RELATIONS BETWEEN TWO RICE BORERS IN SURINAM, *RUPELA ALBINELLA* (CR.) AND *DIATRAEA SACCHARALIS* (F.), AND THEIR HYMENOPTEROUS LARVAL PARASITES

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PROEFSCHRIFT

TER VERKRIJGING VAN DE GRAAD
VAN DOCTOR IN DE LANDBOUWWETENSCHAPPEN,
OP GEZAG VAN DE RECTOR MAGNIFICUS,
PROF. DR. IR. H. A. LENIGER,
HOOGLERAAR IN DE TECHNOLOGIE,
IN HET OPENBAAR TE VERDEDIGEN OP WOENSDAG 9 JANUARI 1974
DES NAMIDDAGS TE VIER UUR IN DE AULA VAN DE
LANDBOUWHOGESCHOOL TE WAGENINGEN

H. VEENMAN & ZONEN B.V. – WAGENINGEN – 1974

STELLINGEN

I

Dat de witte rijstboorder, *R. albinella*, slechts geringe schade veroorzaakt is niet een direct gevolg van geringe aantallen, maar van haar levenswijze.

Dit proefschrift.

II

Het verdient aanbeveling de waarde van *A. stigmaterus* voor de bestrijding van *D. saccharalis* in veldproeven op praktijkschaal te onderzoeken.

Dit proefschrift.

III

De uitspraak dat 'Tachiniden de belangrijkste larvale parasieten van suikerrietboorders in Amerika zijn, in grote tegenstelling met de oude wereld waar Hymenoptere parasieten overheersen' geeft geen natuurlijke maar een door de mens gecreëerde situatie weer.

BENNETT, F. D., 1969. Pests of Sugarcane, chapter 5. Elsevier publishing company.

IV

Dat de Amazone vlieg na introductie in Guyana zich wél verplaatst heeft naar het aangrenzende West-Surinaamse rijstgebied maar niet naar het Midden-Surinaamse rijstgebied is een aanwijzing voor geen of een zeer geringe aantasting door *Diatraea* spp. van de natuurlijke vegetatie in het tussenliggende zwampgebied.

V

Het verstrekken van zout met anti-parasitaire malaria middelen aan de 'Bovenlandse' Indianen in Suriname moet ten stelligste afgeraden worden.

VI

'Dat de roverijen door de Zilvermeeuw (van Eidereend, Bergeend en Kluut) op Vlieland *zorgwekkende afmetingen* zijn gaan aannemen', zoals door Hoogerwerf wordt gesteld, wordt niet gestaafd door het verloop van de plaatselijke broedvogelstand van deze soorten gedurende de laatste decennia.

HOOGERWERF, A., 1973. Vragen rond de geringe aanwas van eiders (*Somateria mollissima*) en bergeenden (*Tadorna tadorna*) op Vlieland. – De Pieper, **12**, 41–52.

VII

Landbouwkundige scholing kan een positieve bijdrage vormen tot de oplossing van het vrije-tijdsprobleem dat is ontstaan bij de gekerstende 'Bovenlandse' Indianen in Suriname.

VIII

Het valt te betreuren dat in het voortgezet onderwijs de aardrijkskunde steeds minder plaats dreigt in te nemen. Zij kan in samenhang met de biologie een belangrijke rol spelen in de verdieping van de kennis van wat er om ons heen gebeurt, en daarmee het gehalte van de discussie over het milieu positief beïnvloeden.

Proefschrift van P. J. Hummelen
Wageningen, 9 januari 1974

En overigens, mijn zoon, wees gewaarschuwd;
er is geen einde aan het maken van veel boeken
en veel doorvorsen is afmatting voor het lichaam.
Van al het gehoorde is het slotwoord:
Vrees God en onderhoud zijn geboden.

Prediker 12:12,13

And further, by these, my son, be admonished: of making many books there is no end; and much study is a weariness of the flesh. Let us hear the conclusion of the whole matter: Fear God, and keep his commandments: for this is the whole duty of man.

Ecclesiastes 12:12,13

CONTENTS

1. INTRODUCTION

In Surinam there are two lepidopterous stem-borers of rice: the white borer, *Rupela albinella* (CR.) and the brown borer, *Diatraea saccharalis* (F.). *R. albinella* has a very restricted host range; apart from rice it is only rarely found in two wild Gramineae (KENNARD 1965). *D. saccharalis* is a polyphagous species. This borer generally attacks sugarcane and maize more than rice. Several wild grasses are also known as food plants.

Most data on the ecology and economic importance of the borers so far obtained in Surinam mainly refer to the 'Wageningen Rice Scheme', an irrigated area of 8000 ha where two crops are grown annually (Figure 1). DE WIT (1960) mentioned local field losses of up to 50%, caused by *D. saccharalis*. VAN DINTHER (1960b) calculated a total reduction in rice yield of about 200 kg/ha as an overall maximum for both borers. He found that *Rupela* damages the stalk only slightly, so that crop losses are small to very moderate. Stems infested by *D. saccharalis* are often seriously damaged and often die. Fortunately *D. saccharalis* is not normally numerous. In 1958 a *Rupela*/*Diatraea* moth ratio of 22:1 was recorded (VAN DINTHER 1960b).

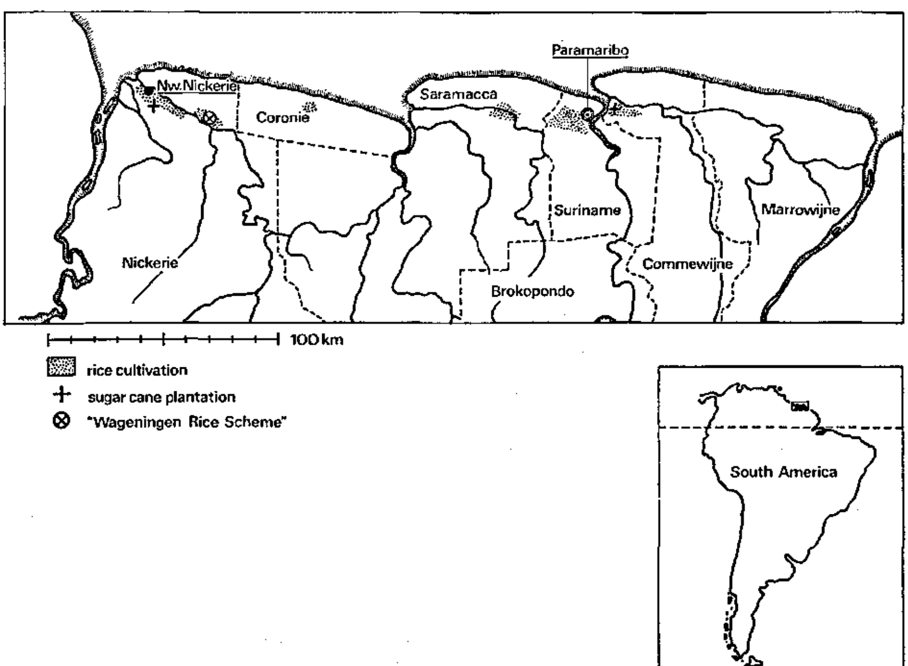

FIG. 1. Review of rice and sugarcane cultivation in Surinam.

In the 'Wageningen Rice Scheme' separated sowing and harvesting periods with as short a duration as possible, in addition to stubble burning and clean cultivation of fallow fields, are practised. Since the reclamation of the area these measures, gradually carried out more carefully, have proved valuable in limiting borer infestation. A further depressive action can be ascribed to the side effect of a more intensified application of insecticides against non-borer pests, such as leaf-eating caterpillars (*Spodoptera frugiperda* SMITH), delphacids (*Sogatodes orizicola* MUIR) and seed bugs (*Oebalus poecilus* DALL.). The mean percentage of total infestation by *Rupela* and *Diatraea* dropped from 31% in 1956 to 8% in 1961 for the crop of the April-September season, and from 40% to 15% for the crop of the October-March period (VAN DINTHER 1971).

Due to the scarcity of information about these borers elsewhere in Surinam, – i.e. in rice areas cultivated by small holders – I concentrated my research on the trial fields of the Centre for Agricultural Research – 'CELOS' – situated near the capital of Paramaribo (Figure 1).

The purpose of my three year study, from November 1969 until December 1972, was to obtain detailed information on the life history and habits of the borers, to establish their economic status and to find out how their numbers were limited, especially by parasites and predators. Since the result of chemical control of stem borers of graminaceous crops in the neotropics are often disappointing, and not economically feasible, research into the value of their natural enemies is most important. Much work on the biological control of *D. saccharalis* by parasites in sugarcane has already been done in Louisiana, the West Indies and some countries in South America, but not as yet in Surinam. Research into *D. saccharalis* was facilitated because this borer could be reared in large numbers on an artificial medium.

1.1. RICE FARMING

Rice is by far the most important crop in Surinam. Its cultivation takes place almost exclusively in the young coastal plain, a lowland zone predominantly of heavy marine clay. Here there are two main rice areas present, viz. one in the Nickerie district in West Surinam (25,000 ha) and the other forming more or less a belt in the districts of Saramacca, Suriname and Commewijne (7,900 ha) (Figure 1).

There is a distinct difference between these two areas with respect to the system of rice cultivation. In West Surinam pre-germinated seed is sown directly in the irrigated fields. Fertilizers are used and attention is paid to the control of weeds, snails and insects. Mechanization has been well introduced. In this region the 'Wageningen Rice Scheme' is situated. Here sowing, fertilization and pest control are done by aircraft.

In the more centrally situated rice belt of Surinam, farming follows the traditional pattern. Rice is sown on a seed bed (nursery) and when about 6 weeks old the young plants are transplanted by hand to the irrigated parcels.

TABLE 1. Areas under graminaceous crops (in ha). (Agricultural census 1969).

district	rice	maize	sugarcane
Nickerie	25,024		800
Coronie	276	9	1
Saramacca	1,655	71	
Suriname	5,155	45	1
Para	15	11	8
Commewijne	1,079	59	2,100
Marowijne	27	25	
Brokopondo	13	3	
Total	33,248	226	2,905

Fertilizers are not commonly applied. The parcels are small, often less than 50 × 50 m.

Besides rice, sugarcane is the only other graminaceous crop of importance in Surinam. It is cultivated on the Marienburg Estate (2100 ha) in the district Commewijne, and on the Waterloo Estate (800 ha) in the district Nickerie. See Table 1.

1.2. CLIMATE

Surinam has a tropical rainy climate which is characterized by a small fluctuation in the mean monthly temperature (Table 2). The mean daily amplitudes are 8.2°C for Paramaribo and 6.3°C for Nieuw-Nickerie.

With the rainfall as a parameter, the year can be divided into four seasons:

TABLE 2. Mean daily air temperatures in °C at the Experimental Station 'CELOS' (Paramaribo) for the years 1970, 1971 and 1972.

	maximum			minimum		
	1970	1971	1972	1970	1971	1972
Jan	29.3	28.4	29.0	23.0	22.7	22.1
Feb	29.4	28.6	28.9	23.3	22.2	22.2
March	29.8	29.2	29.5	23.1	22.8	22.8
April	29.5	29.5	29.2	23.1	22.6	22.9
May	30.4	29.4	30.2	23.7	23.2	23.4
June	30.4	29.4	30.4	23.3	22.9	23.0
July	30.8	29.9	31.4	23.0	22.7	22.4
Aug	31.6	30.9	31.9	23.2	22.6	22.9
Sept	31.7	31.6	32.9	22.9	22.5	23.2
Oct	31.9	31.4	33.4	23.1	22.4	23.4
Nov	31.7	31.0	31.5	22.9	22.8	23.2
Dec	29.8	30.1	29.4	22.4	22.2	21.9

TABLE 3. Monthly rainfall in mm at 'CELOS' in 1969, 1970, 1971 and 1972 compared with the mean monthly precipitation in the Botanical gardens during 1942–1971. Both registration stations are located at Paramaribo.

	average 1942–1971 Botanical gardens	Experimental Station			
		1969	1970	1971	1972
Jan	205.1	183.8	486.7	304.1	352.5
Feb	155.6	195.8	245.7	140.7	126.8
March	129.1	134.0	86.8	113.7	188.9
April	190.2	206.6	290.3	205.8	247.4
May	321.8	440.7	341.6	310.5	368.3
June	315.4	196.0	398.5	319.4	265.8
July	209.4	188.3	147.2	300.4	211.8
Aug	162.4	100.9	251.0	136.5	190.7
Sept	91.8	35.0	150.6	82.3	113.0
Oct	87.4	68.6	165.0	177.8	122.2
Nov	111.3	17.1	31.8	187.5	205.1
Dec	161.9	130.7	181.1	92.5	175.6
Year	2141.4	1898.4	2776.3	2371.0	2568.1

the long rainy season (from beginning of April till mid August)
the long dry season (from mid August till mid December)
the short rainy season (from mid December till beginning of February)
the short dry season (from beginning of February till beginning of April)
The long seasons are fairly reliable, the short seasons often indistinct.

The years during which I studied the rice borers were characterized by a rainfall that distinctly surpassed the yearly mean (Table 3). From records of the longer rainless spells throughout 1970, 1971 and 1972 the following data can be given: 12 days (1×), 8 or 9 days (2×), 4 or 5 days (6×). For the normal to dry year 1969 the intensity and frequency of the periods without rainfall were: 13 or 14 days (2×), 6 or 7 days (3×) and 4 or 5 days (6×).

For a detailed review of the climate of the coastal region see BRAAK (1935), OSTENDORF (1953–1957) and DE WIT (1960).

1.3. GROWTH OF THE RICE PLANT

The growth of the rice plant mainly determines the life history of the borers, especially of *R. albinella*. It therefore will be briefly discussed.

Most of my investigations were carried out with the long growing variety Holland, with a total growth period of 173 days. This is an important variety for the small farmers in the region near the research station.

Already for many years, mainly on behalf of the Wageningen Project for the mechanical culture of rice, breeding work has taken place to shorten the growth period. This has resulted in the production of several varieties with a growth period of about 140 days. At the moment on the 'Wageningen Rice Scheme' varieties with a growth period of 105 days are already used commercially.

For the rice varieties with a 110–140 days cycle, flowering usually starts about 38 days before the crop is mature, whereas 25–35 days earlier the first strong longitudinal growth of the tillers begins. This variation is related to the total growth period of the crop. If I assume that the strong longitudinal growth coincides with the formation of the stem cavities, it occurs about 60–70 days before the crop is mature. For the variety Holland which has a long growth period, flowering starts about the 124th day. In all varieties the stem cavities are present about the 70th day after sowing.

2. RUPELA ALBINELLA (Cr.)

Rupela albinella (Schoenobiidae), sometimes incorrectly listed as *Scirpophaga albinella* (Cr.), is the 'white rice borer' of the neotropics.

The adult is satin-white, the male moth has a wingspan of 19–34 mm and a

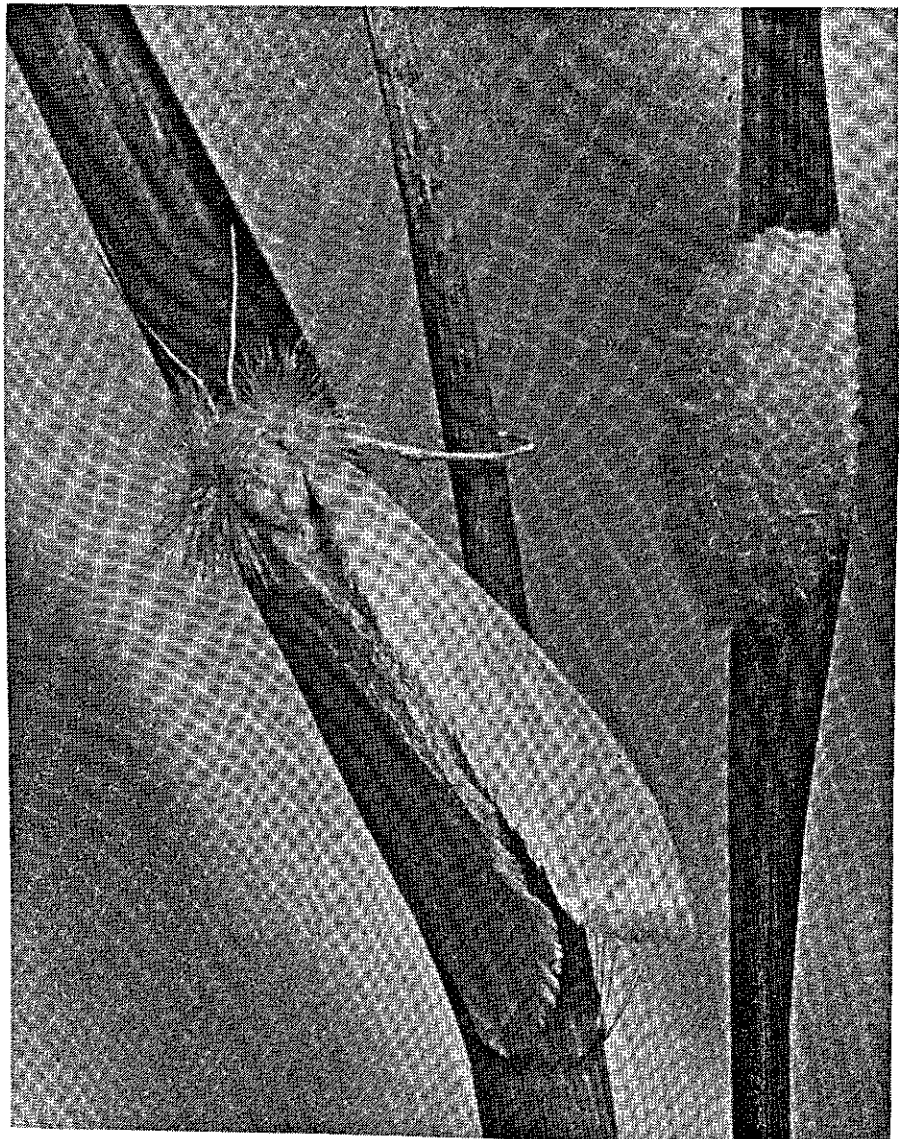

Photo 1. *Rupela albinella*, female and egg mass.

white anal tuft; the female has a wingspan of 24–45 mm and is characterized by an orange-brown tuft.

In studying this borer I mainly observed specimens kept under insectary conditions. The insectary (10 × 6.5 metres) had walls 2 m high which were screened, its roof was made of hammered glass. Normally the robust rice variety 'Holland' was used as a food plant (growth period 173 days). Plants were grown in 6-litre pots. Larvae originated from egg masses collected in the field or from egg clusters deposited in the laboratory by moths collected from the field. As soon as the larvae emerged, they were transferred into a vial of 10 × 2.5 cm and this was placed in the centre of a rice hill (total stems or tillers originating from the 1–3 seedlings planted together). The hills were covered with a plastic bag. The next day the bag was removed. During the time the plants were in the bag they were placed in the shade.

2.1. EGGS

Eggs were normally deposited on rice leaves and occasionally on rice stems. They were laid in clusters and were covered by a membrane 0.2 mm thick. The membrane itself was coated with a 1.5–2.0 mm layer of pale cream scales. The eggs were colourless, oval, 0.8–0.9 mm long and 0.4–0.5 mm wide. The egg mass usually consisted of 30–230 eggs, though lower numbers could also be found. The maximum number of eggs found in a cross-section of one egg mass was 18. The largest egg masses, including the layer of scales were 15 mm long and 5 mm wide.

In the field, moths in copula or sitting with their abdomens directed to each other were often found at daytime. The moths found in these positions were used to determine the egg production. They were placed in a bucket of 4 or 6 litre, lined with paper and closed with a gauze screen. If the atmosphere was very dry, wet cotton was placed on the gauze. After the moths had died the eggs were placed in vials. The emerging larvae were counted and the egg masses inspected for dead larvae and eggs. The average egg production of 47 females was 183 (Table 4). There was a great difference between the fecundity of the moths captured at the rice seed station near Paramaribo and those captured at the 'Wageningen Rice Scheme'.

The duration of the egg stage was ascertained from egg masses deposited on rice plants by caged moths, special attention was paid to the hour of the day at which hatching took place. The caterpillars always emerged during the first hours after sunrise (sunrise 06h00). Only in 3 out of 48 egg masses did emergence take place in darkness. It was striking that from the same egg masses caterpillars emerged both on the 7th and 8th day. In a second group it only occurred on the 7th day. All larvae normally hatched between 06h00 and 10h00 (Table 5).

TABLE 4. Egg production of *R. albinella*. The females were in copula when captured in the fields.

origin	number of females	average egg production	standard deviation of the average	range
Seed station District Suriname	32	153.6	16.5	37–250
'Wageningen Rice Scheme'	15	246.3	27.9	70–476
Total	47	183.2	12.0	37–476

TABLE 5. Hours of emergence of *R. albinella* larvae – 1.

	moment (hours)	number emerged	percentage emerged	percentage of total
First group, 34 egg masses				
After 7 days				79.1
	0.00	0	0	
	2.00	118	7	
	4.00	181	10	
	6.30	448	25	
	8.35	1631	92	
	9.15	1752	99	
	10.40	1767	100	
	21.00	1770	100	
After 8 days				20.8
	6.35	209	45	
	8.20	389	83	
	10.50	452	97	
	20.30	466	100	
After 9 days	6.15	1		0.1
	9.30	2		
Second group, 14 egg masses				
After 7 days				99
	1.30	58	4	
	4.00	59	4	
	5.00	59	4	
	6.45	128	10	
	8.00	358	27	
	9.20	1078	81	
	10.00	1228	92	
	10.55	1289	97	
	11.40	1314	99	
	12.40	1327	100	
	20.00	1333	100	
After 8 days				1
	7.15	6	50	
	10.00	12	100	

2.2. LARVAE

The newly hatched larvae were very active and dispersed from the egg clusters. The larvae were normally black but sometimes grey. (Older larvae became creamy-white.) They moved both up and down on the plants. When the larvae reached a leaf tip they turned, but often for only a few centimetres before they started climbing again. This behaviour could be repeated several times. Finally the larvae often fell off the plant. Larvae that lowered themselves from the plants by silk threads have been noticed incidentally. These threads were never longer than about 0.5 cm, however. After sometimes larvae accumulated on the stem within a zone of 0–20 cm above the water surface. Some approached the water surface, inclining their bodies in such a way that they were only attached to the plant by their last pair of prolegs, and then they let themselves fall. Once they had landed on the water they were quite at home. If there were currents, for example caused by wind, they held themselves stiff and still and floated away. When the current stopped they started walking again. The distance they are transported also depends on the active flow of the water. In a small pond within a few minutes the larvae floated for a distance of 5–8 m. Especially at the moment of inlet or outlet of irrigation water there is a strong water flow. When the delicate caterpillar arrives near a stem it can hardly climb up because the water forms a hollow meniscus against the stem. The caterpillar slips backwards when trying to attach itself to the stem, until the moment it undergoes the adhesion force between water and plant. Then the larva lands on the rice stem.

