pointed and narrow-based waves of *Diatraea* and *Trichogramma* abundance almost invariably occurring on the south and east coasts are decidedly not of the same character. To be sure *Trichogramma* has often parasitized most of the eggs, but if it takes four or five months to produce really effective control at Coloso, the same result can not be obtained elsewhere in much less time. Thus we may conclude that the sudden decrease in abundance of host eggs is not due to parasitism of host eggs of the preceeding generation, but would occur in any case, and is largely or entirely independent of parasitism. In fact, it also occurs where parasites are scarce, in which case, ants tend to fill the vacuum, as well as when parasites are just beginning to become abundant, or are numerous. That is: waves of abundance of *Diatraea* eggs occur in the greater part of the canegrowing area of Puerto Rico for no apparent reason at any particular time, and tend to disappear with equal suddenness without apparent reason. Furthermore, that the larger part of such waves is destroyed by parasitism or eaten by ants is merely an accident that gives no indication of how soon that particular wave will recede, or how long the succeeding trough of scarcity of eggs will continue.

Stimuli to Ovisposition

In captivity, the female moths of *Diatraea saccharalis* live only a few days, but during their short adult life they deposit large numbers of eggs on everything in their environment, showing little discrimination between cane leaves, grass, strips of paper, or the glass sides of the tube. As to what happens in the field, we can only guess, for our search for eggs was conducted only in cane fields, and only exceptionally and by accident did we sometimes happen to find an egg-cluster on a blade of malojillo grass. In Puerto Rico at least, if the eggs are undisturbed by ants or wasps, they almost invariably hatch, as practically no dried-up or infertile eggs were noted.

Nothing is known as to the stimuli affecting oviposition in the field. To the extent that eggs are usually laid in rows, one has the feeling that some care was used in oviposition; but sometimes they are laid without any order in an irregular mass that suggests that no external stimulus to oviposition was needed, as the moth was in so much of a hurry due to internal pressure that there was no time to even lay them straight. In captivity, moths lay from 30 to 40 masses of eggs, and quite possibly do even better than that in the field. Rosenfeld & Barber (1914) note one female in Argentina that laid 72 masses in five days, but some of these masses contained very few eggs. On this basis, it is obvious that not many moths are required to result in a "wave of oviposition," really quite an insignificant number by comparison with that of most other insect pests attacking crops. Indeed, the moths are apparently so scarce in the field, or so difficult to find, that the number of egg-clusters per man-hour gives a much better idea of the abundance of the insect. But it fails to answer the question of whether an abundance of eggs is the result of a stimulus acting on a comparatively few moths, or if it was a stimulus acting on pupae that many moths should emerge at about the same time, or how far back the stimulus must be carried, and acting on what stage of the insect, to produce what we find as an abundance of egg-clusters. Where climatic conditions are more extreme than in coastal Puerto Rico, the effects on *Diatraea* promptly become apparent in all stages of its existence, but under the equable climatic conditions of the cane-growing regions of Puerto Rico, a major response, as expressed in an abundance of moth-borer egg-clusters, is apparently the result of a temporary and partial failure of biologic control in a previous generation. Nowhere in Puerto Rico at any time since entomologists have been here has *Diatraea* even begun to completely occupy its niche and completely destroy a crop of cane. Before the introduction of the Surinam toad, *Bufo marinus* L., such complete occupancy by another insect pest of cane often did occur in Puerto Rico when white grubs ate all cane roots. Only in some coastal valleys of northern Perú (Wolcott 1929) has *Diatraea* been observed to cause 100% damage to mature cane, and this despite the presence there of fully as many parasites as are present elsewhere. Natural control by parasites and predators is so effective in northwestern Puerto Rico that *Diatraea* practically disappears by midsummer, and elsewhere is merely less perfect, and is devoid of any seasonal pattern. In either case, *Diatraea* fails to occupy more than a small fraction of its distinctive niche in Puerto Rico cane fiields.

Phase of Moon

On the possibility that phase of the moon might have a decisive effect on oviposition by *Diatraea* moths, all of our records were summarized on that basis. The vital difficulty proved to be to allocate the eggs according to the phase of the moon in which they were laid, for the records gave no indication of whether a "fresh" egg-mass was laid one or seven days before, and one could be even less exact regarding the age of any other kind of egg-cluster. With an arbitrary approximation as to the supposed age of the egg-clusters, the results were positive in showing most eggs laid when the moon was "new" (dark), and least when it was full, but with so little difference in the totals that the results were by no means conclusive. Waves of egg-clusters do not come at monthly intervals, or, at least as we made observations at five, four and three week intervals, any such monthly waves were obscured by larger waves at somewhat or very much greater intervals.

