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BIOLOGICAL CONTROL OF *DIATRAEA SACCHARALIS* (F.) IN BARBADOS BY *APANTELES FLAVIPES* CAM. AND *LIXOPHAGA DIATRAEAE* T. T. (*)

by

M. M. ALAM (1), F. D. BENNETT (2) & K. P. CARL (3)

(1) Ministry of Agriculture, Science and Technology, Barbados.
(2) West Indian Station, C.I.B.C., Curepe, Trinidad.
(3) European Station, C.I.B.C., CH-2800, Delémont, Suisse.

Early biological control attempts of *Diatraea saccharalis* in Barbados had failed. Subsequent intensive release campaigns of several parasite species from the Neotropics, Africa and India resulted in the temporary establishment of *Metagonistylum minense* and *Trichogramma japonicum* and the permanent establishment of *Lixophaga diatraeae* and *Apanteles flavipes*. The latter built up an extraordinarily high population level within a short period of time. From damage assessments it is evident that due to high parasitism crop damage was reduced considerably. The joint borer infestation which fluctuated around 15 % until 1966 decreased to less than 6 % in 1970.

1. Previous biological control attempts

Biological control of *Diatraea saccharalis* (F.), the only sugarcane moth borer occuring in Barbados, has been attempted for more than 40 years. Before 1958, this work was mainly devoted to mass rearings and inundative releases of the native egg parasite, *Trichogramma fasciatum* PERK. Up to 300 million individuals were released annually and it was claimed that this species reduced the joint infestation from over 30 % to about 15 % during 1930-34. In 1958 the liberation campaign was stopped. The fact that the joint infestation did not return to its original level is sufficient evidence for the claim that the use of the egg parasite as a « living pesticide » had no appreciable effect on the host population level.

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In addition to the control programme with *T. fasciatum* there have been several attempts to establish the Tachinid fly, *Lixophaga diatraeae* T.T., a native of the Greater Antilles. This was unsuccessfully released in 1930 (Box, 1937), again in 1934-35 when it was recovered the following two years and then disappeared (TUCKER, 1938), and a third time in 1948 to 1950, again without becoming established.

These early *Lixophaga* campaigns were thought to have been neither sufficiently intense nor of sufficient duration (METCALFE, 1960; VAN WHERVIN, 1963), to afford permanent establishment. From 1958-63 these authors released over half a million flies, the progeny of stocks obtained from Cuba, Jamaica, the Dominican Republic and Antigua, in order to ensure as wide a genetic variability as possible. Smaller numbers of the parasite were released subsequently; a total of about 92,000 individuals from 1964-69.

During the intensive release campaign before 1963, *Lixophaga* became established in small areas, but at such low levels that VAN WHERVIN (1963, 1966) was lead to the conclusion that « on a whole Barbados is environmentally resistant to the permanent establishment of *Lixophaga* ». In 1966 the species was recorded in 15 different plantations, with a maximum total parasitism of 40 % (BENNETT & PSCHORN-WALCHER, 1968). Parasitism declined in 1967 when *Lixophaga* disappeared from 9 of these plantations and the highest rate of parasitism recorded was only about 10 %.

Later the populations increased again, the species became more wide-spread and the overall parasitism rose to a level which had not been observed before. In 1968 recoveries were made from 18 plantations with the highest parasitism at 73 %, and in 1969 from 42 plantations with parasitism in one area reaching 95 %. For the first time, the species had become established in all three rainfall zones of the island. The significant increase in the survival rate of *Lixophaga* during these two years which continued in 1970 appears to indicate that a strain, better adapted to the environmental conditions of Barbados, has developed over the years.

2. Recent introduction and establishment of natural enemies

In view of the previous failure to achieve biological control of *D. saccharalis* with *Lixophaga*, several other parasites were introduced from Trinidad, South America, Africa and India from 1966 onwards. Some of these had been tried previously, but 13 species mostly from India and East Africa were introduced for the first time. These, together with the more important earlier introductions, are listed in table 1, and the establishments ensuing, either temporary or permanent, are set out in table 2.