The larva subsequently entered the narrow space between the stem and a leaf sheath. It wriggled itself downwards, penetrated into the leaf sheath at the point where the sheath encloses the stem tightly and then tunnelled further downward into the plant tissue. Finally the larva penetrated into the node at the sheath base and arrived within the stem internode or entered this hollow stem part directly by tunnelling through the stem wall, a short distance above the node. A similar pattern of stem penetration has been described by VAN DINTHER (1961, 1962) (Figure 2).

One day after emergence from the eggs, the young larvae were already found in the internodes. After two days nearly all the larvae had entered the internodes.

Larval settlement in the rice stem ultimately depends on the developmental stage of the host plant, i.e. on the presence of hollow internodes. Primordial internode cavities, 1–2 mm in diameter, form the minimum room for larval shelter. This means in practice that rice plants cannot become successfully infested before they are 40–60 days old. The rate of plant growth, which is also closely related to the rice variety, clearly influences this moment of infestation.

Never more than one living larva was found in one internode, whereas one living and one dead larva were regularly found. This suggests that larvae may compete for suitable internode space. Normally I found only one larva per tiller, but sometimes more, often in the connected internodes. Most larvae were

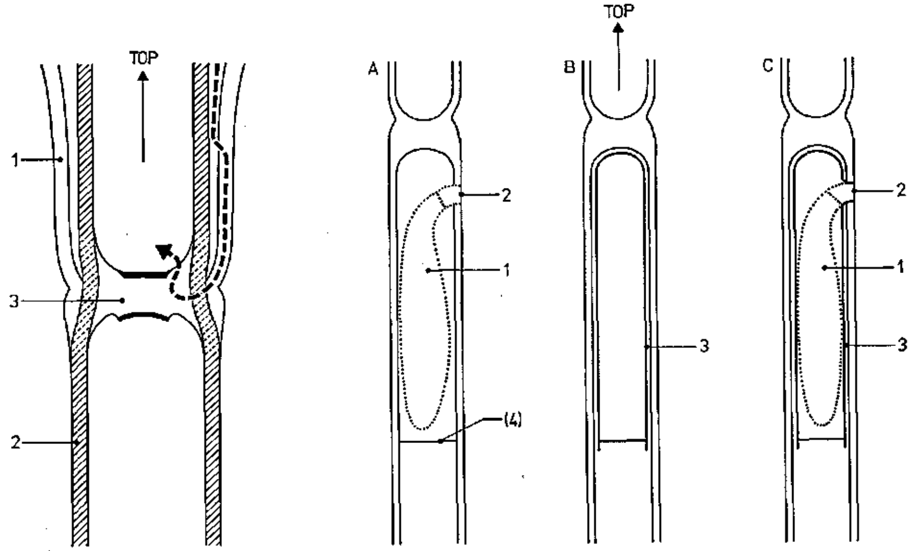

FIG. 2. (At the left) Route of *R. albinella* larva during stalk penetration; A- direct pupation, B- diapause stage, C- pupation following diapause stage. After VAN DINTHER (1962).

found in the lowest internodes, often under the water surface, as the moth prefers to lay her eggs on young plants. In older plants the lowest leaves were dead; the larvae entered through the higher leaves and penetrated in the higher internodes.

Development to maturity normally took place inside one internode. Only when the larva had entered one of the very small lower internodes, did it eat its way into one or two of the superposed internodes.

Feeding was concentrated on the tissue of the stem wall which was only superficially damaged. Occasionally shallow pits were gnawed in the wall. Holes, for instance for extruding frass, were never made, however.

Only the full-grown last instar larva cut an exit hole leaving the epidermis of the stem or the leaf sheath to be punctured by the adult. A white flimsy cocoon was spun connected to this exit hole; incidentally a membranous partition can also be found (Figure 2).

2.2.1. *Number and duration of larval instars*

To ascertain the number of larval instars the width of numerous head capsules was measured. It was concluded that there are 5 instars (L_1-L_5). This number has also been reported by VAN DINTHER (1961).

The first three instars correspond with well separated categories of head width (see Table 6, Fig. 3). Larger than 0.8 mm the width of head capsules

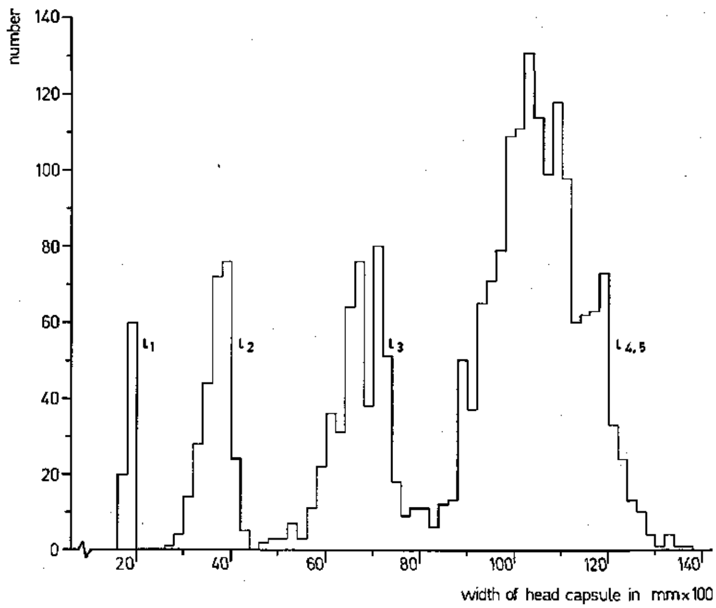

FIG. 3. Width of the head capsules of *R. albinella* larvae, collected in the field.

range continuously up to 1.38 mm. The following arguments have led to the acceptance of the presence of 5 instars:

1. Larvae with head capsules ranging from 0.80–1.11 mm have been observed moulting. The new larvae showed larger head capsules but not wider than the maximum of 1.38 mm of the total range.
2. When comparing the head width of full-grown larvae – i.e. larvae characterized either by a gnawn exit hole in the stem or by the typical diapausing form – with the head width of larvae belonging to the range of 0.81–1.38 mm that

TABLE 6. Duration of *R. albinella* stages. Width of the head capsules of the larval instars.

stage	duration in days	width of the head capsule in mm × 100	
		average	range
egg	7		
L_1	11	20	19–20
L_2	5.6	37	28–45
L_3	8.8	67	48–80
$L_{4,5}$	13	106	81–138
Pupa	12		
Main oviposition period	(3) (estimation)		
Total cycle	60		

could not be recognized as full-grown or diapausing by the lack of these characteristics, a small but significant difference was found. Table 7 shows the data based on larvae collected in the field as well as on larvae studied in pot plants of 10 weeks old in the insectary.

Larval development is affected by the age of the food plant as well as by the rice variety. By using the width of the head capsule of the third instar larvae as parameter, this effect can be demonstrated (Tables 8, 9). Larval development was equal in plants up till the age of 100 days, but was significantly reduced on plants 126 days old at the moment of infestation. The size of the stem cavity and the longevity of the plant form important criteria for larval development. The smaller the plants and stem cavities, and the shorter the total growth period, the smaller the head width of the larvae. Characteristics of the rice varieties are given in Table 10.

A study of the duration of development of the different larval instars by rearing larvae in cut rice stems failed because of the rapid desiccation of this food material. Moreover, transferring larvae from dried-up stem parts to fresh ones was often disappointing because the delicate larvae could not stand handling. Therefore the duration of the larval instars was determined with 10-week-old pot plants that were infested with L_1. Afterwards samples of about 40 rice stems were cut open at least once every 3 days. Larvae found were classified according to their instar group, and the number of specimens per instar was expressed as a percentage of the total of the sample. Fig. 4 summarizes the results. The data recorded for each of the larval instars were derived from a total of about 150 specimens. Besides the expected declining curve for the L_1 instar, the other groups show the type of the normal frequency distribution as based on the duration of life of the individual larva. When these data for each instar are plotted cumulatively on logarithm-probability graph paper, the relationship between instar frequency (in %) and instar duration becomes a straight line (see Fig. 5). The mean developmental duration for each of the instars can now be read directly as it corresponds with the 50% frequency point.

Results are recorded in Table 6. The mean duration of the larval stage was 38.4 days; the shortest period observed was 30 days. VAN DINTHER (1961) mentioned a total developmental variation of 28–36 days.

As is often observed in insect development, the body length of the different instars shows a strong overlap. Fig. 6 summarizes the results of a number of measurements.

2.2.2. *Diapause*

Larval diapause, a stage of 'arrested growth', is a phenomenon which is known from several stalk borers attacking graminaceous crops in the tropics. The classical example is *Tryporyza (Scirpophaga) innotata* (WALKER), the white rice borer of Indonesia. The induction of diapause is believed to depend on the booting stage of the rice plant, while its termination is brought about under the influence of rainfall (VAN DER GOOT 1925).

VAN DINTHER (1961, 1962) studied the effect of precipitation on the break

TABLE 7. Width of head capsules of full-grown 5th instar larvae of *R. albinella* – characterized by a gnawn exit hole in the stem wall or by diapause appearance – compared with the head-width range 0.8–1.38 mm of larvae that could not be seperated in 4th and 5th specimen. A: field samples, B: pot experiment samples.

	number	average head-width in mm × 100	standard deviation of the average	range
A. full-grown 5th instar	195	110.5	0.8	89–138
4th and 5th instar	498	104.0	0.2	80–134
B. full-grown 5th instar	44	112.4	1.4	95–127
4th and 5th instar	194	104.6	0.7	80–136

TABLE 8. Effect of plant age (variety Holland) on head width of third instar larvae of *R. albinella*. n = number of larvae; $\bar{x}$ = average head-width in mm × 100; S_e = standard deviation of $\bar{x}$.

age in days	n	$\bar{x}$	S_e	range
67	26	65.7	2.9	56–78
70–75	130	66.5	0.3	58–79
97	19	66.4	1.2	54–76
126	28	60.6	1.1	49–71

TABLE 9. Relation between rice variety and head width of third instar larvae of *R. albinella*, collected from the field.
n = number of larvae; $\bar{x}$ = average head-width in mm × 100; S_e = standard deviation of $\bar{x}$; P = the chance (Student) that the head width does not differ from that with rice variety Holland.

variety	n	$\bar{x}$	S_e	range	P
Washabo	37	69.7	0.8	61–79	$0.001 < P < 0.005$
Holland	256	67.0	0.3	52–79	
Acorni	35	66.1	1.1	50–77	$0.2 < P < 0.4$
Alupi	75	63.8	0.7	52–79	***
Bluebelle	50	62.7	0.3	47–76	***
Boewani	117	58.9	0.5	46–68	***

TABLE 10. Characteristics of the rice varieties. The number of ++ indicates the robustness of the plant.

variety	robustness of the plant	average length of stem in cm	estimation of size of stem cavity in cm	total growth in days
Washabo	++	76	0.5	134
Holland	+++	112	0.5	173
Acorni	+	73	0.4	108
Alupi	++	76	0.3	138
Bluebelle	+	70	0.4	98
Boewani	+	73	0.3	105

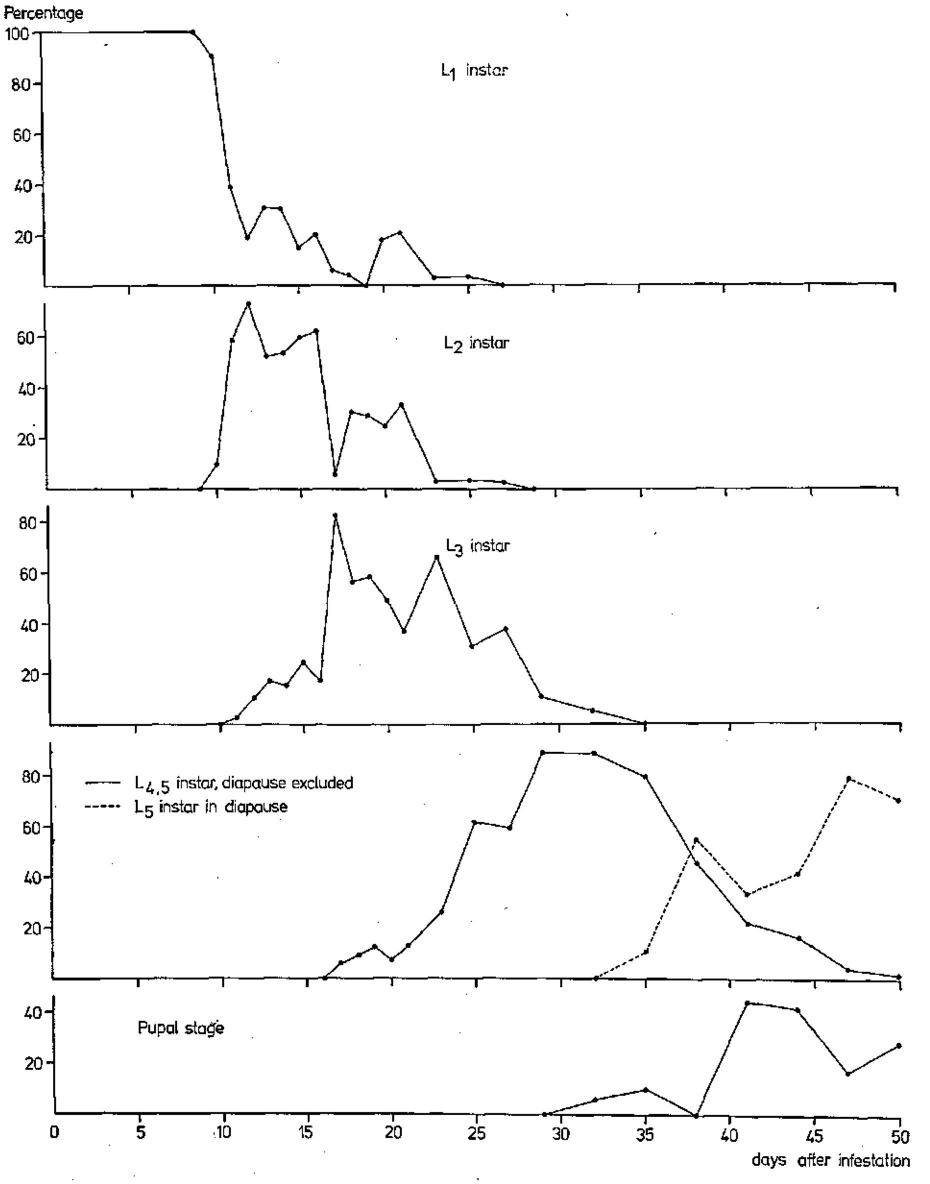

FIG. 4. Percentage of the various instars of *R. albinella* present per sampling day after the infestation with L_1 of 70-day-old pot plants.

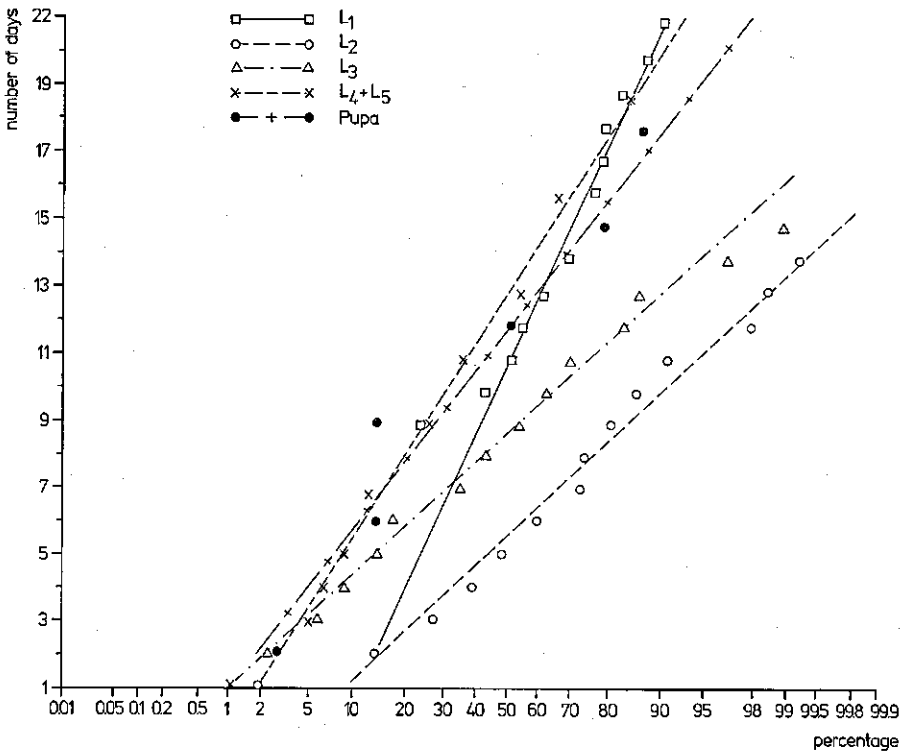

FIG. 5. Cumulative frequency (in percentage) of each instar of *R. albinella* per sampling day, plotted on probability paper.

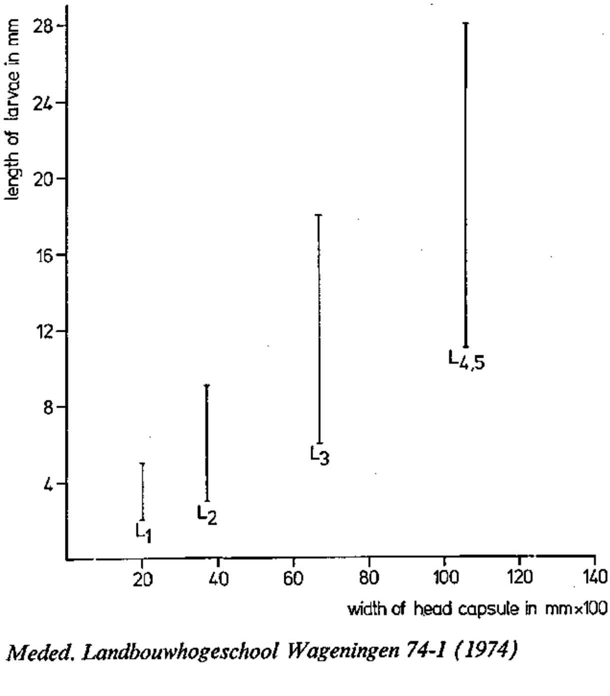

FIG. 6. Body length of the larvae of *R. albinella* in the different instars (n: $L_1 = 23$, $L_2 = 68$, $L_3 = 89$, $L_{4,5} = 147$)

of diapause in *Rupela albinella* at the 'Wageningen Rice Scheme' and showed a striking correlation between rainfall and the duration of diapause in this insect. A stem analysis carried out one week before harvesting (September 1958) showed that in fields that had become well-infested by *Rupela* (18%), about one third of the total number of larvae causing this mean infestation had given rise to moths. Only 1% of the larvae present at the moment of analysis had pupated whereas 7.5% had already entered diapause. All larvae that remained in the stubble after the harvest proved to be diapausing larvae. VAN DINTHER accepted VAN DER GOOT's theory that diapause is induced by the quality of the food plant: larvae developing in a maturing plant enter into diapause.

In *Rupela* the diapausing condition is characterized by the presence of a protective cylindrical paperlike envelope, spun by the larva at the upper or lower side of the internode (VAN DINTHER 1962).

At the 'CELOS' research centre where the rice variety Holland was monthly planted and cultivated throughout the years 1970–1972, diapausing larvae were uncommon and never exceeded a few percent of the total *Rupela* population. Only in September-October 1972 were large numbers of larvae found in diapause viz. 50% of the L_5 larvae present in the field.

From September to November pot plants were studied. About 50 days after the plants (variety Holland) were infested, 50–100% of the larvae were in diapause while nearly no pupae were formed. In July-August the percentage of diapausing larvae was smaller and more caterpillars had pupated. In September-October, some pot plants with larvae were not placed in the insectary but outdoors. In these plants the percentage diapausing larvae was less and the percentage of pupae higher than in the comparable groups in the insectary. Besides, it was clear that the older the plants, the more caterpillars went into diapause. Both in the field and in the insectary caterpillars were found in diapause in plants which had not yet flowered.

Neither the food nor the time of the year, dry periods, or rainfall could be indicated as the causative agent of diapause.

The only climatic difference between September-November 1972 and the other periods, I could ascertain was the temperature. During September-November 1972, the average maximum and minimum were the highest observed during the years of my investigations (Table 2). The difference was 1–2°C and the average maximum reached more than 32°C. The temperature in the insectary was about 2°C higher than outdoors. So I conclude that diapause and high temperature coïncide. It should be mentioned that the temperatures were measured in a thermometer hut.