Variation

The sharp points of the crests of waves in a locality graph represent the average of several fields, the field with most egg-clusters often having twice or many times as many as the field with fewest. Usually the difference between them was considerable. All the details of the graph are also an average, in some classes glossing over differences so great that one might better call the result a compromise. To give some idea of how great are these extremes, those over the entire period of five years are given in the accompanying table (Table No. 2, p. 64) : the maxima for both plant and ratoon, the average of the ten highest, the minima for plant and ratoon, the latter indicating how many zeros were found at each locality. It must be admitted that the figures for each locality are not entirely comparable, for the number of fields examined varied from 440 at Guayama-Arroyo and 422 at Ponce, to 215 at Coloso and 213 at Isabela and Quebradillas, but any correction would only increase the proportion of zeros where they are already most numerous as shown in the table. No correction is possible for the maxima, for even one additional record at a locality might upset its best previous record.

The figures of the average of egg-clusters in the fields with the ten highest records for plant and ratoon at each locality give a better idea of how many high fields may be expected after averaging down the exceptionally high peaks, but are often strikingly persistent in paralleling the extremes, as note Ponce and Guayanilla, Fajardo and Dorado.

Manatí plant fields in 28 instances had no egg-clusters, and Fajardo ratoon fields in 22 instances had none. Of the field of plant cane at Guánica with 160 egg-clusters per man-hour, a detailed discussion has already been given, stressing its inconsistencies. The field at Maunabo (in the Yabucoa-Maunabo-Patillas region) previously called Garona or Bordalesa at Km. 110.5, on November 31, 1938, had the all-time high —172 egg-clusters— for ratoon cane for the entire Island, just following the second (100 egg-clusters), and followed imediately by the third (78) and fourth (64) for its region as well. These records coincided with the only observed appearance of *Prophanurus* in this part of the Island. This does not necessarily mean that it always has an abundance of egg-clusters, for in August 1939 only 8 per man-hour were collected, and less than a month before its second high, it had but 18. It is entirely consistent in parasitism, however, with as low as 25% for 8 egg-clusters, with perfectly graduated increases to the highs at 80%. Even with maximum parasitism, 6 egg-clusters that had hatched were found, thus it failed of 100% actual control by *Trichogramma*. But it is so largely consistent as to serve as an even greater contrast to the inconsistencies of Santa Rita. No. 4, and many similar fields at Guánica and elsewhere on the south coast.

Both of these highs, in plant cane and in ratoon, came at a time when egg-clusters were generally abundant nearly everywhere, but in the Guánica district on the same day one field had only 10 egg-clusters per man-hour, or only one-sixteenth of the number found at Santa Rita No. 4, and at Patillas on the same day, one field had 29 egg-clusters, or one-eighth of the number at Garona.

Unpredictability in Parasitism

It has been previously shown how the average of parasitism increases regularly with increases in the number of egg-clusters. This is only by averages, however, and the variations in total number of egg-clusters, as noted above, are merely symptomatic of an equal variability in parasitism in both directions. While the majority must be sufficiently consistent if the averages are to follow a regular pattern, many individual fields do not follow this patern. Not only are fields with few egg-clusters and high or total parasitism to be found, but also some with large numbers of egg-clusters and little or no parasitism. This is the realistic, practical background for the entire investigation, for in such fields laboratory-reared parasites can be released with reasonably good chances that they will promptly and decisively increase parasitism. Indeed, it is because of the great variation in conditions in individual fields in Puerto Rico, not following a set seasonal pattern except in the northwestern corner where natural control is most nearly effective, that success in the economic aspects of this project is possible.

Our experiments have indicated, as indeed common sense would suggest, that release of laboratory-reared parasites is likely to result only in failure when fresh host eggs are scarce, or, if fresh eggs are abundant, can not be proved to be due to the release when natural parasitism is high. From the practical, commercial standpoint, attempts at the biological control of a pest when it is so scarce are hardly justified, while fields with high natural parasitism certainly do not need additional parasites. Put on a statistical basis, success is hardly to be expected if less than five fresh egg-clusters can be found in an hour's search, and can not be proved if natural parasitism is over 33%. These are the absolute minimum conditions, with results more decisive if parasitism is very low or nonexistent, and more likely to be successful if the abundance of egg-clusters considerably exceeds the minimum of five fresh ones.