TABLE 1

Parasite introductions into Barbados

Species	Source	Year	Approx. no.
TACHINIDAE :			
Lixophaga diatraeae T.T.	Cuba, Domin. Republic	1930-50	27,000
— —	Jamaica, Antigua	1958-63	500,000
— —	— —	1964-69	92,000
Metagonistylum minense T.T.	Brazil	1930-40	16,000
— —	—	1966-68	96,000
Paratheresia claripalpis WULP (several crosses)	Bolivia, Peru, Mexico, Trinidad, Columbia	1964-69	59,000
Palpozenillia sp.	Bolivia	1967-69	2,100
Sturmiopsis inferens T.T.	India	1966	100
Leskiopalpus diadema (WIED.)	Trinidad	1967	300
BRACONIDAE :			
Apanteles chilonis (MUNAKATA)	India	1966	2,000
Apanteles sesamiae CAM.	East Africa	1966-67	200
Apanteles flavipes CAM.	India	1966	2,000
Apanteles diatraeae MUES.	Trinidad	1966-67	500
Bracon chinensis WLK.	India	1966-67	200
Campyloneurus mutator (F.)	India	1966	47
EULOPHIDAE :			
Pediobius furvus GAH.	East Africa	1967-69	4,000
TRICHOGRAMMATIDAE :			
Trichogramma japonicum ASHM.	India	1966-67	65,000
Trichogramma australicum GIR.	India	1966-67	50,000

TABLE 2

Establishment of parasites in Barbados

Species	Year	Temporary	Permanent
Lixophaga diatraeae	1936-37	x	
— —	about 1960		x
Metagonistylum minense	1967-69	x	
Trichogramma japonicum	1967	x	
Apanteles flavipes	1967		x

Two of these species became temporarily established. In 1967, *Trichogramma japonicum* ASHM. was recovered, some weeks after the release of approximately 20,000 adults, but establishment was not permanent. *Metagonistylum minense* T.T. was established in one area in 1967 and became locally abundant, with total parasitism

up to 60 %. Although this species appeared to be promising in the beginning, it did not spread outside an area of about 1,5 sq. miles and eventually died out, two years after the first recoveries had been made.

The most important establishment was that of a third species, *Apanteles flavipes* CAM. In July and August 1966 about 2,000 individuals obtained from India were released in one field in the intermediate rainfall zone. The species was first recovered more than a year later, in October 1967. We are very definite that the parasite population during this year must have been extremely low, since the regular monthly recovery surveys that were carried out in the release area never produced evidence of the establishment of *Apanteles*. Following the first recovery populations of the parasite built up with amazing rapidity: 22 % of the half to fullgrown larvae collected on October 17 were parasitized, 31 % on November 9, 65 % on December 11, 67 % on December 20, and 74 % on January 4. Simultaneously with the increase in density of this localized population, there occurred a rapid spread outside the release site: within three months the parasite had dispersed over an area covering at least 2.5 sq. miles. The onset of the reaping season, and the re-distribution of field-collected and laboratory reared parasite material throughout the island made it impossible to follow the original population or to distinguish it from new colonizations.

To enhance the spread of the species, the following numbers were released at various sites throughout the island: some 2,000 individuals in 1967, 120,000 in 1968 and 56,000 in 1969. Nine months after the beginning of this campaign an island-wide recovery survey indicated that the parasite was firmly established in all 11 parishes. In 1968, parasitism ranged from 0.5-89.9 % in individual fields, with an average of 36.5 %, and in 1969 from 0.5-95.5 %, with an average of 30.3 %.

The reasons for the fluctuation of parasitism in individual fields are still poorly understood and warrant further investigations. The level of parasitism increases significantly with the increase in precipitation in the different rainfall zones of the island. In 1968, the average parasitism recorded in the low, intermediate and high rainfall zones was 24.0, 30.6 and 41.3 % respectively; the corresponding figures in 1969 were 7.2, 28.9 and 29.8 %.