Break of diapause was studied in one rice plot. The results are given in Table 11. About 115 days after sowing, i.e. two weeks before the rice plant started flowering the first larvae in diapause were noticed. Three weeks later, viz. 135 days after sowing, the first diapause termination could already be recorded. At harvest time only a few larvae remained in diapause. Which factor caused the termination of diapause cannot be stated. In that period the temperature decreased but also rain was not scarce.

TABLE 11. Break of diapause of *R. albinella* in a rice plot at 'CELOS' research station. Rice sown 7-7-72. First flowers 13-11-72.

date	larvae 4,5			pupae		sum of rainfall in mm
	no diapause	in envelope without exit hole	in envelope with exit hole	not in diapause envelope	in diapause envelope	
12/10	6					0.8
16/10	10					13.1
19/10	14					13.1
23/10	25					13.1
26/10	51					13.1
30/10	84	2				44.1
3/11	81	14		2		49.5
7/11	69	14		0		56.2
11/11	68	9		15		84.1
13/11	51	16		11		117.3
16/11	42	12		22		172.0
20/11	46	14	1	11		190.8
23/11	31	14	1	12		195.4
27/11	27	10	0	18	1	221.8
30/11	4	1	18	14	7	253.9
4/12	8	2	6	9	3	255.1
7/12	8	5	6	14	10	266.3
11/12	7	3	11	4	3	296.5
14/12	1	2	7	1	4	337.6
18/12	6	2	2	5	1	409.6
22/12	2	3	0	2		420.7
26/12	3	3	0	1		427.7
29/12	0	1	4			429.5
2/1	3	4	0			
5/1	0	2	1			
9/1	1	5				
12/1		3				
Total	648	141	57	141	29	

The role of diapause in the ecology of the borer is not clear. First of all it does not always occur in a large percentage. If termination of diapause is induced by rainfall (VAN DINTHER 1961) it follows that the moths appear at the latest in the short rainy period, in January. At that time no rice is available in Mid Surinam.

2.3. PUPAE

Pupation takes place in the internode inside a white, loosely spun bag-like cocoon which via a short, sturdier tunnel-part gives access to a freshly gnawn exit opening in the stem wall. Diapausing larvae, after having terminated their

TABLE 12. Pupal weights of *R. albinella*. Group A, B without and group C with diapause. P refers to the difference in numbers of males and females (χ^2-test)

group	♀			♂			
	n	$\bar{x}$ in mg	S_e	n	$\bar{x}$ in mg	S_e	
A	26	136.7	6.4	49	63.1	1.0	$0.010 > P > 0.005$
B	62	141.5	4.2	82	65.7	1.0	$0.025 > P > 0.010$
C	61	105.1	5.3	105	57.1	1.2	$P < 0.005$

resting stage, construct a similar cocoon inside their protective envelope (see Fig. 2).

The pale-coloured and somewhat hyalinous pupa is very delicate and is easily irreparably injured if handled.

Pupae show a wide range of body weights (Table 12). First the female pupae are much heavier than the male pupae. This holds for pupae originating from non-diapausing larvae as well as from diapausing larvae. As could be expected this difference directly relates to differences in larval size: bigger larvae as a rule turn out to belong to the female sex.

A weight difference within the sex is also noticeable. Pupae formed by post-diapause larvae weighed less than pupae formed by non-diapausing individuals.

Significantly more males than females pupae were always found. The average developmental time for the pupal stage was about 12 days.

2.4. MOTHS

2.4.1. *Flight activity*

The white satiny adult flies during darkness. Observations made on moths in cages as well in rice fields showed that flight activity is maximum immediately after nightfall. After this, activity gradually decreases; this diminution stops if a shower occurs and activity is rapidly resumed.

In addition to this daily flight pattern, attention was paid to the general flight activity during the year. Since this nocturnal moth is readily attracted to incandescent light, use was made of light traps.

The dimensions of the traps used were 50 × 50 × 50 cm. All the sides were covered with cheese cloth. The roof was made of zinc plate and the bottom of wood. At 7 cm from the roof, the wall was provided with a slit 6 cm broad, which was screened with three wires to prevent birds from entering the trap. A bulb of 75 Watt and 127 V was placed in the middle of the cage, just on level with the slit.

Figure 7 summarizes the results obtained from one of the traps that operated in the Paramaribo (rice) area from June 1971 until June 1973. These data show that moths were present throughout the years and that they appear in a distinct

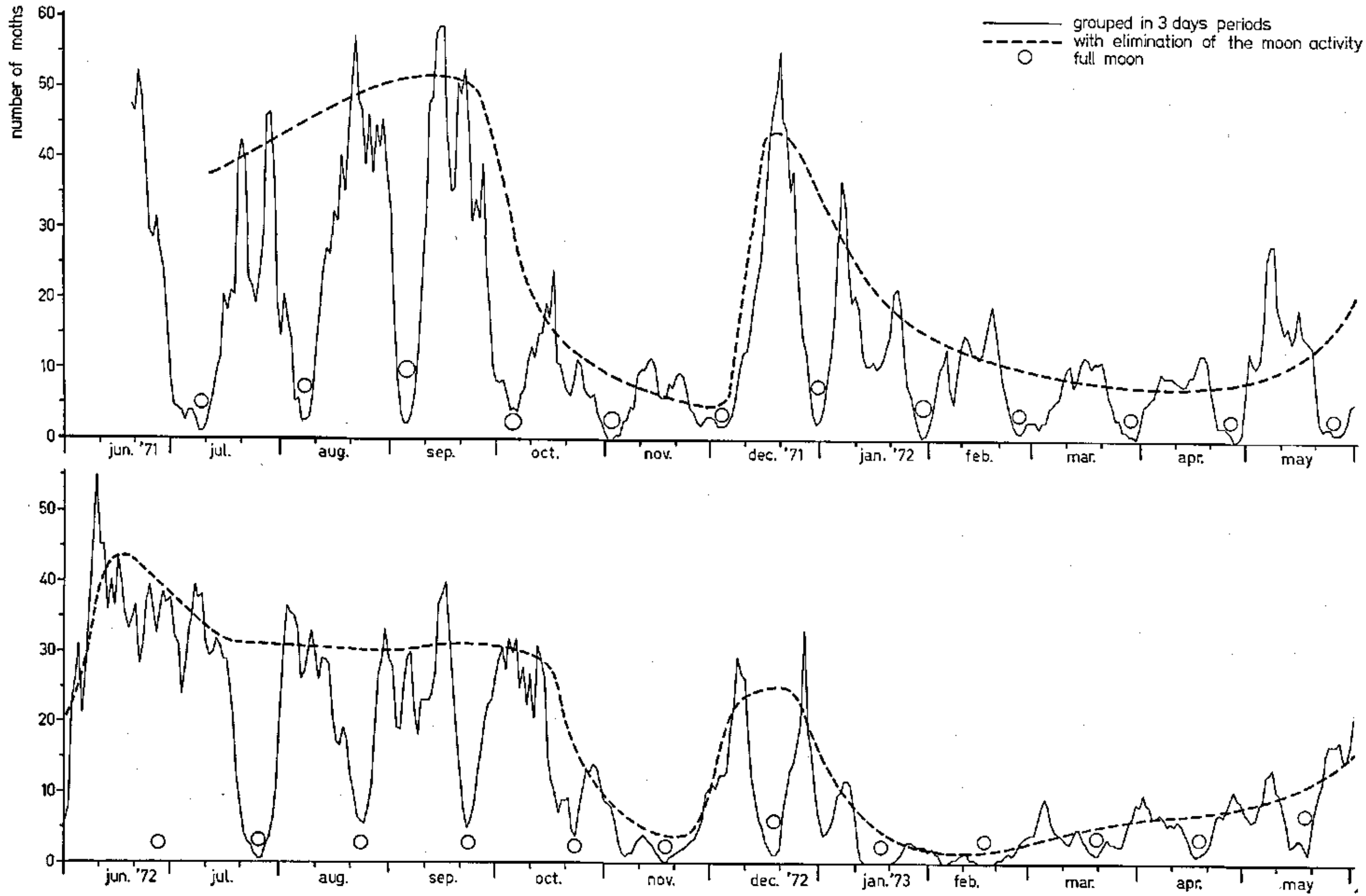

FIG. 7. Number of trapped *R. albinella* moths, grouped in 3 day periods. In addition, the estimated flight activity is given when the influence of the moon is eliminated.

fluctuating pattern, which is synchronized the full moon. In Figure 7 also the line is sketched which is obtained when the influence of the moon is eliminated. This year-around occurrence of *Rupela* moths cannot easily be explained because in the Paramaribo area rice is grown only once a year in the period April-August. Diapausing larvae surviving in stubbles could have turned into moths outside this period whereas wild rice species and grasses could perhaps have acted as wild hosts plants. *Rupela* larvae were noticed indeed in grasses, *Hymenachne* spp. The *Hymenachne* spp. are very common grasses in Surinam (DIRVEN et al. 1960). However, since these borer larvae have not been specified and several *Rupela* species occur in Surinam (HEINRICH 1937), the role grasses may play as wild hosts needs further checking.

VAN DINTHER (1962) studied *R. albinella* flight activity in the 'Wageningen Rice Scheme', and showed the regular annual occurrence of two major flight periods. This regularity is the result of growing two crops a year, sown in two rather fixed seasons. During most of the time between these periods of maximum flight activity, moths were present in low numbers. From his data the effect of moonlight on reducing the number of moths caught can be derived. Also VAN DER GOOT (1925) mentioned that during full moon less rice borers were attracted.

The number of captured males was nearly always less than 30% of the total. Also in *Scirpophaga innotata*, less males were captured (VAN DER GOOT 1925). YOSHIMEKI (1967) mentioned that he captured more males than females in Japan.

2.5. PARASITES

Four parasites of *R. albinella* can be listed from Surinam, namely: the egg parasite *Telenomus* sp. (Scelionidae) and the larval parasites *Venturia ovivenans* (Ichneumonidae), *Strabotes rupelae* (Ichneumonidae) and *Heterospilus* sp. (Braconidae). I came across all four parasites in the Paramaribo 'CELOS' area, and paid especial attention to the larval parasites, not only because they were the most common ones.

From *Telenomus* sp. and *Heterospilus* sp. some data have already been recorded (VAN DINTHER 1960a). *V. ovivenans* and *S. rupelae* were for the first time detected as *R. albinella* parasites by ZWART (1969, 1973); *Strabotes* was mentioned as *Ischnoceros abdominalis.*

From Guyana the following larval parasites of *R. albinella* have been recorded by KENNARD (1965): *Hecabolus* sp. (Braconidae); *Idecthis* sp., which may be identical with the above named *Venturia;* and *Polycyrtidea flavopicta* (ASHM.) (Ichneumonidae). The last mentioned parasite was collected and identified from Surinam by ZWART (i.l.); sofar the parasite has not been bred from *R. albinella* or another host.

2.5.1. *Telenomus* sp.

This 0.9–1.1 mm long, black species parasitizes eggs of up to 4 days old. The female burrows through the layer of scales covering the egg mass. Very often it crawls backwards in the newly made excavation to parasitize. The tapering abdomen can be lengthened like a telescope. More females may parasitize one egg mass simultaneously.

In the 'CELOS' fields up to 65% of the number of egg masses deposited have been found parasitized. On average about 66% of the eggs of an egg mass were infested; once all the eggs of an egg mass were found parasitized.

WOUTERS' (1957) corresponding figures for the 'Wageningen Rice Scheme' are 97% and 65%, respectively.

2.5.2. *Venturia ovivenans* (ZWART)

2.5.2.1. Adults

The adult is 9–12 mm long, whereas the female has also a 2–3 mm long ovipositor. The thorax is black, the abdomen predominantly brown. The wings are uncoloured. The abdomen is strongly pressed together laterally. *R. albinella* is the only known host (ZWART 1969, 1973).

Adults are especially active in young rice stands and in the top zone of older rice plants. These form the sides where the host normally deposits its egg masses. Immediately after having detected an egg mass the female inserts the ovipositor. In walking over the egg mass insection is often repeated. During this activity the female seems to become almost immune to any disturbance. In the field it was observed that three females simultaneously attacked one host egg mass.

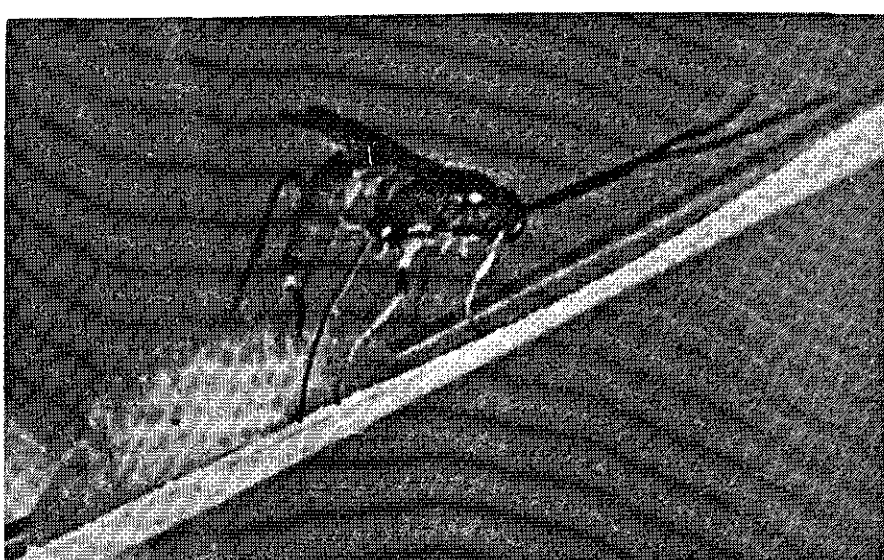

PHOTO 2. *Venturia ovivenans* female parasitizing a *R. albinella* egg mass.

Host eggs were parasitized just after being deposited up till at least two days before hatching.

Also host eggs, deposited in the laboratory on paper were parasitized immediately when offered to the females.

The maximum longevity was 18 days, the mean was 9.0 days (n = 12) for the females and 8.7 days (n = 16) for the males.

2.5.2.2. Eggs

Each of the ovaries is composed of 32 ovarioles that are so closely grouped together that the ovary is sack-like in appearance (Figure 8). Oviducts of newly

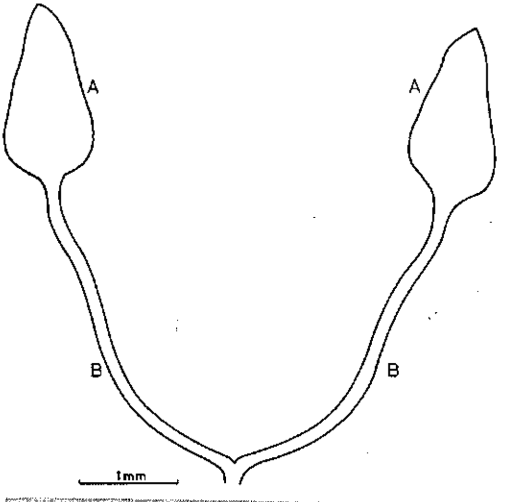

FIG. 8. Sack-like grouped ovarioles (A) and oviducts (B) of *Venturia ovivenans*

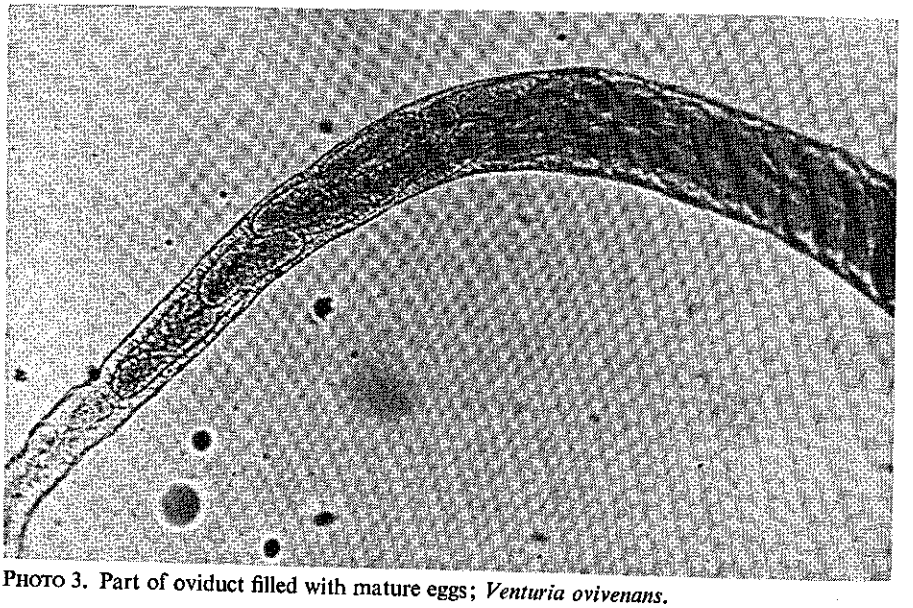

PHOTO 3. Part of oviduct filled with mature eggs; *Venturia ovivenans.*

emerged wasps are already partly filled with eggs, whereas up to 750 mature eggs have been counted in the oviducts of an older female. Eggs in the oviduct as well as freshly deposited eggs are pear-shaped and 0.16–0.17 mm long (Figure 9, Photo 3). Once inside the host egg the parasite egg swells and some hours later it is already 0.30 mm long and has become kidney-shaped. After 2–3 days the egg is 0.32–0.35 mm long.

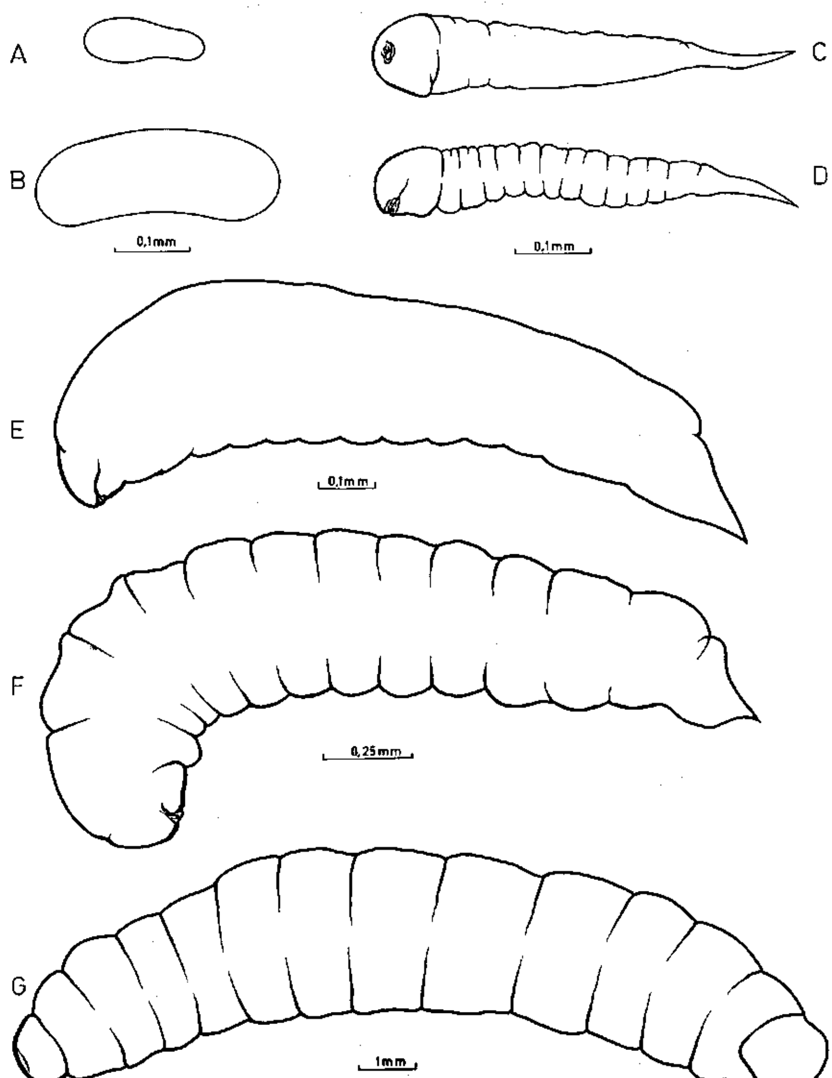

FIG. 9. *Venturia ovivenans* eggs and larvae.
A. Egg from oviduct; 0.16 mm.
B. Egg 2–3 days after oviposition, swollen; 0.32 mm.
C. Just emerged larva, ventral view; 0.57 mm.
D. Just emerged larva, lateral view; 0.57 mm.
E. Larva about 22 days old from L_4 host; 1.23 mm.
F. Larva about 33 days old from L_4 host; 2.28 mm.
G. Larva nearly full-grown; 14 mm.

2.5.2.3. Larvae

Freshly emerged hyalinous parasite larvae (Figure 9) were dissected from newly emerged host larvae, originating from eggs that had been parasitized 3–4 days before hatching. In host eggs that had been parasitized 5–6 days before hatching, parasite eggs were still present. This means that the hatching moment of the host and parasite egg probably coincide.