Fields for Releases

Of fields meeting these minimum conditions, 445 were noted during the five years observations in Puerto Rico, out of a total of 4,707, approximately every tenth or eleventh field. Evenly distributed, finding such conditions might seem difficult, and indeed the real purpose of the latter part of the investigation was to find some sign or indication of how they might be predicted without continued inspection of all fields. We found no such sign or indication, and their occurrence can not be predicted except in a general way, but a preliminary inspection of ten minutes is sufficient to indicate all that one needs to know of a particular field, in practise. If no fresh egg-cluster is found in the first ten minutes of inspection, there is little point in looking further. If one fresh egg-cluster is found in the first ten minutes, conditions at least come up to the irreducible minimum; if two or more fresh egg-clusters are found, the field is worth more careful inspection, and in most cases will be found suitable for releases. Actually, their distribution is by no means uniform as to locality or season. In 100 fields of plant cane, 12.4 are of this character, but of ratoon fields only 6.4. Only at Dorado and Toa Baja, of all the regions examined, was the number of such fields equal in plant and ratoon: 11 in 100 fields. Twice as many fields of plant cane at Ponce, Salinas and Guayama were suitable for the release of parasites as of ratoon cane, and Santa Isabel had four and a half times as many. Even greater were the contrasts in the northwestern corner of the Island, and Coloso had no fields of ratoon cane of this character. except one where the trash had been burned.

During the month of July, hardly 1 field in 100 meets these conditions, only 2 in 100 in June, and hardly 3 in 100 in August. April and May have more of these exceptional fields, but it is only beginning in September and October that they constitute a tenth of all fields; in February and March average 12 in 100; 13 in November and January, and reach a high of 14 in 100 in December. By localities, only 4 such fields were found in 100 examined at Coloso, where the near perfection of natural control makes their occurrence least likely, and 5 at Arecibo and Fajardo, but Ponce and Guánica had 14 in 100, and Salinas 17. Combining locality and month, January at Ponce had 39 such fields out of 100 examined in 1936-41, Santa Isabel 37 in November, Salinas 34 in February and Guánica 30 in November. These figures only show what was observed in 1936-41, and give only an indication of what may be expected in other years, but in general are so consistent as to indicate a strong probability that during any of the autumn, winter and early spring months of any year one should find one out of every four or five fields suitable for the release of parasites at these localities. To this limited extent in Puerto Rico therefore, temperature, or season, does have an effect on *Trichogramma*. even if not on its host. The chances are only slightly less of finding such suitable conditions at most localities on the east and northern coasts during the winter, and while plant cane is most likely to offer suitable conditions for release, ratoon cane needs them with sufficient frequency not to be entirely neglected.

Experimental releases have an equal chance for success at any locality, regardless of how low are the chances of finding suitable conditions at that locality at that time, if a field can be found which meets the requirements of an abundance of fresh egg-clusters and low parasitism at the time of release. It certainly is like looking for a needle in a haystack, however, to attempt to find the exceptional field in mid-summer, and in practise, attempts at release should be confined to the autumn, winter and spring. The northeast coast, because of scarcity of egg-clusters at all times of year, and the northwest coast, because of normal near perfection of natural control, offer the least opportunity for conducting successful releases. The south coast during the fall and winter has the greatest number of such exceptional fields with many fresh egg-clusters and low parasitism, and offers the best opportunity for the successful release of laboratory-reared parasites in Puerto Rico.

SUMMARY

To determine the optimum conditions for releasing laboratory-reared egg-parasites, *Trichogramma minutum* Riley, in Puerto Rican fields of sugar-cane for the control of the lesser moth borer, *Diatraea saccharalis* F., field observations on natural conditions of parasitism at sixteen coastal localities were commenced in the autumn of 1936, and continued until the autumn of 1941.

For a locality record, observations of one hour or one-half hour were made at four or five week intervals, later at three week intervals, in from five to eight or more typical fields, not adjacent, but not too far distant from the point where rainfall and temperature records were made by co-operative observers of the Weather Bureau.

Of the 45,430 egg-clusters collected from 4,595 fields, 5,391 had had parasites emerge from them, 638 were partly parasitized and 11,433 were parasitized: a total of 17,462 for parasitism, or 38% of the total. At all localities, and during all months, *average* parasitism increased with abundance of egg-clusters.

Egg-clusters eaten by ants, *Monomorium carbonarium ebeninum* Forel, totaled 7,377, or 17% of the total.