Seasonal changes in parasitism also occur, but definite trends could not be shown. For example, the average monthly parasitism in the intermediate rainfall area in 1968 fluctuated between a minimum of 13.8 % in April and a maximum of 46.8 % in December, in 1969 between 16.2 % in November and 45.2 % in July. Similar inconsistent results were obtained in the low and high rainfall areas.

3. Evaluation of effect of parasitism on joint infestation

It is generally accepted in the Neotropics that a parasitism of 10-20 % by Tachinids in association with other mortality factors already prevailing should be sufficient to reduce the host density below the threshold of economic importance, for which a joint infestation level of 5 % is the generally accepted criterion. As both, *Apanteles* and Tachinids attack identical host stages, there is no reason why the mortality caused by *Apanteles* should not have the same regulating effect on the host population as that caused by Tachinids. Thus, in Barbados with an average parasitism by *Apanteles* of more than 30 % in 1968 and 1969 — and the parasitism by *Lixophaga* added, — effective control should be obtained. Let us now consider the joint infestation as a reflection to changes of crop damage as this is the only valid criterion for the impact of the natural enemy on *Diatraea* (Table 3).

TABLE 3

Percent joint infestation in Barbados determined during the reaping seasons 1963-70.

Year	Plant Crop	Ratoon crop	Total
1963	15.2	11.5	13.4
1964	19.6	13.7	16.6
1965	18.3	14.3	16.3
1966	19.5	13.7	15.7
1967	14.7	11.6	12.7
1968	11.3	8.5	9.7
1969	10.3	7.0	8.0
1970	6.6	5.1	5.9

We know from past investigations that the joint infestation since 1934 fluctuated insignificantly around 15 % (TUCKER, 1935; METCALFE, 1959; VAN WHERVIN, 1963). The infestation continued at the same high level until 1967 when the total joint infestation was 12.7 %. In 1968 this dropped to 9.7 %, in 1969 to 8.0 % and in 1970 to 5.9 %. The figure for 1968 refers to the growing season of 1967 when *Apanteles* had just become established and *Lixophaga* was rare. It is improbable that the comparatively low infestation at the end of this growing season, the spring of 1968, can be attributed entirely to the action of parasites, but the correlation of increasing parasitism and decreasing joint infestation in 1969 and 1970 is evident. The crop damage measured during the reaping seasons of these two years was the lowest ever recorded in Barbados, and it is apparent that this is due to the action of the parasites. It is planned to assess the

level of damage caused by *Diatraea* over a longer period of time in order to determine the long-term control value of the parasites. It will also be interesting to see whether the 6 % joint infestation presently observed reflects the equilibrium position around which the interaction of the *Diatraea* population and its parasites will fluctuate.

4. Discussion

Extensive efforts have been made over the past ten years to explain which ecological factor or factors were responsible for the repeated failures of *Lixophaga* and other Tachinids to become established in Barbados, and for its low abundance for several years after its establishment. Although several factors, such as climate, the number and timing of releases, diseases, host plants of adults, etc. have been investigated, there has never been a satisfactory answer to this. Nor do we have an answer as to why *Lixophaga* is now apparently thriving. All we can say at this stage is that apparently the parasite has become genetically better adapted to the ecological conditions currently prevailing in Barbados and that the pessimistic view held previously that Barbados is somehow environmentally resistant to the permanent establishment of this fly no longer applies. The prolonged efforts made with *Lixophaga* in Barbados, and the success eventually achieved despite initial failures, demonstrate clearly the merits of persevering with a programme of biological control over a long period of time.