Growth is moderate during the first three larval instars of the host. In the 4th or the 5th larval instar of the host, the parasite larva increases markedly

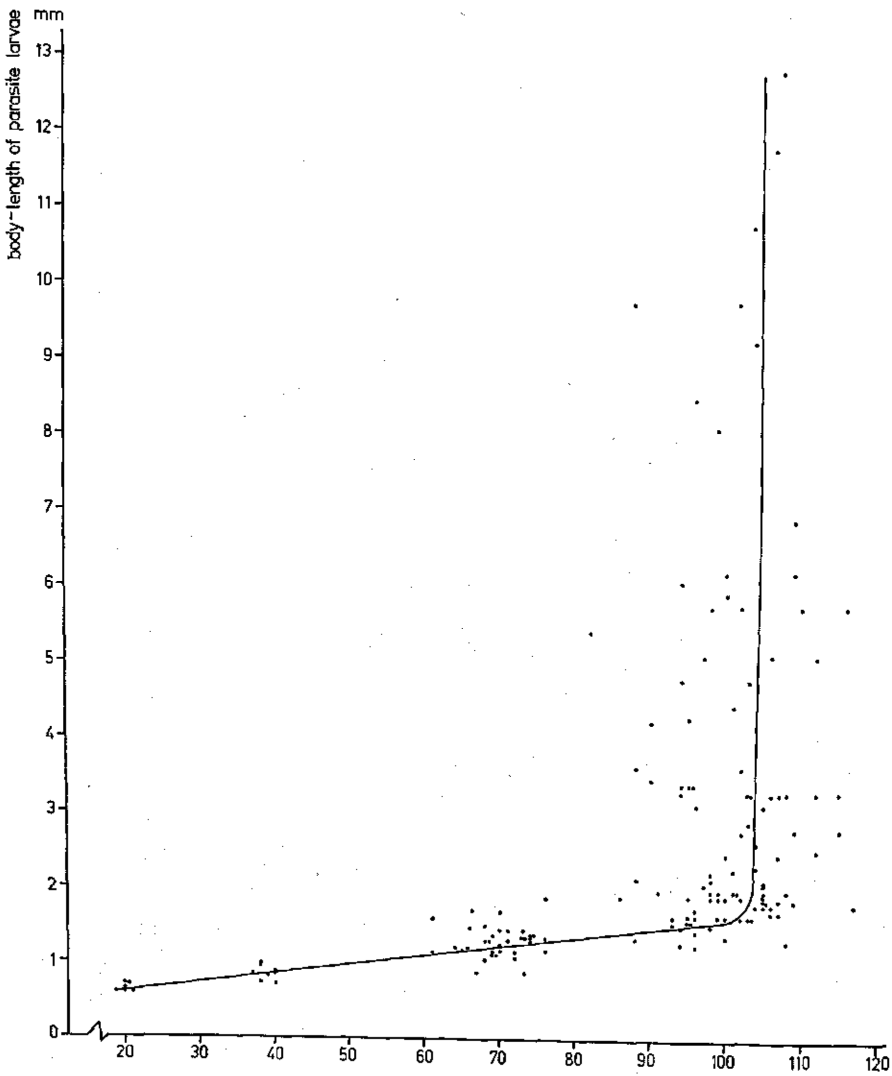

FIG. 10. Relation between length of *V. ovivenans* larvae and host size.

in size, however (Figure 10). After the caterpillar has gnawed an exit opening in the stem wall, the parasite leaves ist host. Moulting of the parasite has not been observed. Larval shape changes markedly during ageing; the tail becomes shorter and the head capsule less clear (Figure 9).

More than 2000 host larvae have been dissected, about 400 of these were of the first instar. In one case 3 parasite larvae were present in a first instar host, and in another case 2 parasite larvae were found in a 2nd instar hosts larva. In both cases only one parasite was alive. A few times the only parasite larva was dead.

The percentage parasitized hosts decreased quickly in the succeeding larval instars under field circumstances (Table 19). Mainly parasitized hosts may die.

Sampling of almost full-grown *Rupela* larvae in the 'Wageningen Rice Scheme' at the time that diapause also started in the fields revealed that the ratio diapause/non-diapause in parasitized host larvae was 4 times as high as in non-parasitized hosts. At the 'CELOS' research centre, where sampling could continue over a longer period, the ratio diapause/non-diapause in parasitized hosts which initially was again 4 times as high as in non-parasitized larvae, dropped to 2 afterwards (Table 13). The conclusion is that parasitized hosts not only go into diapause more frequently, but also with a much shorter delay.

TABLE 13. Ratio of diapausing and non-diapausing *Rupela* larvae in relation to *Venturia* parasitism. P = the chance that the ratio diapause/non-diapause in parasitized and non-parasitized hosts is equal (χ^2 test). A = shortly after appearance of diapause in the field. B = at the end of diapausing period.

origin	*Venturia* parasitized *Rupela*			Non-parasitized *Rupela*			P
	dia-pause	non-dia-pause	ratio	dia-pause	non-dia-pause	ratio	
'Wageningen Rice Scheme' A	19	11	1.73	8	20	0.40	$P<0.005$
'CELOS' research station A	19	42	0.45	34	299	0.11	$0.010>P>0.005$
'CELOS' research station B	34	69	0.49	122	465	0.26	$0.50>P>0.25$

2.5.2.4. Pupae

When full-grown, the parasite larva leaves its host, spins a pale-brown parchment-like cocoon of 12–22 mm connected with the exit opening in the rice stalk. The period between leaving the host and the appearance of the adult is 10–14 days.

2.5.2.5. Total time of development

Development time from the moment of hatching of the host egg to the adult stage has exactly been ascertained for two wasps, viz. 46 and 50 days.

An overall picture of the duration development has been obtained from weekly samples taken at the 'CELOS' research centre. In two successive years, 426 and 1161 *Rupela* moths and 192 and 415 *Venturia* wasps were reared, respective-

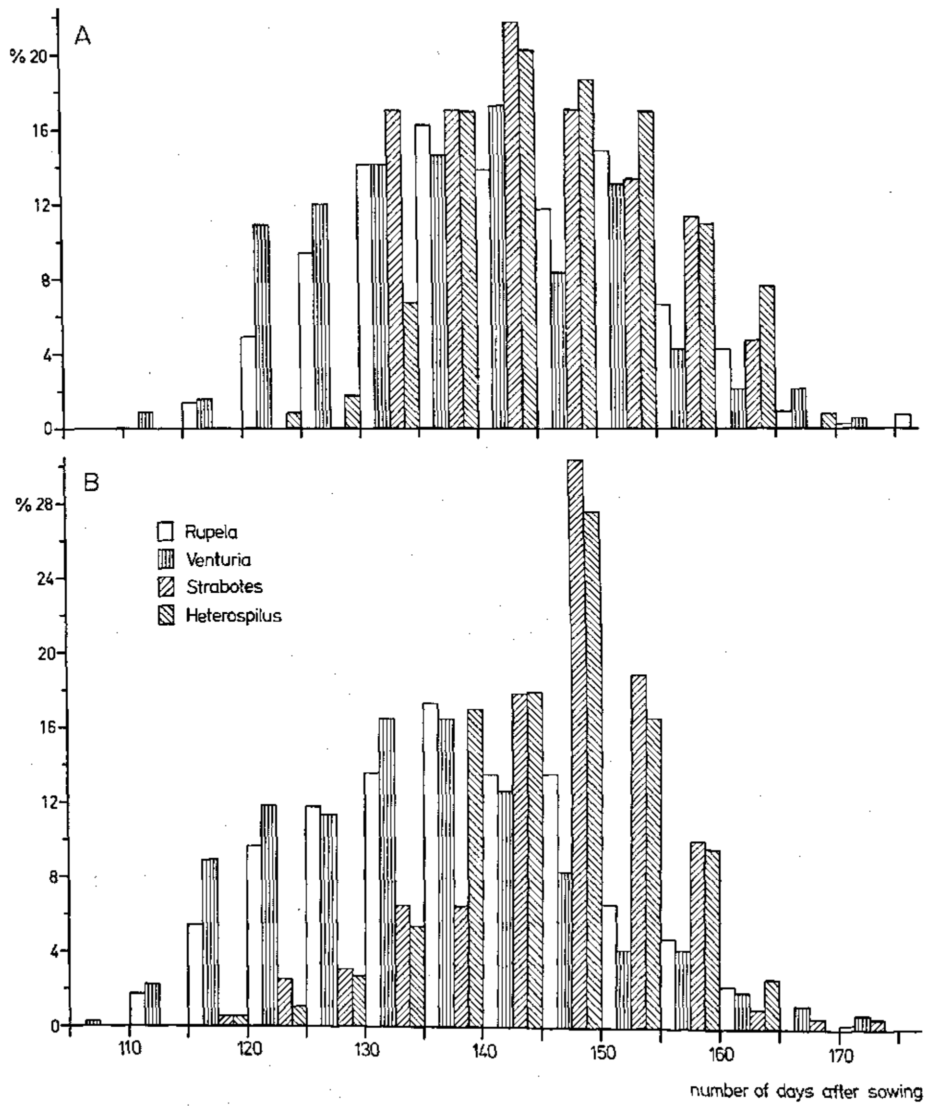

FIG. 11. Rearing results of *R. albinella* and its larval parasites, given in percentages per 5-day period.
A. July 1970–June 1971 and B. July 1971–June 1972. The percentages are obtained from the following numbers: *Rupela* 426 and 1161; *Venturia* 192 and 415; *Strabotes* 106 and 203; *Heterospilus* 119 and 189. Of the gregarious parasite *Heterospilus* the numbers of hosts out of which wasps emerge are mentioned.

ly. The mean time of appearance of the parasites was respectively 2.0 and 1.9 days earlier than from their hosts. In addition to the mean date of appearance the spread in time for both host and parasite was nearly the same (Figure 11).

2.5.2.6. Discussion

This parasite is very well synchronized with its host *Rupela*. The total developmental period is slightly shorter and its adult lifespan somewhat longer than for its host. The parasite enters diapause together with its host.

The parasite is common throughout the Surinam rice areas. At the 'CELOS' research centre it parasitized 25% of the *Rupela*, the samples ranging between 5 and 46% (see Section 2.8.2.). In the 'Wageningen Rice Scheme' at the end of the growing season the caterpillars were parasitized for 23–42%.

2.5.3. *Strabotes rupelae* (ZWART)

2.5.3.1. Adults

This brownish black parasite has a body length of 7–12 mm, whereas in the female a 3–4 mm long ovipositor is present. Between the individuals there is a great difference in measurements. The thorax often shows some cream dots whereas the abdomen has some cream rings and/or a last segment. Also the antennae often have a ring of this colour. *R. albinella* is the only known host (ZWART 1969, 1973).

The adults are usually met in the older rice crop, normally in the basic region of the plants. This is where the hosts, the older larvae (L_5 and L_4) and pupae, are living. The wasps walk up and down the stems, moving their antennae over the substrate. The antennae are curved 90° in the middle and the tops are curved backwards, so a large contact surface is present. A third to a half of the stem circumference is touched. When a host is localized the stem is pierced within 20–60 sec. The host is not paralysed, not even for a moment. The same internode may be perforated several times. Boring in internodes in which no host was present has been noticed. Several times it was observed that the female went downwards along the stem, crawled into the water and pierced the stem. After slightly more than one minute she left the water at some distance away from the stem. One egg is deposited near the host. In a field sample two eggs were once found behind the membrane of the exit opening, at some distance from a host pupa. Hosts in a diapause envelope are seldom parasitized, the parasitization will be only successful if the egg is deposited within the diapause envelope. The development on hosts in diapause is normal.

The mean longevity in cages with a rice plant and honey was 27 days, both for the males ($n = 18$) and the females ($n = 27$). The maximum longevity was 61 days in males and 67 days in females.

2.5.3.2. Eggs

Each of the two ovaries is composed of four nearly 5-mm long ovarioles. One or two almost full-grown eggs per ovariole can be present simultaneously

(Figure 12). The hyalinous, whitish eggs show a rather large variation in size; their length being 1.5–2.2 mm. Eggs hatch about one day after being deposited.

2.5.3.3. Larvae

After eclosion from the egg the young larva crawls to its host and starts an ectoparasitic life. Within a period of 6–10 days, during which time the host is sucked out more or less completely, the larva moults at least 3 times. Its body length has then increased from 1.5 to 13 mm, its head capsule from 0.34–0.50 (variation within L_1) to a good 1.0 mm in the final larval instar. The hyalinous whitish colour of the first instar has gradually changed into a marbled shade during the last instar.

The larvae are of the mandibulate type (Figure 12, Photo 4); antennae are distinct. The head, which protrudes at first, is nearly fully retracted within the first body segments in the last instar.

2.5.3.4. Pupae

In 1–2 days the full-grown larva spins a 15–30 mm long cocoon connected with an exit opening. The cocoon is parchment-like and pale-brown. After a period of 6–9 days the adult leaves the cocoon.

2.5.3.5. Total time of development

In the female the total time of development ranged from 16–23 days with a mean of 19.1 days (n = 20), for the male it was 16–20 days and 17.3 day (n = 16), respectively.

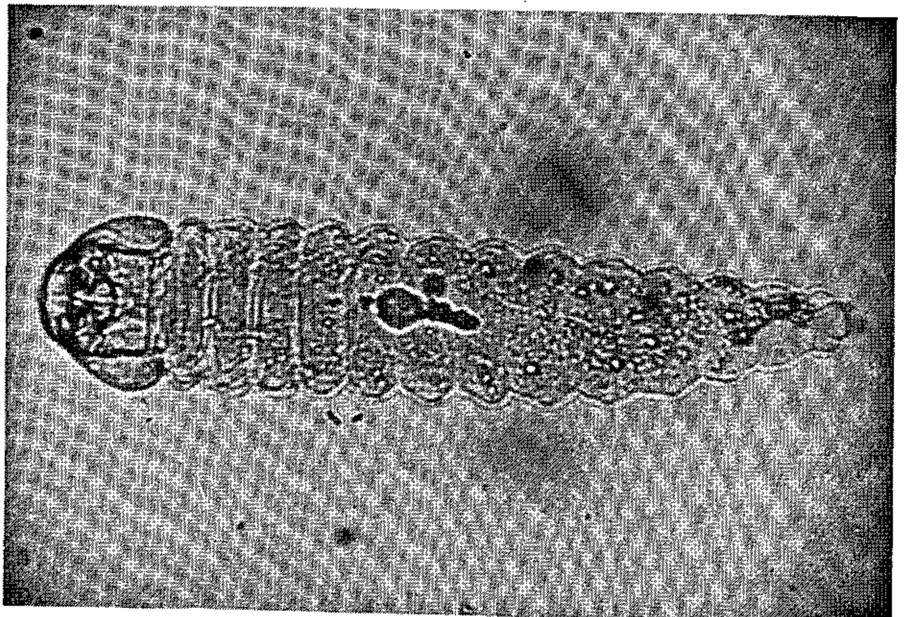

PHOTO 4. *Strabotes rupelae;* just emerged larva.

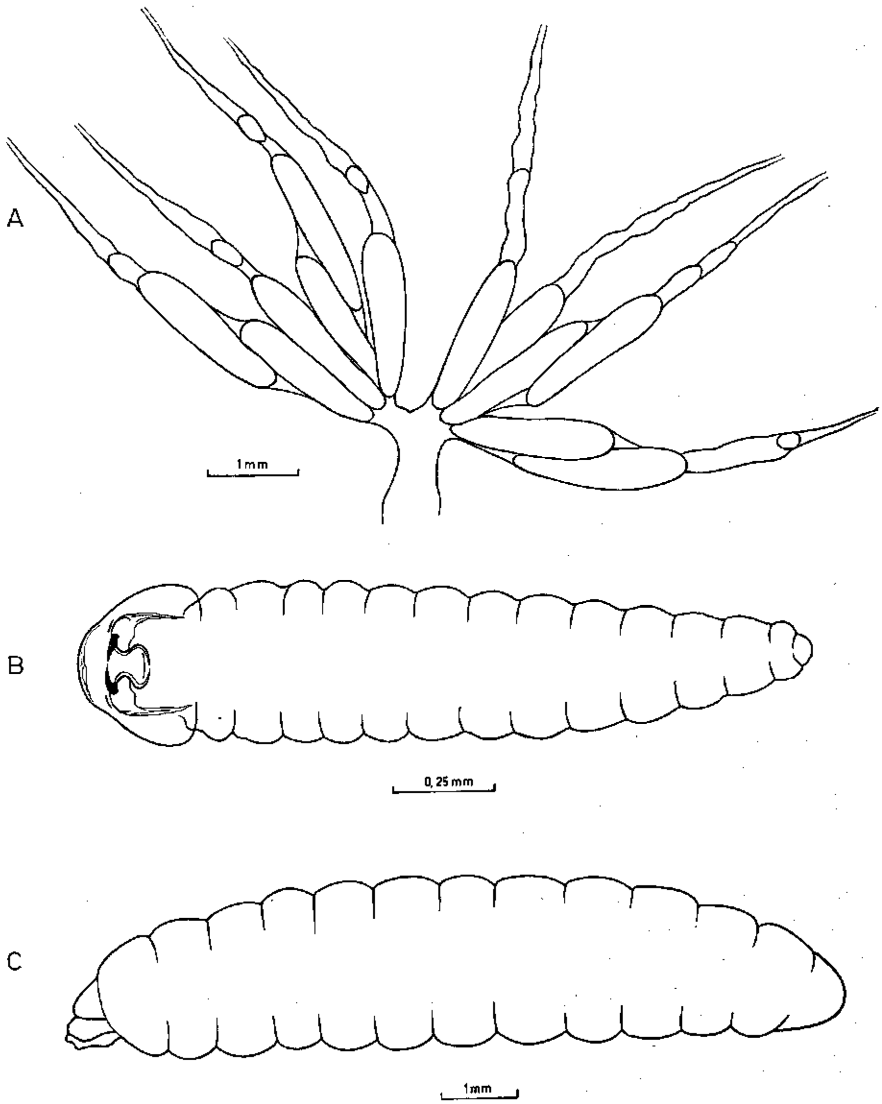

FIG. 12. *Strabotes rupelae*; Ovaries (A), newly hatched larva, 1.9 mm (B), full-grown larva, 10 mm (C).

2.5.3.6. Discussion

At the research centre with permanent rice cultivation the parasite was quite common (see Section 2.8.2. for details). It was also obtained from the rice plots of the small holders near Paramaribo. In West Surinam I never found the parasite, perhaps because the stubbles are burnt and the fields ploughed after the harvest.

Although *Strabotes* only parasitizes the large larvae and pupae of *Rupela*, this parasite is able to pass two or perhaps even three generations in a rice plot during the time its hosts passes only one generation.

A few times it was observed that *Strabotes* sucked out a full-grown *Venturia* larva, thus acting as a facultative secondary parasite.

2.5.4. *Heterospilus* sp.

VAN DINTHER (1960b) already mentioned this species, the larva of which he found feeding gregariously and ectoparasitically. The female Braconid paralyses a well-fed larva and deposits her eggs inside the rice stalk near the caterpillar. Egg numbers up to 27 have been counted. His findings, also those on the size of the different *Heterospilus* stages, largely agree with my data (Table 14). The following additional information can be given.

Each ovary (Figure 13) consists of two ovarioles of the polytrophic type. The ovarioles are widened at the base and each contains 11–12 full-grown eggs. This modification of the ovarioles is nearly identical with that in the Braconid *Opius concolor* (STAVRAKI-PAOLOPOULOU 1966).

Ovarioles of newly emerged females already contain rather well-developed eggs. Their shape, showing a swelling in the central egg part, however, differs from the banana-like form of the full-grown eggs of the mature females (Figure 13).

The larvae bear short antennae. Larval growth is fastest between the 4th and 6th day (Figure 14). The head becomes smaller in relation to the body (Figure 13). Egg development takes about 1½ days. The period of larval development in the males was 7–8 days and 8–9 days for the females. At the end of this period the larva spins a 5–8 mm long, white flimsy cocoon in the internode in about 2 days. After 8–11 days (mean 9 days), the newly emerged adults eat their way outside through the stem. The males emerge first and are directly followed by the females. The average total developmental period was 19.5 days. The mean longevity was 15.6 days for the females (n = 539) and 10.5 days for the males (n = 103).

From one host I reared a maximum of 48 adults. Normally not even half this number was found.

The sex ratio (♂/♀) was 1:14 in laboratory breeding; in October-November 1972 I reared field samples and found a ratio 1:8. Unmated females produce eggs that give rise exclusively to males (arrhenotoky).

Hosts in a diapause cocoon are also parasitized.