Egg-clusters from which caterpillars had hatched numbered 12,635, or 28% of the total. Unhatched, apparently unparasitized or "fresh" egg-masses numbered 7,965, or 18% of the total. The presumed fate of these "fresh" egg-clusters was not in proportion to the collected number of hatched, eaten and parasitized, because, as pointed out by Dr. G. W. Kenrick, so many parasitized and eaten eggs had already been subtracted. Had they not been collected, but left in the field, he estimated that somewhat more than half would hatch, nearly one-sixth be eaten by ants, and nearly one-third become parasitized. Adding these to the observed number in each class indicates that approximately 38% of all *Diatraea* eggs hatch, 21% are eaten by ants and 46% become parasitized, or with some eggs in both classifications, a total for natural control by ants and wasps of 62%.

Young plant and ratoon cane, from 18 inches to four or five feet in height only, was examined. Height of cane within these limits had

no effect on abundance of egg-clusters or parasitism. The percentage of parasitism in plant cane was 27%; in ratoon cane of which the trash had been burned 31%. In ratoon cane of which the trash had not been burned, natural parasitism was 50%.

Nearly half of the environment of the fields examined was high cane, and sugar-cane in some stage of growth formed two-thirds of the environment.

Within the normal range of temperatures and humidities (rainfall plus irrigation) experienced in the coastal cane-growing regions of Puerto Rico, *Diatraea* oviposition, and parasitization by *Trichogramma* most of the time, depends on other factors than rainfall and temperature.

The initiation of the typically broad-based, blunt-topped waves of abundance of *Diatraea* eggs and high parasitism by *Trichogramma* observed each year in the northwestern corner of Puerto Rico, is presumably seasonal, being due to the coming of spring, but their height, duration and sudden break before autumn are all aspects of the near perfection of natural control by parasitism in this region.

In the remaining four-fifths of the coastal cane-growing area of Puerto Rico, sharp-pointed and narrow-based waves of abundance of *Diatraea* eggs occur for no apparent reason at any particular time, and disappear with equal suddenness without apparent reason. That the larger part of the eggs in such waves is often destroyed by parasites or eaten by ants is merely an accident that does not imply adequacy of natural control in the egg stage at that time to account for their disappearance.

Maxima of 160 egg-clusters per man-hour in plant cane and 172 in ratoon cane, and many instances of minima of zero are symptomatic not only of variation in abundance of egg-clusters, but also of deviation from the average of parasitism in proportion to the abundance of host eggs. Conditions of abundance of moth borer egg-clusters in any particular field can be determined only by inspection, and no specific prediction can be made based on vigor or age of cane, weather, location of the field, environment, or any other kind of sign or indication that we have been able to detect. Fields with more than five fresh egg-clusters per man-hour of examination, and parasitism of not more than 33% constituted nearly a tenth of all fields. Such fields offer the best opportunity for the effective release of laboratory-reared parasites, and are the only ones in which releases can be commercially justified.

Generalized predictions as to the occurrence of such conditions can be made. They occur twice as often in plant as in ratoon cane, and are scarce almost to the vanishing point in mid-summer. They are most abundant on the south coast during autumn, winter and spring, with a peak of abundance in December, and it is here and at this time that releases made in fields selected on the basis of previous inspections will be most successful.

Conclusion

The initiation in the formation of waves of abundance of egg-clusters of *Diatraea saccharalis* F. each spring in the northwestern corner of Puerto Rico is seasonal, but their height, duration and sudden drop is late summer are due to the near perfection of natural control by *Trichogramma minutum* Riley. In the remaining four-fifths of Puerto Rico, the factors responsible for the initiation, height and usually much shorter duration of waves of abundance of egg-clusters are not seasonal at all, but apparently depend on temporary and partial failure of biologic control in previous generations of the host. Natural control in the egg stage, even with often almost as many egg-clusters eaten by ants as attacked by parasites, rarely occurs, because of the shortness of the period of the wave. Irrigation so modifies humidity that rainfall, varying from less than 30 inches to nearly 90 inches per year, can not be proved to be a factor, and the variations in temperature are within too narrow limits to produce an effect. Height of cane and variety of cane has no effect on egg-clusters, but ratoon cane averages greater abundance of host eggs, and higher parasitism, than plant cane or ratoon cane of which the trash has been burned. Parasitism invariably averages higher when or where host eggs are most numerous, but great variation in abundance of eggs in individual fields is paralleled by comparable variation in parasitism not depending on host abundance. Fields with more than five fresh egg-clusters per man-hour and less than 33% parasitism are one out of every ten or eleven, and generalized predictions as to the occurrence of such conditions can be made. The release of laboratory-reared parasites can be commercially justified only in fields meeting these conditions, which occur most often in plant cane on the south coast during the winter.

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