Another equally puzzling problem is that of the establishment of *Apanteles flavipes*. If considered on theoretical grounds, this species would rank well down the list of potential candidates for the biological control of *D. saccharalis*. A closely related neotropical species, *Apanteles diatraeae* which is a specialized *Diatraea* parasite attacks numerous species in the Greater Antilles, the southern U.S.A. and Central America. Although in a few instances it has been reported as abundant in Mexico and U.S.A. e.g. *A. diatraeae* attacked up to 20 % of the larvae of *D. grandiosella* DYAR. in corn in Arizona (DAVIS *et al.* 1934), it occurs in Cuba as a rare species and attempts to use it as biological control agent against *D. saccharalis* have failed. *A. flavipes*, on the other hand, is a widespread asiatic parasite of graminaceous borers, e.g. *Chilo*, *Proceras*. It is impossible to define its exact distribution and host range because it has often been confused with a closely related species, *Apanteles chilonis*, and only recently have the two species been clearly separated (WATANABE, 1965; RAO & NAGARAJA, 1967) and it has been shipped from country to country in Asia. *A. flavipes* was sent to Florida where it bred readily on *D. saccharalis* in the laboratory, but establishment in the main cane area was not permanent (GIFFORD & MANN, 1967). Laboratory experiments in Trinidad with stocks from Mauritius were also unsuccessful (BENNETT, 1965).

Considering the general similarity of *A. flavipes* to *A. diatraeae*, the latter of which has never shown signs of being an effective control agent of *D. saccharalis*, and also the origin of the former parasite in Asia with different climatic and ecological conditions, its different host range, and its failure in laboratory experiments with *Diatraea* as host in Trinidad, it seems clear that *A. flavipes* was not a promising species to recommend for the control of *D. saccharalis*. And yet, the results in Barbados indicate that the parasite has become an extremely effective control agent. Hence, it is not always possible to make reliable predictions as to the efficiency of exotic natural enemies on the basis of preliminary laboratory experiments.

Possibly the failure of *A. flavipes* to become effectively established in the U.S.A. is due to the winter diapause of the host. Introductions into other areas where *Diatraea* breeds continuously would appear to be very promising and have been recommended (BENNETT & CARL, 1969). Following releases in the Bahamas preliminary field recoveries from *D. centrella* (MÖSCHL.) have been made.

The biological control of *D. saccharalis* in Barbados has resulted in an appreciable increase in revenue. The reduction of damage from the average 15 % joint infestation, prevailing prior to the successful establishment of *A. flavipes* and *L. diatraeae*, to 8 % in 1969 and 6 % in 1970 has resulted in an increase in revenue estimated at £315,000 and £405,000 respectively for these two years.

RÉSUMÉ

Lutte biologique contre *Diatraea saccharalis* F. aux Barbades à l'aide de *Apanteles flavipes* CAM. et de *Lixophaga diatraeae* T.T.

Des essais de lutte biologique contre *Diatraea saccharalis* ont été poursuivis à la Barbade pendant plus de 40 ans. Des libérations en masse de *Trichogramma japonicum*, faites jusqu'en 1958, se révélèrent infructueuses; la mouche de Cuba, *Lixophaga diatraeae*, fut introduite au début de l'année 1960, mais sa répartition demeura inégale et sa fréquence généralement faible jusqu'en 1968, date à laquelle elle se répandit soudain dans toute l'île et augmenta en abondance (moyenne de parasitisme en 1968 : 13,6 %). Tout s'est passé comme si, durant les années précédentes, une race s'était développée qui est maintenant mieux adaptée aux conditions environnantes de la Barbade.

En 1966 et 1967, plusieurs autres espèces de parasites furent introduites à la Barbade. Parmi elles, *Metagonistylum minense* et *Trichogramma fasciatum* s'établirent temporairement, tandis que *Apanteles flavipes*, introduite des Indes, s'acclimata d'elle-même en permanence. A la suite d'une libération d'environ 2 000 individus en juillet et août 1966, ce parasite fut retrouvé pour la première fois, plus d'un an après, en octobre 1967; à la fin de 1969, il avait colonisé toute l'île avec un taux de parasitisme de 0,5 à 95,5 % et en moyenne de 30,3 %. Ces deux dernières années, la réduction des dégâts a produit une augmentation de revenu estimée à 315 000 et 405 000 £, respectivement.

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