TABLE 14. Length of the different stages of *Heterospilus* sp. in mm.

		average	range	number	range (VAN DINTHER)
eggs		0.78	0.70–0.86	44	0.89–0.96
eldest larvae	♂♂	3.3	3.1 –3.4	5	3–5
	♀♀	5.0	4.2 –5.6	45	
adults	♂♂	2.7	2.0 –3.0	12	1.8 –2.7
	♀♀	3.7	2.5 –4.5	181	3–4

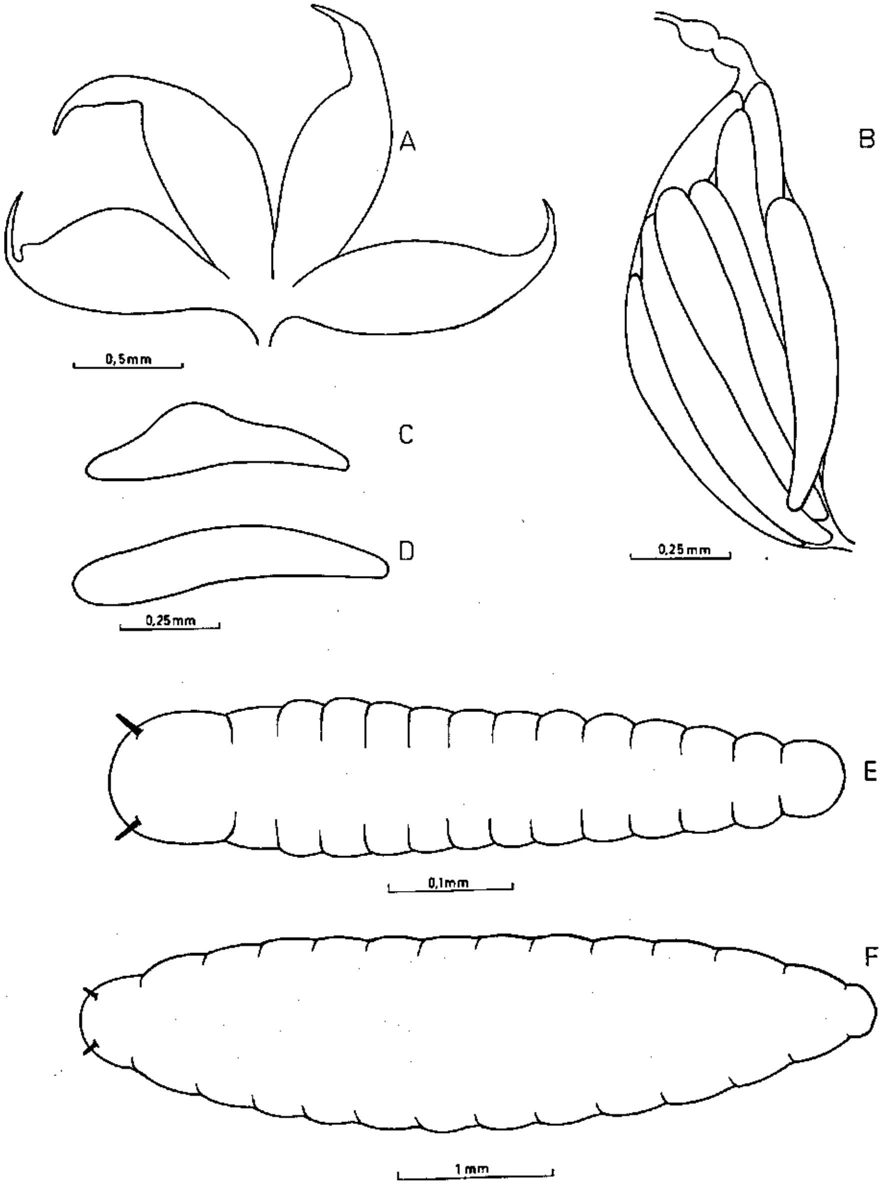

FIG. 13. *Heterospilus* sp.; ovaries, eggs and larvae.
A. Both ovaries each with two widened ovarioles.
B. Ovariole, widened part with full-grown eggs.
C. Egg from ovariole of just emerged female; 0.7 mm.
D. Egg from ovariole of mature female; 0.8 mm.
E. Newly hatched larva; 0.6 mm.
F. Full-grown, 7-day-old larva; 5 mm.

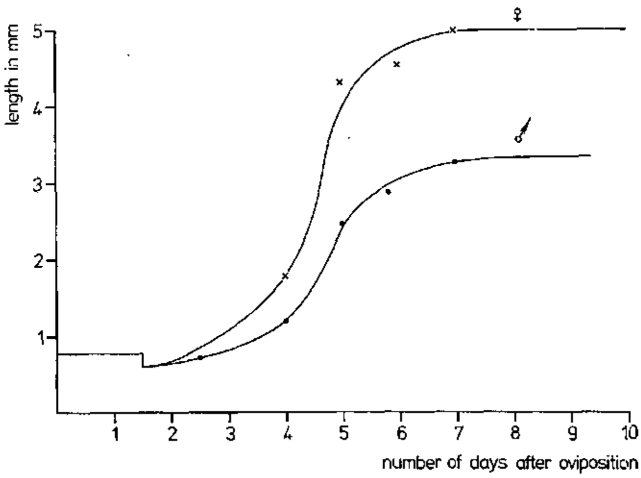

FIG. 14. Growth rate in *Heterospilus* sp. larvae. (Mean egg length has been indicated to mark the starting point. Males: n = 13; females n = 57.)

2.5.4.1. Discussion

Heterospilus is normally found later than *Strabotes*. But it probably also passes two or three generations during one host generation in a rice plot. This parasite is not synchronized with its host and just like *Strabotes*, it has difficulties to survive when only a few hosts are available.

Heterospilus was quite common at the 'CELOS' research centre with permanent rice cultivation; it was striking, however, that sometimes no parasites were found while hosts were still abundant. In West Surinam this parasite was very rare.

2.5.5. *Total view of the parasite complex*

In Figure 15 a schematic review is given of the parasite complex of *Rupela*. The life history of both the borer and the parasites are represented as circles. The radius of the circles is related to the total time of development (longevity of the adult forms is not incorporated). Arrows indicate where a parasite attacks. For *Venturia*, which arrests the development of the host after a long time, it is also indicated when it leaves the host. From the diagram it is easy to read which parasites will be competitors.

The larval parasites all pupate in about the same period as the host. These data are used for calculating the total percentage of parasitized larvae (see Section 2.5.6.). Several data concerning the parasites are also placed together in Table 15.

Telenomus was numerous in the field when host eggs were also numerous.

Venturia, the egg-larval parasite, has proved to be fully synchronized with its host; it also enters in diapause. The risk of mortality of this parasite is very high, because many hosts will die before being full-grown. This is eliminated by the high egg production of the parasite which is at least 4 times as high as that of its host. The structure of the ovaries is adapted to the requirement of the

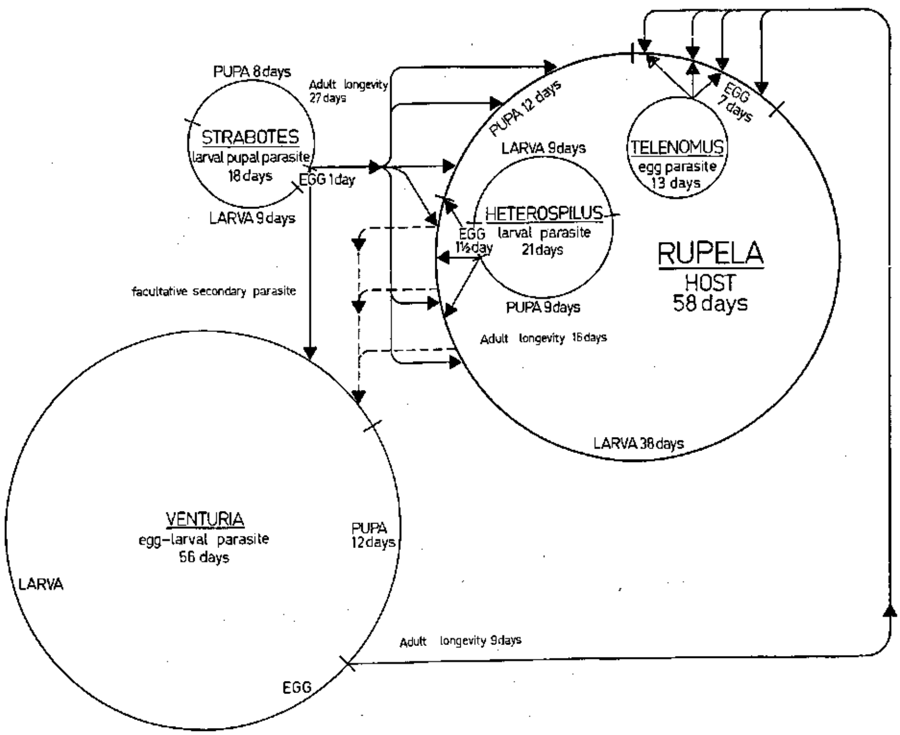

FIG. 15. Life history of *R. albinella* and its parasites. The radius of the circles is related to the developmental time (longevity of the adult forms is not incorporated). Arrows indicate where the host is attacked.

TABLE 15. Life history data of the parasites of *R. albinella*.

	R.albinella	*Telenomus*	*Venturia*	*Strabotes*	*Heterospilus*
Stage in which the host is parasitized	–	egg	egg	$L_{(4),5}$, pupa	$L_{(4),5}$
Mean time of development in days	58	13	56	18	21
Longevity in days: mean			9	27	16
maximum			18	67	37
Number of mature eggs in ovaries			-750	6–12	40–50
Egg production	183				
Number of generations in one rice plot	1		1	2–3	2 (3?)

quick supply of many eggs (Figure 8). The high egg production and the synchronization result in high parasitizing percentages, which often reach 35% both in continuous rice cultivation and in cultivation in separated seasons.

Strabotes and *Heterospilus* are not synchronized with their host. I found that they were scarce or absent in areas with well separated rice seasons. With continuous rice cultivation the percentages fluctuated very much and reached a maximum of 50% and 25%, respectively. *Strabotes* is also parasitic on the *Venturia* larva and it may be expected that if *Heterospilus* larvae attack a host containing a *Venturia* larva, the latter will die. Also the life history is reflected in the structure of the ovaries of *Strabotes* and *Heterospilus*. The chance of mortality is small, the eggs large and not numerous.

It was striking that in two successive periods of one year the composition of the parasitic complex on the experimental station was equal, namely: *Venturia* 50%, *Strabotes* 31% and *Heterospilus* 19%.

For further details with continuous rice cultivation, reference is made to Section 2.8.2.

2.5.6. *Estimating the parasitizing percentage*

In estimating the total parasitizing percentage and the share which the different parasites take in it, the moment of sampling is an important factor. If sampling is done early in the life cycle of *Rupela*, relatively more *Venturia* will be found than other parasites. Besides, the total time of development of the parasites is important. If caterpillars are searched for parasites the chance that a larva of *Strabotes* or *Heterospilus* will be found is much smaller than the chance to find a *Venturia* larva. *Venturia* takes more time to develop.

An acceptable estimation of the parasitizing percentage is obtained by exclusively taking into account the pupae of *Rupela* and the pupae and largest larvae of the parasites. Then the period during which the borer and the parasite will be found is nearly the same.

Only for *Venturia* was it feasible to check this method. In three rice plots the parasitization was estimated both by dissecting the caterpillars and by comparing the numbers of pupae. In one case both methods gave the same result, but in two cases the pupal count yielded a number $1\frac{1}{2} \times$ as high as obtained by the dissection. The results however, are biassed as the cocoons of *Venturia* and *Strabotes* cannot be distinguished. The pupae which did not emerge were classified according to the numbers emerging from the two species. It would be worth while to check this estimation for *Venturia* in the 'Wageningen Rice Scheme' where no *Strabotes* is present.

2.6. PREDATORS

As potential predators of the *Rupela* eggs and newly hatched larvae, lady bird beetles and ants can be mentioned (see also Section 3.6.). When the larvae are on the water surface also fish may play a role.

Partly eaten *Rupela* egg masses were observed several times in the field. However it was not always clear whether predation had occurred before emergence of the eggs or whether the egg shells had been destroyed after hatching. Our conclusion is that the total predation is small and always below 2%.

Predation of the caterpillars and the pupae within the internodes will be very small because no entrance is possible.

Predation of moths by dragon flies, e.g. *Orthemis ferrugunia* (F.) was observed.

2.7. Residual mortality

Residual mortality is referred to as the mortality not caused by parasites and predators. Various climatic factors and the condition of the plant (rigidity and age) can play an important role.

2.7.1. *Egg mortality*

Moths still in copula were captured in the field. The egg masses, deposited on paper in the laboratory, of 10 females were checked after emergence of the larvae. Only 4% of the eggs had not hatched. These eggs may have been unfertilized.

2.7.2. *Larval mortality*

No data on the larval mortality during dispersion were obtained, but laboratory experiments were done to fix the mortality during entering the plant. Because the mortality will be also influenced by the number of caterpillars placed per stem, I tried to establish the correlation between the number of larvae placed per stem and the number that was be able to enter the stem cavity. Such a correlation was not present (Rs = 0.38; Rank correlation coefficient, method Spearman). There was a clear correlation between the age of the plant and the mortality (Rs = 0.72).

The mortality, which was always higher than 60%, was between 90 and 99% in the oldest plants (Table 16). In September-November 1972 the temperature was about 2°C higher than is normal in that period (Table 2). The temperature in the insectary was always about 2°C higher than outside.

The lowest mortality was found in the plants which grew at the lowest temperature. These were the pot plants sampled in August, and the plants placed outside the insectary (Table 16).

In Table 17 the data are given which were obtained during periodic sampling between the 10th and the 48th day after inoculation with L_1. Because dead larvae very slowly deteriorate inside the stem cavity, they are nearly all recovered. The highest mortality was again found in the oldest plants, mainly before entering the internode. About 5% of the larvae died, normally in the first instar, after entering the stem cavity; this is about 33% of the larvae which reached the internode.

TABLE 16. Mortality of *R. albinella* larvae on pot plants of different age, placed in an insectary. Rice variety Holland. Samples were taken after 45–55 days in September-November 1972. Exceptions: (1) plants sampled in August; (2) plants placed outside the insectary at moment of infestation.

age of rice at infestation in days	number L_1 used	number L_1 offered per tiller	number of L_1 entered per tiller	% mortality
60 (1)	160	0.82	0.32	63
70	880	2.04	0.65	68
90	2890	2.59	0.63	76
105 (1)	155	1.24	0.44	65
105	240	2.58	0.17	93
120 (2)	57	3.95	0.42	90
120	240	1.88	0.02	99
135	200	6.91	0.42	95
145 (2)	250	2.66	0.52	80
145	700	2.04	0.11	94

TABLE 17. Mortality of *R. albinella* larvae on rice of different age. Samples taken after 10–48 days. Rice variety Holland.

age of rice at infestation	number L_1 used	% mortality	
		total	of larvae entered stem cavity
67	285	61	0
70	2240	71	5
97	375	72	16
126	885	89	34
135	760	93	37

To get an idea where the mortality occurred before entering the stem cavity, I did an experiment in the insectary with about 100-day-old hills. Samples were taken between the 2nd and 9th day after inoculation. The parts of the plants were observed by translucent illumination. Sampling had to start early, otherwise the dead larvae could not be recovered. In the hills 56% was recovered, half of it already dead (Table 18). As many larvae were set on one plant, two larvae entered one internode in a number of cases. Then one larva always died. A large number of the larvae died inside the leaf sheath.

In four rice plots I estimated the mortality under field conditions. One plot, with the rice variety Boewani (total growth duration 105 days), was situated in the 'Wageningen Rice Scheme'. The others, situated on the 'CELOS' research centre, were planted with 'Holland'. Under the conditions prevailing in the field it was not possible to eliminate the influence of the parasites. In Table 19 the results are summarized. However the mortality varies; it was always highest in the L_1. The results of plots 1 and 2, sampled at the same time, are nearly identical. The very high mortality of the first instar larvae in 'Boewani'

TABLE 18. Part of the plant where *R. albinella* larvae were recovered on the 2nd-9th day after inoculation with 50 L_1 per rice hill. Of 500 larvae used, 56% was recovered.

	% alive	% dead
In/between leaf sheaths	5	33
In stem, not in cavity	4	3
In stem cavity	43	12
Total	52	48

TABLE 19. Field data of the mortality of *R. albinella* and its parasites. Of the living caterpillars the percentage parasitized by *Venturia* is given. Plot 1, 2, 3 were planted with rice variety Holland, plot 4 sown with Boewani. Plot 4 was already harvested before pupae were present.

	instar	number	% dead	% with *Venturia*
Plot 1	L_1	28	18	?
	L_2	19	5	?
	L_3	32	13	?
	$L_{4,5}$	68	15	19
	Pupae *(Rupela)*	33	39	
	Venturia + Strabotes (pupae)	16	6	
	Heterospilus (pupae)	6	0	
Plot 2	L_1	86	21	?
	L_2	54	9	?
	L_3	60	15	20
	$L_{4,5}$	149	15	18
	Pupae *(Rupela)*	73	23	
	Venturia + Strabotes (pupae)	51	8	
	Heterospilus (pupae)	47	0	
Plot 3	L_1	343	12	25
	L_2	166	0	12
	L_3	278	1	12
	$L_{4,5}$ no diapause	699	6	12
	with diapause	200	7	21
	Pupae *(Rupela)*	212	38	
	Venturia + Strabotes (pupae)	144	14	
	Heterospilus (pupae)	41	0	
Plot 4	L_1	107	35	41
	L_2	97	9	34
	L_3	111	4	30
	$L_{4,5}$ no diapause	82	7	30
	with diapause	30	0	67

may be caused by the unsuitable stems which had nearly no cavities.

A few times I sent dead larvae to a specialist to investigate whether they were infested by parasitic microorganisms. From one sample two parasitic fungi were isolated: *Aspergillus flavus* LINK ex FR. and *Aspergillus parasiticus* SPEAR*.

* Identified by Mr. R. SAMSON, Laboratory Willy Commelin Scholten, Baarn.

2.7.3. *Pupal mortality*

Pupal mortality was determined under field conditions in three rice plots. The pupae were taken out of their cocoons. Mortality figures for these plots were 39%, 13% and 38%, respectively (Table 19).

2.8. FLUCTUATIONS IN THE NUMBERS OF THE BORER

2.8.1. *Experimental plots and methods*

For studying the fluctuations in the numbers of *Rupela*, on the experimental station 4 rice plots of 20 × 20 m were sampled. Each month one plot was planted with 6-week-old rice seedlings (variety Holland). From the 90th till the 150th day twice a week 15 hills were selected for sampling. Each hill contained about 20 tillers. Tillers were cut lengthwise and inspected for borers of the 3rd instar and older, for pupae and parasites. The L_1 and L_2 were not included in this scheme as the search for these instars in the plant takes too much time. Sampling of parasites was also, for practical reasons, limited to the larger instars. All animals found were reared to determine the taxonomic composition of the parasitic population.

To complete the observations, a few rice plots were examined for the presence of L_1 and L_2 instars of *Rupela*. All caterpillars found were dissected and examined for the smaller instars of the parasites. The pupae of both borer and parasites were reared.

2.8.2. *Fluctuations per rice plot*

If the fluctuations of *Rupela* are given per instar, the normal correlation pattern is as in Figure 16. The pupal stage, both of borer and parasites, shows a long dispersion since also the pupae are noted originating from, or formed in diapausing larvae.

When the numbers of *Rupela* larvae, pupae and parasites are plotted cumulatively as a function of time, the curve is S-shaped (Figure 17).

The results of rearing the borers and their parasites shows a rather fixed pattern (Figure 11). The data of emergence of *Rupela* and *Venturia* are strongly correlated. *Strabotes* and *Heterospilus* appear slightly later.

The limited numbers of *Rupela* eggs sampled and the small *Rupela* infestation of the experimental plots prevent the compilation of life-tables. However it is possible, starting with a theoretical number of 1000 L_1, to estimate the reduction in the numbers of the successive stages (Table 20). The following detailed observations are the basis for the data mentioned in the table. The total larval mortality before entering the stem cavity is about 70% (Table 16, 17). The residual field mortality is computed, based on the numbers of larvae established (Table 19). The mortality in the L_4 and L_5 is supposed to be equal. I started from the supposition that the parasites only cause mortality in the last larval instar. The borer pupae belong for 40% to the female sex (Table 4). It follows that from three series of 1000 L_1, 17, 15 and 30 female moths res-

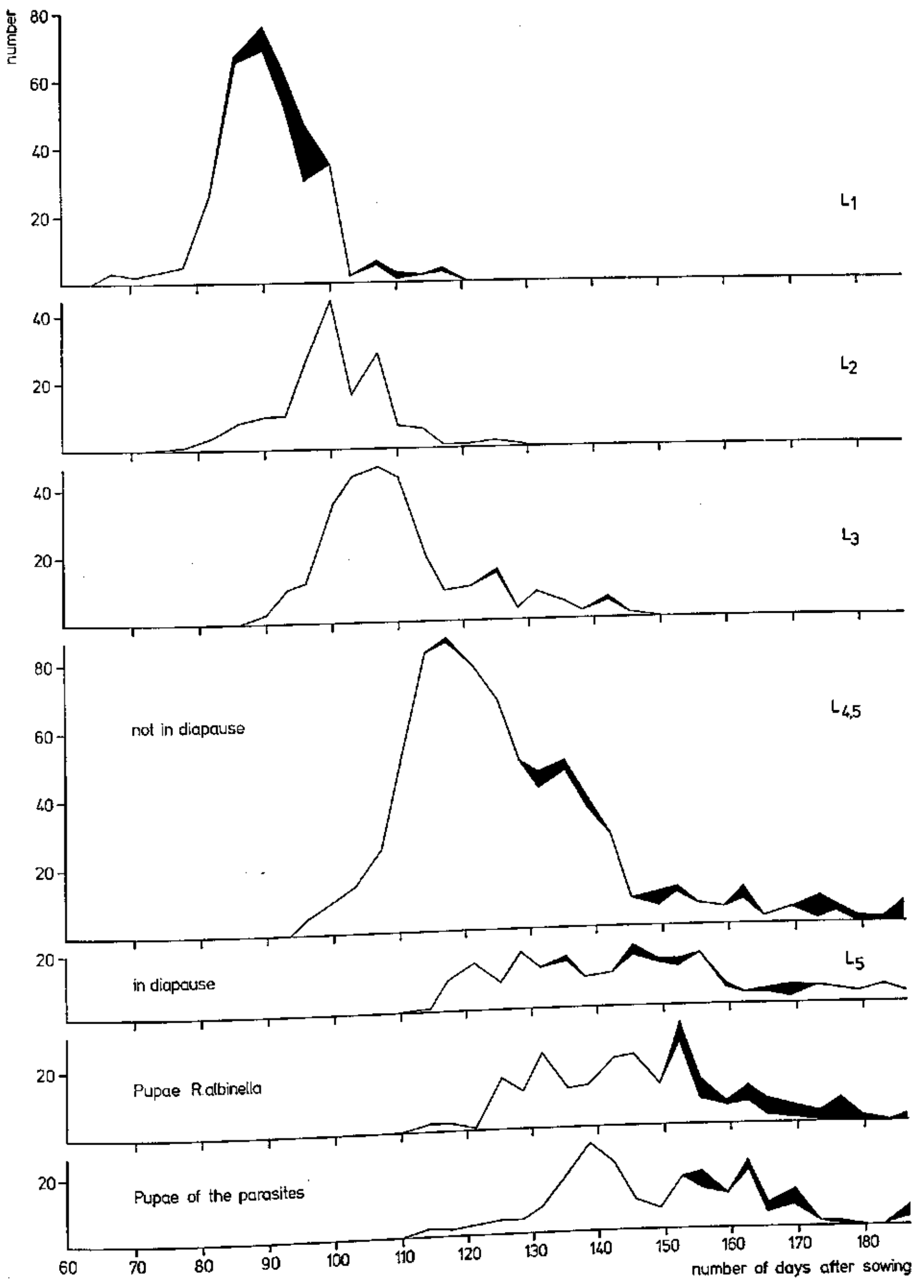

FIG. 16. Fluctuations of numbers of *R. albinella* per instar. The dead individuals are represented by black thickenings of the lines (samples of 15 hills).

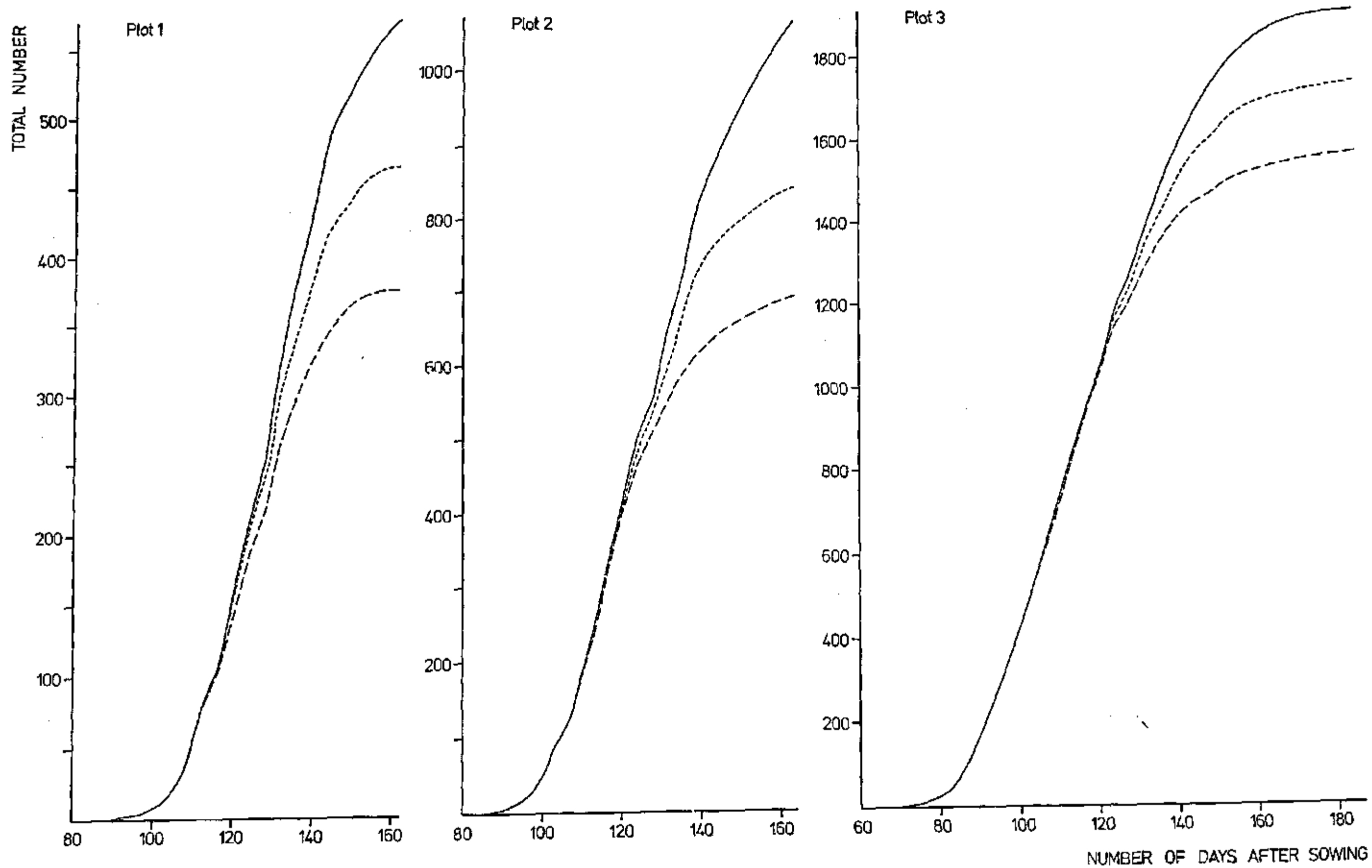

FIG. 17. Numbers of *R. albinella* and its parasites plotted cumulatively with time. Of three rice plots samples of 15 hills were taken twice a week.

- - - - larvae of *Rupela*
- · - · - larvae of *Rupela* + pupae of *Rupela*
——— larvae of *Rupela* + pupae of *Rupela* + pupae of the parasites

TABLE 20. Decrease in the numbers of *R. albinella* when starting with the theoretical number of 1000 L_1 on the plants. Larval mortality is estimated for three rice plots (see Table 19). For further information see section 2.8.2.

stage	Plot 1		Plot 2		Plot 3	
	number alive at beginning of stage	% mortality	number alive at beginning of stage	% mortality	number alive at beginning of stage	% mortality
L_1 during dispersion and boring	1000	70	1000	70	1000	70
in stem cavity	300	18	300	21	300	12
L_2	245	5	236	9	264	0
L_3	233	13	215	15	264	1
L_4	203	15	182	15	261	6
L_5	172	15	155	15	246	7
Parasitizing	146	53	132	63	229	47
Pupae	69	39	49	23	121	38
Moths	42		38		75	
Female moths (40%)	17		15		30	

pectively emerged. As 4% of the eggs are sterile (Section 2.7.1.) these females deposited 3000, 2650 and 5300 fertile eggs. Starting from these numbers we again reach about 1000 L_1, which involves a mortality of 67%, 62% and 81%. Several factors which I was not able to measure, play a role. I observed egg predation and egg parasitism, the latter may be very important under some circumstances (Section 2.5.1.). Predation is nearly completely unknown. The influence of climate, especially the heavy and numerous rains, on the dispersing L_1 has never been studied. It may be expected that the increase in numbers of the borer normally will not be high. The picture I sketched will repeat itself in every generation.

Continuous rice cultivation shows a small increase in the numbers of borers (Section 2.8.3.).

2.8.3. *Fluctuations under continuous rice farming*

During a period of slightly more than two years rice was planted and sampled every month. Thus the borer does not need to pass periods without the host plant. The behaviour of the borer and the parasites with continuous rice cultivation is given in the scheme of Figure 18. *Rupela* and *Venturia* deposited their eggs between the 70th and 90th day after sowing the rice; 120–150 days after sowing of the crop the moths and the wasps emerge. These moths and wasps deposit their eggs in the rice plot sown two months later than the one in which they

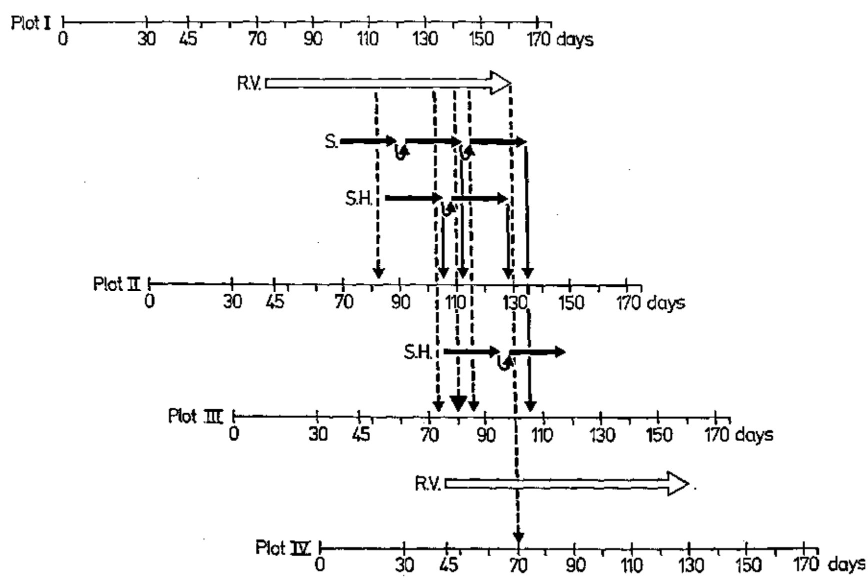

FIG. 18. Scheme of the succession of the generations of *R. albinella* and its parasites with continuous rice cultivation with monthly sowing. Note that *Rupela* (R) and *Venturia* (V) always pass over one plot and that *Strabotes* (S) and *Heterospilus* (H) form about 2 generations in one plot. The rice variety Holland is used (total growth period 173 days).

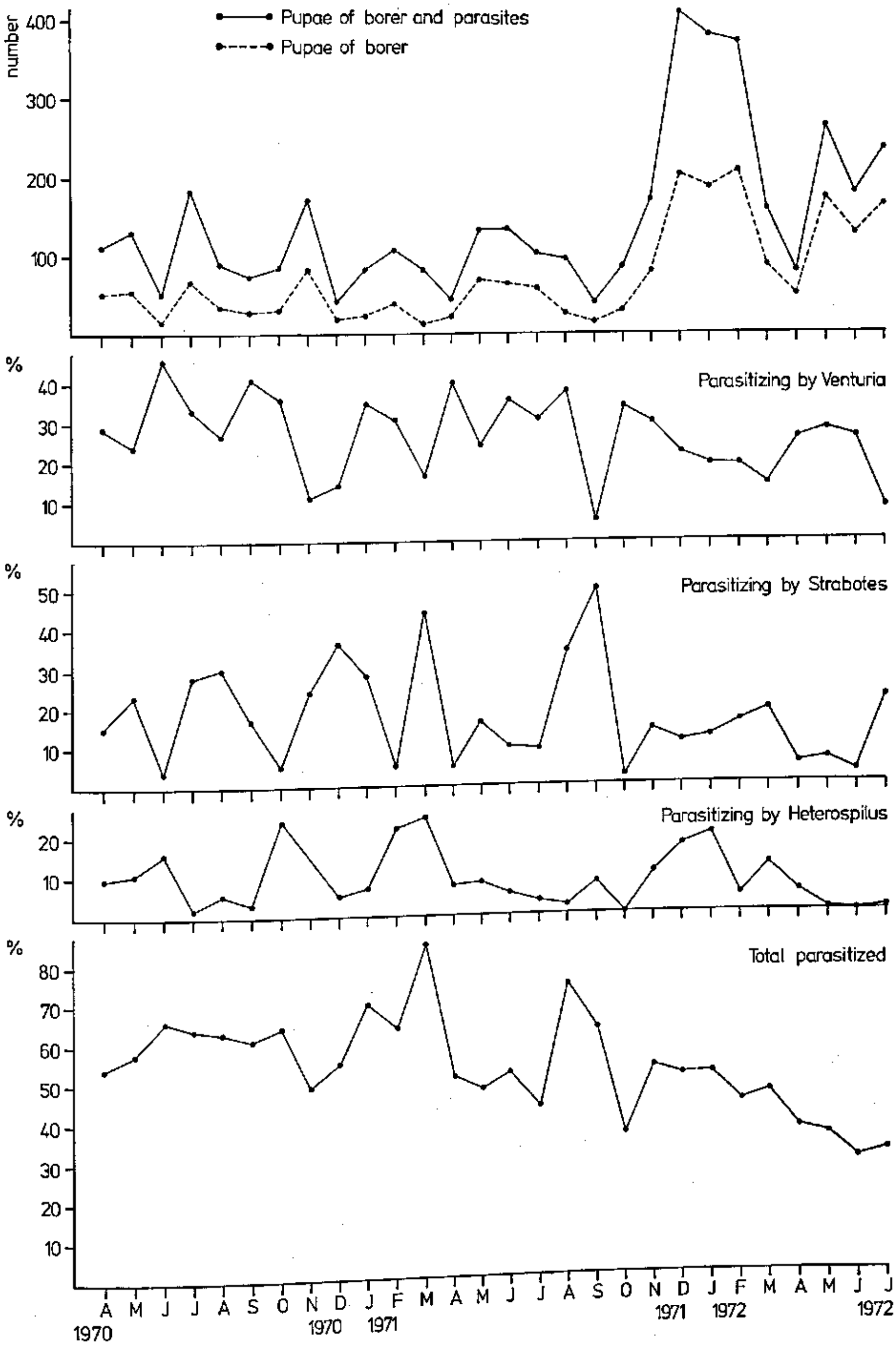

FIG. 19. Numbers of pupae of *R. albinella* and its parasites per month in 270 rice hills. Parasitizing is given in totals as well as specified according to the parasites.

grew up. In our case, this is plot 3 (see Figure 18); the second plot cannot be infested by this generation. *Strabotes* and *Heterospilus* start parasitizing about 110 days after sowing the crop, when the first larger host larvae are present. They will make a second and perhaps even a third generation in the same plot. If they start on about the 120th day, they can make the second generation in the same plot or they go to the next plot, sown one month later than the plot in which they grew up; in this case plot 2 is infested. Whether they stay in the same plot or go on to the next, will partly depend on the number of hosts available. Only the parasites emerging very late in a plot can go from plot 1 to 3.

Therefore the complicated situation occurs that the number of *Rupela* pupae in a plot will be determined by the number of pupae of *Rupela* and *Venturia* two plots earlier. However, the number of *Strabotes* and *Heterospilus*, in the previous plot will have the most influence. Therefore it is not practical to connect the numbers in two plots or at two moments. The difficulty is enhanced as almost nothing is known of emigration and immigration.

In plotting the fluctuations of the borer I took the pupal stage. The pupae of borer and parasites are present nearly at the same time and they are easy to find. The total stem infestation ranged between 3 % and 28 % in the years of my research. When the years July 1970 – June 1971 and July 1971 – June 1972 were compared, the stem infestation increased from 10.2 to 14.9 % and the parasitism of the borer decreased from 60 to 40 %. The composition of the parasitic complex did not change and was as follows: *Venturia* 50 %, *Strabotes* 31 % and *Heterospilus* 19 %.

In Figure 19 the numbers of pupae of borer and parasites are given per month as well as the percentage parasitization of the borer by each parasite. The increase of the borer population and the decrease of the percentage parasitization is very clear. It is striking that there are periods without *Heterospilus* whereas the host is still present. Peaks in parasitization by *Strabotes* are often coupled with low percentages of *Venturia;* this may be caused by secondary parasitism as mentioned in Section 2.5.3.6.

2.9. Importance of the borer

The way a *Rupela* larva develops inside a rice plant strongly deviates from all other rice stem borers so far described in the world literature. The complete larval development takes place in one internode during which time the stem wall tissue is only eaten superficially. No holes are gnawed in the wall, except for the exit hole which is made shortly before pupation and adult appearance. *Rupela* infested stalks form panicles that cannot be distinguished visually from those of non-infested stalks. Indeed crop losses caused by the borer are very small. For the 'Wageningen Rice Scheme' yield losses of only 70 kg/ha at a stem infestation level of 10 % were found (van Dinther 1960b).

In the small holder rice plots, with one harvest a year, the number of borers remains small. A few generations are formed during the rice growing season

(April-August). In these plots in the years 1971 and 1972, the mean infestation is supposed always to have been less than 2%.

With continuous rice cultivation, as practised on the 'CELOS' research station, stem infestation increases but the three larval parasites play an important role in the control of the borer. The mean stem infestation was 12.5%.

In well-separated rice growing seasons, the increase of the borer is especially accompanied by the increase of *Telenomus* and to a lesser extent by that of *Venturia*. Before *Strabotes* and *Heterospilus* will be of any importance, the growing season is ended.

The present tendency to introduce rice varieties with a shorter growth period, will lead to a decrease in the number of borers. It is the phenomen of 'escape resistance'.

It is not to be expected that *Rupela* will ever do important damage to the rice crop. This opinion is not yet generally held outside Surinam. In Colombia, *R. albinella* or 'novia del arroz' as the moth is popularly called, is considered as a pest (CALLEGO 1946). The borer is shown on the colour chart 'Plagas y enfermedades del arroz' issued by the Bayer Industries. Also in Guyana *R. albinella* is listed as a pest (MADROMOOTOO 1972, 1973, RAI 1972).

3. DIATRAEA SACCHARALIS

Diatraea saccharalis (F.) belongs to the Crambinae (Pyralidae, Lepidoptera). The moth was first described by FABRICIUS in 1974 as *Phalaena saccharalis*. It was included in the genus *Diatraea* by DYAR and HEINRICH in 1927 who reported 55 related other species belonging to this genus. BOX (1931, 1935, 1948, 1949, 1951) added several new species to this group. A taxonomical review of the Crambine moth borers of sugarcane, reduced to 21 valid species, has been published more recently by BLESZYNSKI (1969).

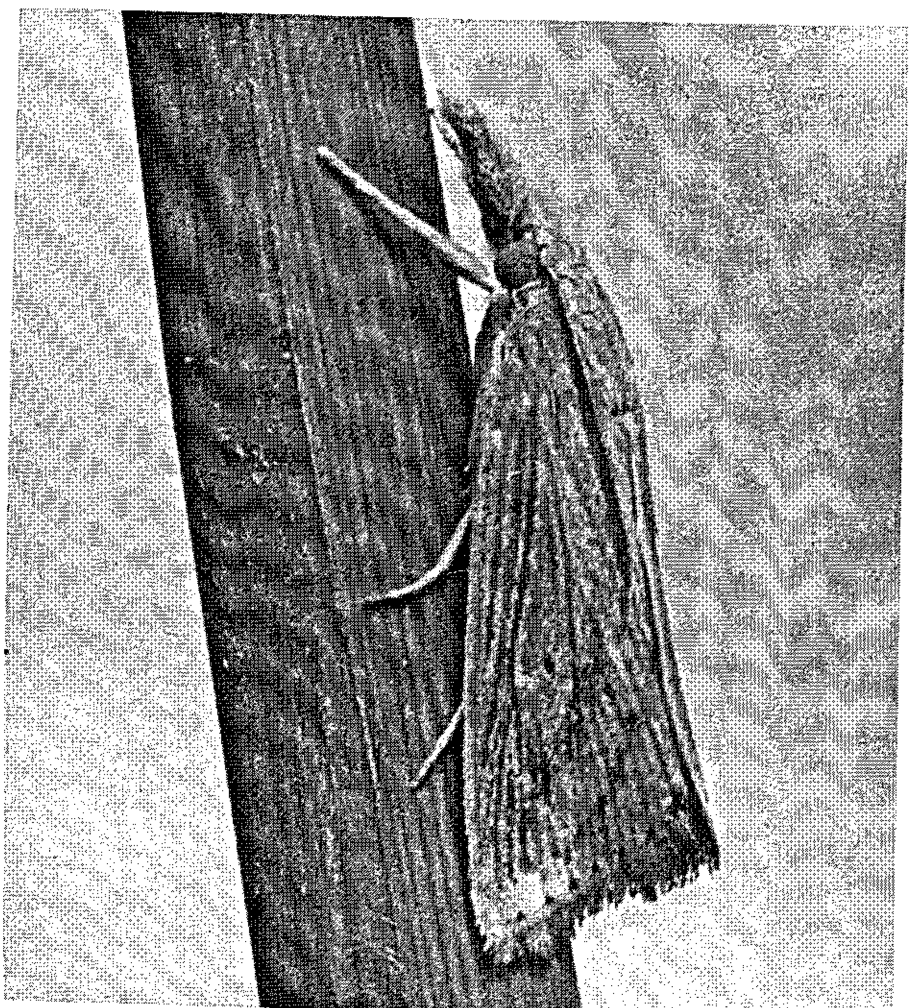

PHOTO 5. *Diatraea saccharalis* male.

3.1. Rearing on an artificial diet

The study of the bionomics of insects under laboratory conditions has been facilitated during the last two decades by rearing these insect species on artificial diets. With these diets large numbers of insects can also be reared for population studies in the field.

Moreover, artificial diets have opened prospects for the mass-production of parasites and entomophagous organisms like viruses for biological control. The possibility to apply the sterile-male technique also received attention.

The following requirements for the artificial diet are now generally accepted:

1. Quick and cheap preparation.
2. Good keeping quality which guarantees the rearing of larvae from eggs to adults without need for regular care.
3. A food composition which results in a uniform and fast larval development and the production of vigorous adults with a high reproductivity capacity.

Artificial diets for *D. saccharalis* have already been developed with some degree of success outside Surinam.

Under the CELOS laboratory conditions rearing could not be done aseptically so that the aseptic rearing methods of PAN and LONG (1961) and of WONGSIRI and RANDOLPH (1962), could not be used for our planned procedure. Neither could MISKIMEN's method (1965). This method is not aseptic but includes several laboratory sanitation precautions i.e. a double-door system, a room with completely sealed windows, germicidal lamps. Results obtained by HRDÝ et al. (1968) were not very encouraging. The keeping quality of their diet was poor because of mould infections after 14–20 days.

VAN DINTHER and GOOSSENS' (1970) diet was selected for further testing. This diet, containing a combination of ingredients of the recipes of BOWLING (1967) and WALKER et al. (1966), had already been developed under non-aseptic conditions at the 'CELOS' Institute, Surinam, in 1968. Results were promising and could compete with the results of other diets.

3.1.1. *Ingredients used*

The following list includes all substances used in one or more of the various diets tested:

a. *Kidney beans, Phaseolus* sp. Beans were obtained from the local market. Before milling, beans were crushed with blender and dried overnight at 50 °C.
b. *Maize plants.* Locally grown maize plants that had just reached the flowering stage, were harvested. After removing the old, brown leaves, stalks were cut lengthwise, dried at 50 °C for 3–4 days and milled.
c. *Carrots.* Tinned powder of *Daucus carota* L. was imported from the Netherlands. The powder was manufactured from sliced carrots, after drying for 12 hours at 50 °C.
To prevent deterioration the powder in the tins was kept under a nitrogen pressure of 1 atm.
d. *Pumpkins.* Ripe, locally grown fruits of *Cucurbita pepo* L. formed the raw

material. Fruits were sliced, dried for 2–3 days at 50 °C, and milled.
e. yeast powder, f. casein, g. agar, in powdered form, h. ascorbic acid, i. methyl parahydroxy benzoate (nipagin), j. sorbic acid, k. penicillin, l. streptomycin sulphate, m. HCl (1N), n. (tap)water.

3.1.2. *Development of the diet*

I started a new breeding programme with diet No 4 of VAN DINTHER and GOOSSENS (1970). The results were not quite satisfactory. The diet proved to be too wet when kept in rearing vials and the larvae often adhered to it. In the second generation the amount of water was decreased to raise the percentage of dry matter from 32 to 45. At the same time the penicillin was omitted because it was judged to have no effect in presence of the broad acting streptomycin. The amount of carrot powder and streptomycin was doubled and the amount of sorbic acid reduced to half. This resulted in a diet with good keeping quality (Table 21).

The number of the larvae that survived was moderate, however. To improve survival I changed the amount of nipagin and streptomycin in the third to the sixth generation. The amount of nipagin greatly influences the start of the larvae on the diet.

It turned out that the high larval mortality which mainly took place in the L_1, resulted from the higher doses of nipagin. On the other hand lowering the nipagin quantity caused an increase in mortality in the older stages through overgrowth of fungi. Therefore the dose could not be reduced appreciably. Changing the amount of streptomycin had no effect. A few times HCl was added without any marked influence.

Because carrot powder is not always available in the tropics I looked for a substitute and used pumpkin powder.

3.1.3. *Preparation of the diets*

Ingredients were mixed with a blender and of each medium tested 300 ml was prepared. Later, when the standard diet had been selected, a Hobart laboratory mixer (motor 1/6 HP, net mixing capacity 5 litres) was introduced.

TABLE 21. Composition of the artificial standard diet for *D. saccharalis*. (Amounts in grams unless indicated otherwise.)

Kidney beans	21
Corn plants	6.7
Carrots	6.7
Yeast	6.7
Casein	0.67
Ascorbic acid	0.33
Agar	2.0
Nipagin	0.63
Sorbic acid	0.063
Streptomycin	0.12
Water (ml)	100

The standard diet was prepared as follows. Agar was dissolved in 1½ litre of boiling water and the solution was stirred for 4 minutes, Carrots, yeast, casein, ascorbic acid, nipagin, sorbic acid, and streptomycin were added and the mixture was blended for 8 minutes with the mixer. During this procedure the temperature of the mixture dropped to about 55°C. Maize plant powder and kidney bean powder were then added and the total mixture was blended for another 10 minutes during which time the temperature further dropped to about 45°C.

The warm medium, now having reached an optimum viscosity, was directly piped into 25-ml vials and/or 250-ml Erlenmeyer flasks that had been sterilized before use. These containers were then stoppered with cotton wool and stored over-night in an air-conditioned room at 25°C to eliminate condensation of water.

3.1.4. *Rearing procedure*

The larvae were reared in a screened laboratory room where the temperature fluctuated with the outdoor conditions. Three newly hatched larvae were transferred with a fine brush to each vial which contained 15 grams of the diet. Erlenmeyer flasks containing 75 g of diet received 25 larvae.

To avoid infection with mites, the tables were cleaned with alcohol and flamed before starting the inoculations. After 20 days the vials were regularly inspected for pupae. These were collected, weighed and stored in vials (10 × 2.5 cm). Adult emergence was checked daily. Couples of moths were placed in plastic (coffee) cups (height 8.5 cm, diameter about 7 cm). The inner wall of the cup was lined with ordinary writing-paper whereas the bottom of the cup was cut out and replaced by a small-mesh plastic screen. The cups after being closed with a similar screen were then placed above buckets containing water in order to maintain or enhance the relative humidity of the environment. The moths soon mated and egg clusters were readily deposited on the writing-paper. The paper was transferred shortly before emergence of the larvae.

3.1.5. *Results*

Six moth generations were reared during the development of the standard diet. The cultures deteriorated after the 4th generation and in the 6th generation almost no fertilized eggs were laid. Therefore fresh males were introduced, whereupon the results improved. Rearing continued during three more generations when in the 10th generation fresh blood (♂♂) was again necessary; it immediately improved the results.

Experiments with the standard diet in which carrot powder was replaced by pumpkin powder looked very promising during one generation but in the following generations the results became less encouraging. This was especially shown by the decreasing percentage of surviving individuals (Table 22). After 4 generations the experiment with pumpkin powder was stopped. However, since fresh male moths were not introduced, the use of pumpkin powder certainly deserves renewed consideration in the future. Females originating from the 4th generation on standard diet, containing carrots, when provided with new males

TABLE 22. Results of rearing *D. saccharalis* on artificial diet (expressed as overall averages). A. Standard diet, B. Standard diet with pumpkin instead of carrots.

generation	number L_1 used	% larvae reaching pupal stage	development time in days L_1–adult		pupal weight in mg		adult longevity in days				egg production			percentage fertilized females
			♀	♂	♀	♂	♀		♂		total	% not fertilized	% L_1 not hatched	
							n	$\bar{x}$	n	$\bar{x}$				
	A: standard diet													
1st	–	–	–	–	135	64	–	–	–	–	–	–	–	–
2nd	1941	50	39	36	129	77	191	4.5	228	4.0	453	14	25	87
3rd	1455	42	39	36	124	71	94	4.8	87	4.2	421	18	28	82
4th	1209	21	37	35	121	74	51	4.9	51	4.1	386	15	17	89
5th	1002	56	38	34	120	69	55	4.7	55	4.2	412	13	17	81
6th	600	51	36	36	125	73	31	4.7	31	3.9	395	16	19	70
	B: standard diet with pumpkin													
1st	297	84	37	32	133	73	33	5.0	46	3.8	507	14	26	75
2nd	369	43	36	34	132	76	19	4.4	26	4.2	346	32	39	71
3rd	355	25	36	35	111	69	11	5.3	11	3.7	411	32	26	58
4th	543	26	36	36	117	73	16	4.4	22	3.4	389	23	39	64

produced offspring that showed a distinct increase in survival (Table 22).

Often there is a relation between egg production and pupal weight. Figure 20a, b gives the results. There is a significant correlation between these parameters in all the generations tested. The confidence of the linear regression lines was very good (test criterion is F, $P < 0.001$), in the 3rd generation less good ($P < 0.1$). An average pupal weight on the diet of about 125 mg resulted in an egg production of something more than 400 eggs. PAN and LONG (1961) listed the egg production of larvae bred on sugarcane tops. A fecundity of 380–474 corresponded with a pupal weight of 113–147 mg. HRDÝ et al. (1968) found an average of 282 and 310 eggs with a pupal weight of 71–90 mg and 91–110 mg, respectively. BOWLING (1967) reported a production of 268 eggs with a pupal weight of 107 mg on his diet. These results correspond with my data. The other listed egg productions, 222 (TAYLOR 1944), 300 (WALKER and FIGUEROA 1964), 330 (KEVAN 1945) are not related to pupal weights. WALKER et al. (1966) found an abnormally high egg production of 500–600 with the corresponding low pupal weight of 112 mg for moths reared on an artificial diet.

The highest egg production ever found in the course of my study originated from two diet reared moths. Their pupal weights of 124 mg and 138 mg corresponded with 947 and 914 eggs, respectively.

3.1.6. *Discussion and conclusion*

Rearing in vials containing 15 g diet gave good results. Rearing in Erlenmeyer flasks was less satisfactory because of the risk of mould.

Larval mortality, predominantly during the L_1 instar, was mainly caused by nipagin, one of the antibiotic agents of the medium. However, if the nipagin quantity is reduced the likelihood of mould is increased.

The time of development from L_1 to moth, 35–38 days, was longer than on rice. Pupal weights, 75 mg for the males and 125 mg for the females, are higher in comparison to those originating from rice plants (Table 26). Mortality among pupae originating from the diet proved negligible, whereas mortality in pupae obtained from rice stalks is generally high (Table 24).

A comparison of my results with those of WALKER et al. (1966) and BOWLING (1967) showed that WALKER et al. recorded a shorter time of development, a higher egg production, and smaller pupal weights. The time of development observed by BOWLING is in agreement with my observations; the egg production he found is much lower than the egg production I recorded.

Permanent rearing of *D. saccharalis* on the artificial diet resulted in a gradual increase of larval mortality and a decrease in pupal weight and egg production during the successive generations. Inbreeding also resulted in a final offspring of black-eyed moths. More light-eyed than black-eyed specimens were present in the original parent stock. MISKIMEN (1965) also found reduced fertility and fecundity as a result of inbreeding.

The standard diet has proved to be adequate for rearing large numbers of larvae for laboratory studies. Modifications will be necessary, however, if mass-rearing, for instance for parasite introduction in the field, should be considered.

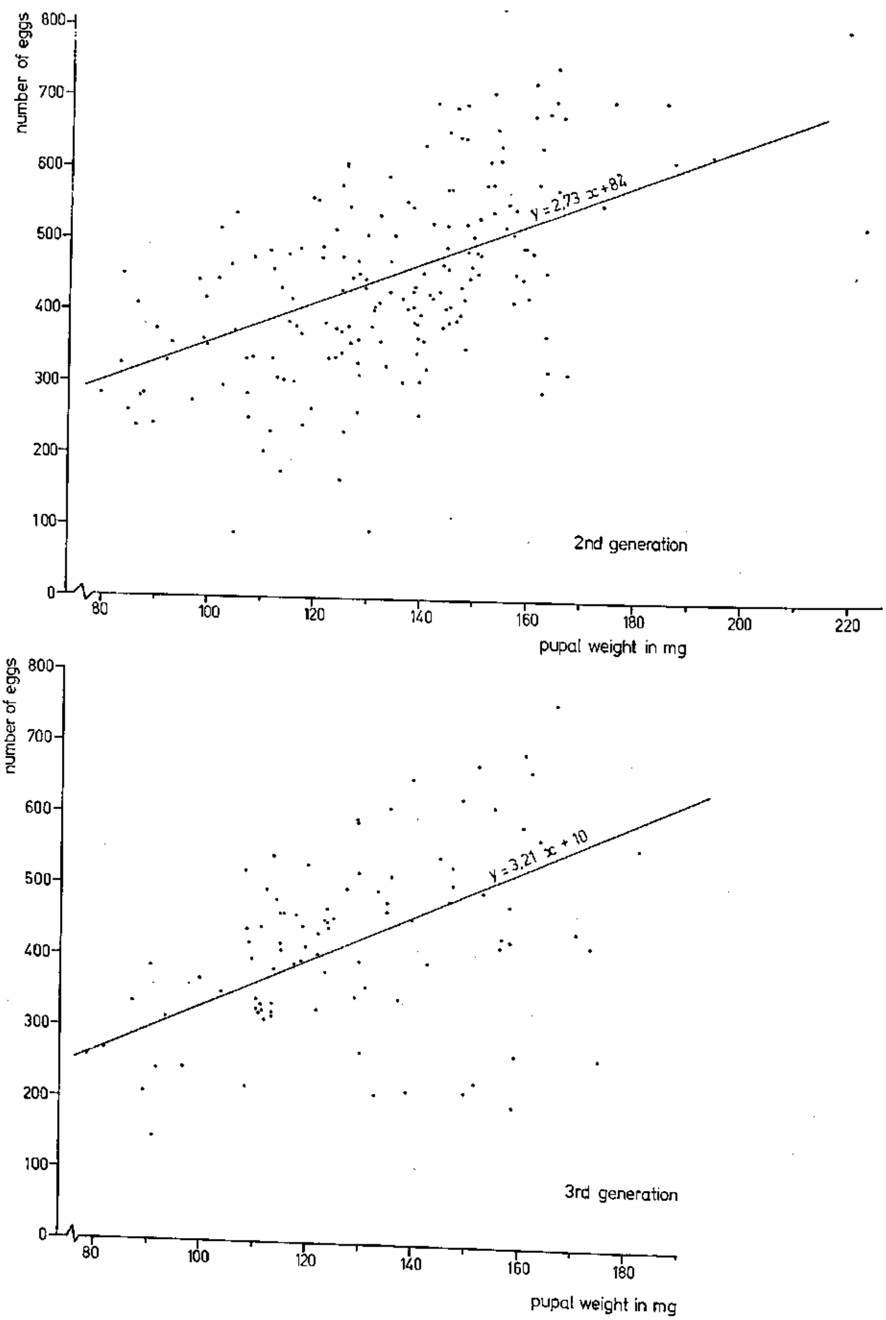

FIG. 20a. Correlation between total egg production and pupal weight of *D. saccharalis*, for four successive generations reared on the standard diet.

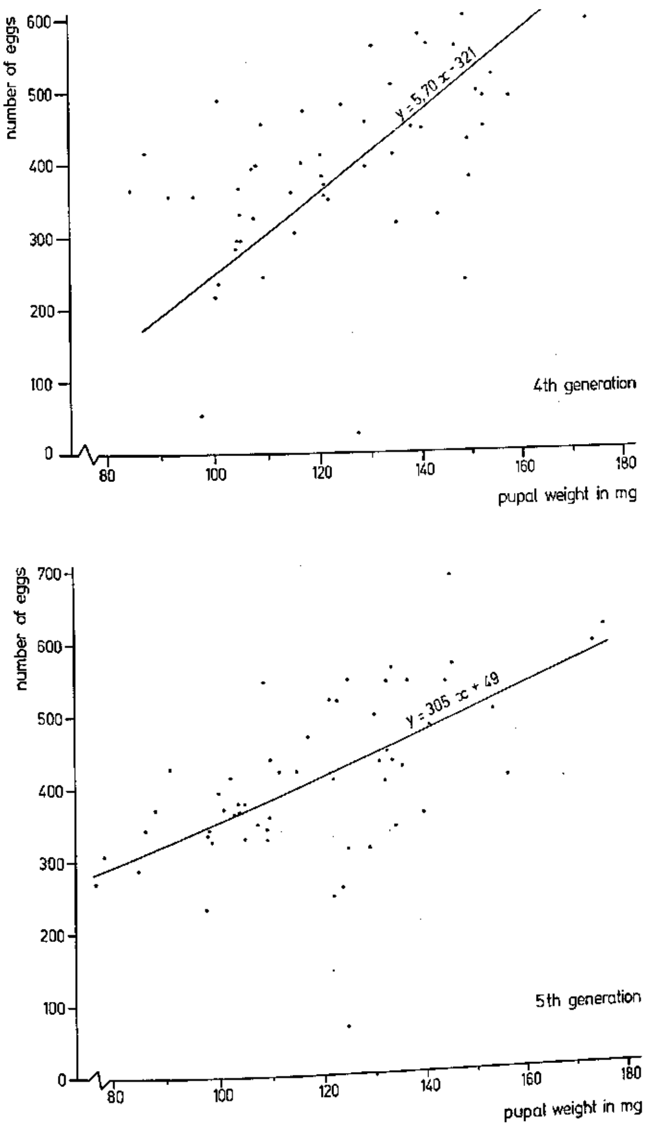

Fig. 20b. For explanation see Figure 20a.

3.2. Life cycle of the borer

Although many biological data about *D. saccharalis* have already been reported from the neotropics and the southern States of the USA, a study of the life history and the habits of this borer in Surinam was felt necessary since there is little information on its occurrence in rice. Most literature data refer to sugarcane: viz., from Guyana (Box 1926), the USA (Holloway et al. 1928, Katiyar

1960), Peru (WILLE 1932), Puerto Rico (WALKER et al. 1964, 1965, 1966 and 1967), Cuba (HRDÝ et al. 1968). Attention has also been paid to wheat (WILLE 1932), maize (WALKER et al. 1964, 1965 and 1967, HRDÝ et al. 1968) and sorghum (HRDÝ et al. 1968).

My observations and experiments took place in the laboratory as well as in an outdoor insectary (page 7).

Rice, growing in 6-litre buckets with clay, served as food plants. *D. saccharalis* material in the different stages of development were taken from the standard diet stock culture.

For nightly observations a 6-volt red-light torch was used.

Normally rice of the variety Holland was used in the experiments.

3.2.1. *Eggs*

According to the literature the average number of eggs per cluster on sugarcane amounts to 15.8 (JASIČ 1967), 35 (BOX 1926), and 50 (WILLE 1932). WILLE reported 3–25 eggs per cluster when wheat was the host plant.

The developmental period of the eggs depends on temperature and ranges from 4–9 days in the USA (HOLLOWAY et al. 1928); BOX (1926) reported 7 days for Guyana.

Newly deposited eggs are creamy white. They gradually darken and become reddish brown during maturation; the eyes and head turn black towards the final stage of embryonic development.

In the subtropical region of the dispersal area, the moths usually hatch in the early morning during the summer, and later in the day in cooler weather (HOLLOWAY et al. 1928).

Under Surinam conditions the development period of the eggs always lasted 6 days.

A fixed moment of hatching could not be ascertained. Young larvae made their appearance in daytime as well as during the night.

I found that the number of eggs per cluster depends on the place where they were deposited. On rice leaves 1–3 eggs were laid side by side and 5–25 in the row. The average on rice was 27 eggs per cluster with a S_e value of 1.9 ($n = 87$). Under laboratory conditions when eggs were laid on writing paper that lined the inner wall of the cups, the round or oval clusters often contained more than 100 eggs.

3.2.2. *Larvae*

3.2.2.1. Habits

Newly hatched *Diatraea* larvae are very active. They move about and lower themselves with silken threads (HOLLOWAY et al 1928). TUCKER (1937), in his comprehensive experiments found no significant differences in infestation levels between plots where egg clusters were removed and plots where clusters could hatch normally, even when these plots were situated 75 m from the nearest cane fields. This underlines the distribution potential of the L_1. Dispersion of half-grown larvae in sugarcane (Box 1926) and wheat (Wille 1932) has also been observed. According to Holloway et al. (1928) newly hatched larvae start eating the epidermis of the leaf and gradually burrow into the midrib. They are often found between the leaf sheath and the stalk while some enter the stalk immediately. Wille (1932) reported that the young larvae enter the wheat stem through one of the lowest internodes. Inside the stalk they eat their way upwards by perforating one or more nodes. The inner wall is damaged only superficially except for the few round holes that are gnawed in the wall. Through these holes the frass is expelled; it is subsequently found between the leaf axil and the stem.

I observed that newly hatched larvae after landing on the water surface start floating. They do not walk as *Rupela* larvae do. If the caterpillar meets a rice stem or another obstacle it crawls onto it. The larva starts feeding on the leaf near the place where the leaf sheath encloses the stem. Moving downwards during feeding, the larva enters the leaf sheath. Occasionally the larva moves upwards and after some time penetrates into the midrib of the leaf. Generally it can be said that larvae can be found in those places where they can hide themselves. Until they are 5 days old nearly all the larvae live in the leaf sheaths or between the leaf sheath and the stem. At that age they start tunnelling in the stem, especially at the side of the nodes. Larvae often congregate within one internode. From groups of 150 newly hatched larvae that were transferred to individual rice hills, numbers of 10–20 larvae were regularly found congegrating inside one internode; 38 larvae formed the maximum number detected. From the third instar onwards larvae always live separately. Feeding is concentrated on the inner tissue layers of the stem leaving the outer surface of the stems intact. The nearly full-grown larva often gnaws an 'internal ring wound'. The stem often breaks at this place and the larva pupates in the remaining stubble. If plants younger than 60 days are attacked often only a fibrous mass remains. The frass of the L_1 and L_2 instars remains in the burrows. Frass of the older larvae is found in the stem cavity or outside the stem, the latter especially when young stems are attacked.

Normally the stem wall was so badly damaged and perforated that the making of a special exit hole for moth escape was superfluous. Very often the pupa was found in a filthy, brown, rotted mass that had once been a stem.

3.2.2.2. Number and duration of instars

There is much diversity in the literature about the number of instars. Normally 5–6 instars are found (Box 1926, Holloway et al. 1928, Wille 1932, Taylor 1944, Katiyar 1960, Jasič 1967) but a total of 7 or 8 is also common. Holloway et al (1928) even listed a maximum of 14 instars in sugarcane; when the larval period is prolonged – the result of poor quality food or of handling the larvae – the larvae continue moulting with no increase or even with a decrease in size. The width of the head capsule increases from 0.28 up till 1.90 mm in sugarcane in the six instars that can be distinguished, and overlap in the 4th and 5th instars (Katiyar 1960). Hrdý et al. (1968), recording a similar

TABLE 23. Width of the head capsules (in mm × 100) and duration in days of *D. saccharalis* larval instars. In one experiment seedlings were used for 10–12 days and later on stem parts. All data obtained from 30–50 observations except the L_6 of seedlings/stem parts (n = 14) and stem parts (n = 6). $\bar{x}$ = average.

Food	Head width											
	L_1		L_2		L_3		L_4		L_5		L_6	
	$\bar{x}$	range	$\bar{x}$	range	$\bar{x}$	range	$\bar{x}$	range	$\bar{x}$	range	$\bar{x}$	range
seedlings/stem parts	29.5	28–31	37.0	30–40	49.6	40–55	61.4	56–81	93.1	70–112	127.9	90–144
stem parts	28.7	28–30	39.7	33–45	58.2	36–71	92.9	50–112	138.3	99–164	152.7	136–162
artificial diet	28.3	28–29	38.6	30–47	60.8	50–71	87.4	67–101	121.6	101–146	154.2	142–172
pot plants 70 days	29.2	27–31	39.6	33–49	60.9	52–73	95.7	75–114	121.7	110–154	153.3	146–156
	Duration											
seedlings/stem parts	4.7	4–6	3.6	3–6	3.5	3–5	4.8	3–7	5.6	3–8	7.2	6–12
stem parts	3.5	3–6	3.7	2–6	3.2	2–5	3.6	2–5	4.8	4–5		
artificial diet	3.2	2–6	3.1	2–6	4.1	2–6	3.3	2–6	4.0	2–7	6.8	4–10

range of the width of the head capsules, found an overlap in the 7th and 8th instar only.

The total larval development takes 25–35 days (HOLLOWAY et al. 1928, KEVAN 1945, KATIYAR 1960). HRDÝ et al. (1968) listed a duration of 41 days but mentioned that manipulation and disturbance of caterpillars reared in confinement could have caused differences with the development in nature and could have produced an additional instar.

In my own experiments head widths were measured of larvae that were bred on:

a. seedlings (Method of FUKAYA and KAMANO 1967) for 10–12 days, followed by stem parts;
b. stem parts only;
c. artificial diet;
d. plants 70 days old at the moment of infestation.

In the first three experiments (*a*, *b*, *c*) each larva was checked daily. In the fourth (*d*) plants were cut after a fixed number of days and searched for larvae and head capsules; in this case the duration of the instars could not be established. The results are given in Table 23.

The rearing method with rice seedlings or stem parts proved to be not very useful since nearly all the larvae died in the 5th or the 6th instar. About 50% of the larvae reared on the 70-day-old plants reached the pupal stage. Nearly all larvae bred on the artificial standard diet pupated.

Normally 6 larval instars occurred, both in males and females. In a very few cases 7 or 8 instars developed. From the 3rd and 4th instar onward the larvae could not be separated by their head width due to overlap. See also Figure 21.

To determine the total duration of development of the larvae, rice plants of different age were inoculated and sampled after 25 days. It was found that the duration of larval development increased as the plants were infested at a later age; pupal weights also increased. Data obtained from 3 age-groups of rice plants of the variety Holland show this effect (Table 24).

TABLE 24. Time of development of *D. saccharalis* – expressed in percentage of pupae formed within 25 days after the time of infestation – in relation to plant age.
(Rice variety Holland; infestation rate 10 larvae/hill)

Age of the rice in days at the time of infestation	60	80	110
Number of L_1 used	70	440	200
% specimen recovered	34	54	40
of which: a. larvae (%)	5	12	34
b. pupae (%)	95	88	66
Additional data			
♂ average pupal weight in mg	46.3	58.5	65.1
♀ average pupal weight in mg	58.9	79.7	88.5
% pupae emerged	67	63	55

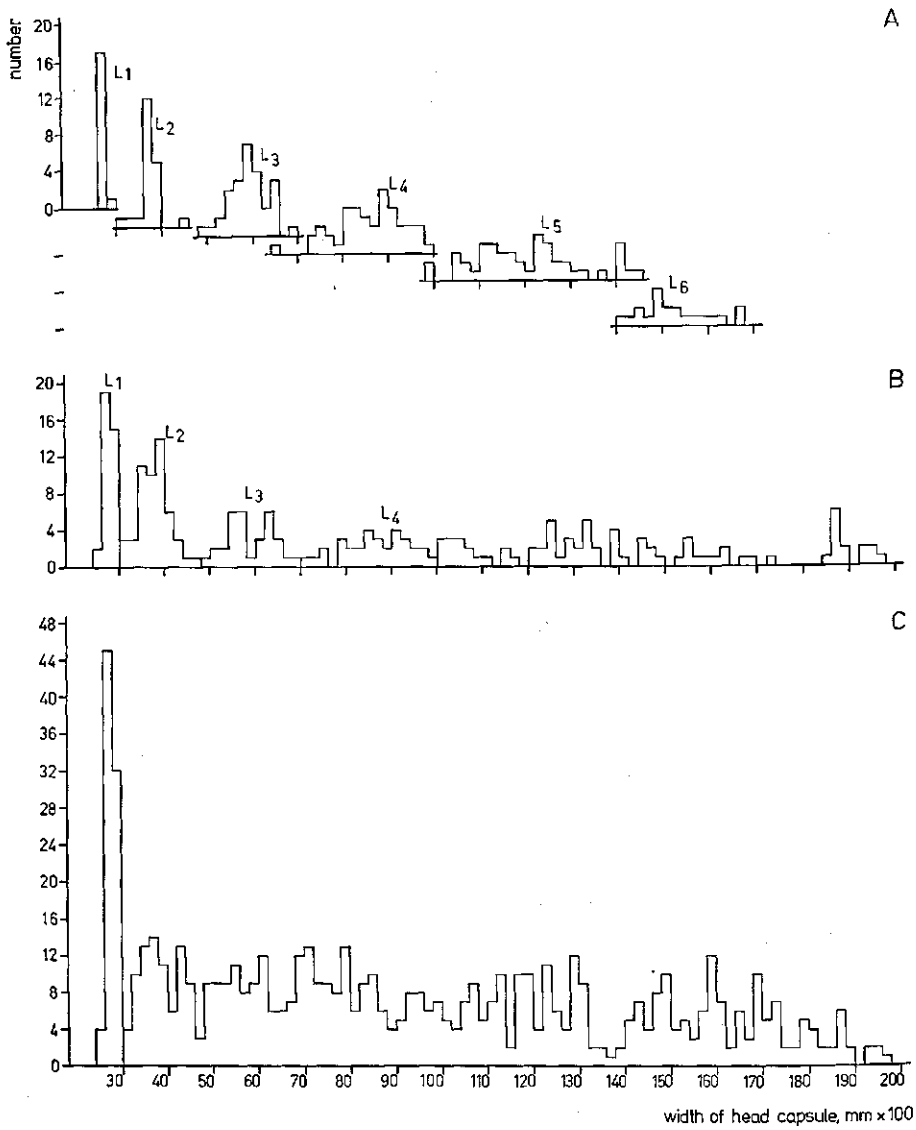

FIG. 21. Head width of larval instars of *D. saccharalis*.
A. On artificial diet.
B. On rice plants. From the 4th instar onwards instars cannot be separated due to overlap.
C. Field observations (September–December 1971).

Table 25 gives a classification of the data on duration of development and on width of head capsules for each of the six larval instars.

TABLE 25. Developmental duration of *D. saccharalis* larvae based on a classification of the head capsule width in six groups.

instar	duration in days	width of headcapsule in mm × 100
L_1	3.3	27–30
L_2	3.3	31–50
L_3	3.3	51–70
L_4	3.3	71–110
L_5	4.0	111–145
L_6	7.0	>145
Total	23.7	

TABLE 26. Pupal-weights of *D. saccharalis*. Origin of pupae: a. CELOS fields; b. pot plants infested when 80 days old, and sampled 25 days later.

origin	♀ n	♀ average weight in mg	♀ $S\bar{x}$	♂ n	♂ average weight in mg	♂ $S\bar{x}$
CELOS fields	41	115.8	18.3	63	66.8	8.5
Pot plants	105	79.7	2.2	96	58.5	1.5

3.2.3. *Pupae*

The sex of the pupae is easy to identify by examination of the abdomen. The distance between the external reproductive organs and anal orifice of the female pupa is greater than that of the male (HRDÝ et al. 1968).

Pupal weights of field samples are never given in the literature. For animals bred on sugarcane tops, pupae weighed 60–66 mg and 113–147 mg for males and females, respectively (PAN and LONG 1961). Pupae gathered from the CELOS rice fields showed a wide range of weights. The average for males was 67 mg and for females was 116 mg (Table 26). In pot plant experiments these weights proved to be distinctly less (Table 24, 26). Pupal weights originating from larvae reared on the artificial standard diet were highest (Table 22). The pupa with the lowest weight ever found (20.3 mg) was a male from rice pot plants, whereas a female obtained from the artificial diet was heaviest (257.3 mg).

In Surinam, pupae obtained from larvae reared on the artificial standard diet had a developmental duration of 7–11 days. The average was slightly more than 8 days. For the Caribbean region a developmental duration of about 8 days has been recorded (BOX 1926).

3.2.4. *Moths*

All observations reported in this chapter were made under natural conditions, viz. under the normal daily sequence of light and darkness, and refer to moths obtained from larvae reared on the artificial diet.

3.2.4.1. Emergence and longevity

Nearly all the moths emerged before midnight. Fifty percent of the males had already emerged at 20h00; the females reached this point 1½ hours later. No emergence occurred in daylight. In Cuba HRDÝ et al. (1968) found a more uniform emergence over the whole day; here nearly 34% of the moths emerged in daylight.

Under Surinam conditions a mean longevity of 4.7 days in the female moth and of 4.1 days in the male has been determined (Table 22). On the 5th day 80% of the females and 90% of the males had already died (Figure 22).

A longevity of 3–8 days is also mentioned in the literature (HOLLOWAY et al. 1928, HRDÝ et al 1968, WALKER et al. 1967). The last author also found many dead moths after 4–5 days.

3.2.4.2. Copulation and oviposition

Mating has long been supposed to take place during darkness, and probably during the second half of the night (HOLLOWAY et al 1928). PEREZ and LONG (1964) in studying moth behaviour ascertained that maximum sexual activity occurred between 01h00 and 04h00. WALKER (1965) observed copulation during

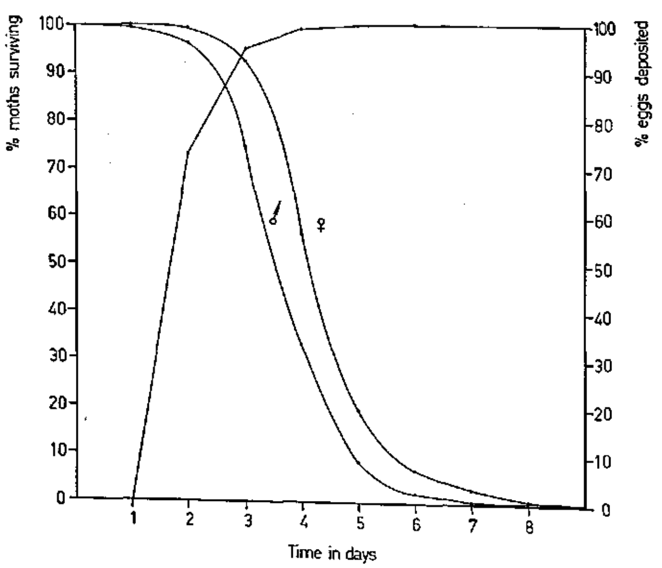

FIG. 22. The percentage surviving moths of *D. saccharalis* and the percentage of the number of eggs deposited. Couples formed the day after emergence. (Number of moths tested = 775.)

the night following the night of emergence. It normally took place in the first half of the night, and oviposition often followed in the same night. MISKIMEN (1966) reported that copulation starts immediately after dusk.

At the 'CELOS' institute copulation always occurred late in the night, viz. after 04h00. Bringing two sexes together directly after emergence or 24 hours later, i.e. the night after emergence, did not influence this moment of mating. At dawn moths are often still in copula. The first eggs are laid during the night after the night of copulation.

The periods of copulation and oviposition mentioned by WALKER (1965) and MISKIMEN (1966) for Puerto Rico differ from the observations made in Surinam. The data of HOLLOWAY et al. (1928) and PEREZ and LONG (1964) agree with my observations.

3.2.4.4. Number of copulations

PEREZ and LONG (1964) reported that 16% of the laboratory-reared female moths did not copulate whereas 5% of the field-trapped moths had not mated. WALKER (1965) mentioned that both females and males normally copulate once a night; males have been observed to mate twice during their lifespan. HRDÝ et al. (1968) reported that a male may mate up to three times during ageing, but that this ability decreased very rapidly. Unmated pairs of three-day-old moths rarely copulated. However, if only one of the partners was three days old, more matings occurred.

My own experiments were carried out as follows. One male was placed together with one female moth for one night. The male was then removed and placed together with another virgin female the following night, etc. I only combined one specimen of each sex because I found that a male could only fertilize one female per night.

Whether or not a successful copulation had occurred was ascertained by checking the fertility of the eggs that were deposited. (In one out of 15 copulations that were observed, no fertilized eggs were deposited.)

Of 83 males, 78% copulated throughout their lifetime. The total number of females mated by one male varied with the moment the couples were formed. When the couples were formed in the night of emergence (night No O), 63% of the males copulated in that night for the first time and 42% again copulated in the following night (night No 1). If the couples were formed the day after emergence, 93% of the males copulated in the following night, and then 24% again copulated in the night thereafter (night No 2). If the first copulation occurred in the night of emergence, the male could copulate three times. Therefore, the number of females fertilized by one male depends on the time of the first copulation and the longevity of the male. If males of two days old were for the first time united with females that had just emerged, then only 15% of the females were fertilized.

3.2.4.4. Egg production

Egg production during successive nights was determined in moths that were combined in couples the day after emergence. Mating took place the following night (night No 1) but fertile eggs were not yet laid. Occasionally, a few sterile eggs were produced. The number of eggs produced during night No 2 constituted 73.5% of the total egg production, whereas during the two following nights the egg numbers corresponded with 22.0% and 4.0% of the egg total, respectively. From the 5th night after emergence onwards, the production of a few final eggs definitely marked the end of the oviposition period (Figure 22). In the first night of egg laying (night No 2) nearly no unfertilized eggs were deposited. This number increased rapidly, however, and 80% of the few eggs produced on night No 5 turned out to be sterile.

When daily egg production is related to moth longevity, it appears that the more eggs they produce during the first oviposition night, the shorter the longevity of the moths. During this night, females with a longevity of, for instance three days and six days produced 90% and 64% of the total egg production, respectively (Figure 23).

If couples had been formed during the night of emergence the egg production line would have started earlier and decreased less rapidly. This line would very probably have been in agreement with the data given by WALKER and FIGUEROA (1964) and HRDÝ et al. (1968).

For information on the total egg production, see Section 3.1.5.

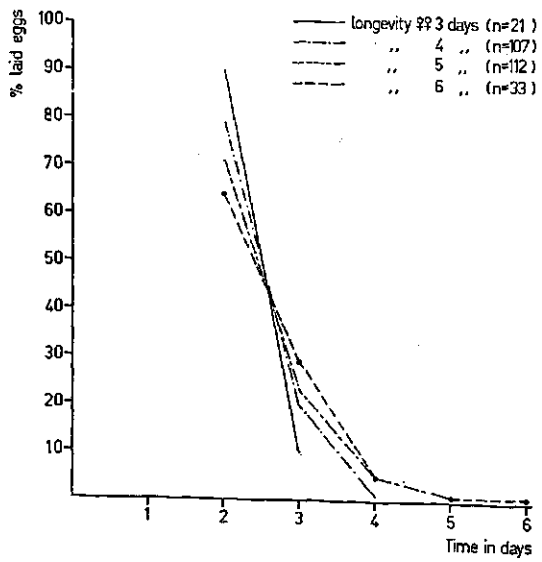

FIG. 23. Daily egg production of *D. saccharalis*, related to longevity. Couples formed the day after emergence.

3.3. Host plants

Jepson (1954), in his treatise on the lepidopterous stalk borers of tropical graminaceous crops, reviews the host plants of these borers. From the total number of host plants of *D. saccharalis* listed, 17 are present in Surinam. Besides in rice I found large numbers of *D. saccharalis* in *Echinochloa polystaga*. In *Echinochloa pyramidalis* only a few larvae were detected. Both maize and sugarcane contained *D. saccharalis* but in small numbers; in these crops *D. centrella* was the dominant species. Furthermore, larvae of *D. saccharalis* were observed in *Hymenachne* sp. and *Paspalum virgatum*.

3.4. Residual mortality

Residual mortality is referred to as the mortality not caused by parasites and predators. It comprises factors like egg-sterility, losses during larval dispersal, larval cannibalism, host plant resistance, climate.

3.4.1. *Egg mortality*

In the Surinam rice fields, the proportion of eggs that hatch will be high since unhatched eggs were seldom found. Exact data are difficult to give because egg clusters transferred to the laboratory for detailed observation soon became injured and died as a result of the shrivelling and twisting of the leaf blades on which they were deposited.

Egg masses laid in the rearing cups as part of the laboratory stock culture procedure contained 13–18% non-fertilized eggs.

In field observations on sugarcane, Holloway et al. (1928) seldom found non-emerged eggs. Walker and Figueroa (1964) mentioned that 80% of the eggs of laboratory-reared females were fertile whereas Hrdý et al. (1968) recorded that nearly all eggs were fertilized and that 80% of the eggs hatched.

3.4.2. *Larval mortality*

Box (1932) reported a larval mortality of more than 90% of *D. saccharalis* in sugarcane fields; Pickless (1936) mentioned a mean of 82% for *Diatraea spp.* Holloway et al. (1928) observed cannibalism, especially in the younger instars. Quintana-Muniz and Walker (1970) working with stem parts that were replaced every 96 hours, found a larval mortality of 80% for rice, 5% for maize and 35% for sugarcane.

High larval mortality was also observed in my laboratory studies when larvae were reared individually in rice stem parts and seedlings (see also Section 3.2.2.2.). Larvae were thriving till the 5th or the 6th instar but thereupon became sluggish and died.

Larval mortality was further studied in the laboratory by infesting screened rice plants with newly hatched larvae. From four rice hills of one hundred days old, each infested with 150 larvae, 64% of the larvae, 97% of which were alive, could be recovered after 3 days. Reduction in numbers was undoubtly due to losses during dispersal.

Larval mortality increases with time. Rice, one hundred days old and infested with young larvae, contained 59% of the original number of larvae (50 L_1/hill) of which 92% was alive when examined after 10 days. Table 24 shows the inoculation results after 25 days for rice of different age-groups. The percentage recovery ranged from 35–54.

Finally sampling activities in the field (September-December 1971) yielded mortalities ranging from 8–29% for the different instars (Table 27). Disease could also have contributed to these percentages, but no exact data can be given in this respect.

TABLE 27. Larval mortality in *D. saccharalis* under field conditions (September-December 1971). Data based on 20–45 individuals/instar/plot.

Instar	1	2	3	4	5	6
plot 1	29	17	27	8	15	19
plot 2	14	16	19	23	19	19

Several dead larvae did not show any external disease symptoms. Cadavers of others were flaccid and contained a milky white to yellowish haemolymph. Hard, dry, brown cadavers were also found.

Actual cannibalism has been observed only incidentally; a L_5 was once detected while consuming a living L_4.

Cannibalism may eventually prove to be an important reduction factor. After artificial infestation of rice stems with L_1 larvae, 5 or more larvae are often recovered together in one internode. However, not more than one pupa has ever been found per internode, and per stem only one pupa is present as a rule.

This suggests that all but one larva have been killed and probably eaten.

To summarize, the early larval mortality I found was less than that mentioned in the literature for sugarcane. The total larval mortality on rice is very high when the larvae are reared on stem parts or in dense cultures on plants.

3.4.3. *Pupal mortality*

Pupae collected from potted rice plants infested at different age intervals were stored to ascertain the percentage eclosion. Results have been summarized in Table 24. From these data it follows that under laboratory conditions, the total pupal eclosion (i.e. moth emergence) decreased as the food plant, in which the larvae developed, grew older.

Pupal mortality under field conditions reached an overall level of 50–60%, with 41% as a minimum.

In contrast to this rather high mortality, pupal mortality in specimens reared on the artificial CELOS-diet was almost nil.

Based on laboratory observations on maize, HRDÝ et al. (1968) reported a mortality of 54% in the female pupae and 60% in the male. KATIYAR (1960), working with sugarcane under laboratory conditions, obtained the much lower overall mortality of 10%.

3.5. PARASITES

Parasites of the lepidopterous stem borers may play an important role in the mortality of these moths. In the neotropics much attention has already been paid to the egg parasites (*Trichogramma* spp., see JEPSON 1954). The same holds for the Tachinid flies as parasite of the larvae (BENNETT 1969, 1971).

Since this field of research has hardly been touched in Surinam, attention was focused on the natural enemies of *D. saccharalis* present there. Because nothing was known about the importance of the hymenopterous parasites of *D. saccharalis* larvae I especially concentrated my investigations on this group.

3.5.1. *Egg parasites*

Two not yet fully identified egg parasites are known from Surinam, viz. *Trichogramma* c.f. *fasciatum* (PERKINS), belonging to the family Trichogrammatidae, and *Telenomus* sp., belonging to the family Scelionidae.

Both wasps occur in the same area and often jointly attack a *Diatraea* egg mass. *Trichogramma* sp. proved somewhat more numerous than *Telenomus* sp. For both species the life-cycle from egg to adult lasts 8–10 days.

In general the percentage of parasitism increases during ageing of the rice fields where *D. saccharalis* is active. From the first laid egg clusters only a few are parasitized, whereas of the final clusters nearly all were attacked by parasites. A total of 30–50% of the eggs per field become parasitized as a rule.

Incidental gregarious parasitism has been noticed. *Trichogramma* specimens reared from an egg mass a few times outnumbered the eggs present.

3.5.2. *Larval parasites*

Larval parasites of *D. saccharalis* so far detected during my studies either belong to the hymenopteran family Braconidae or to the dipteran family Tachinidae. They are the Braconids: *Agathis stigmaterus* (CRESSON), *Iphiaulax grenadensis* (ASHM.) and *Iphiaulax* sp.; the Tachinids: *Leskiopalpus diadema* (WIED) and *Metagonistylum minense* (TWNS.)

Of these Braconids, the two first mentioned species were already reported from *D. saccharalis* in rice fields in Surinam (VAN DINTHER 1960a, ZWART 1969), *A. stigmaterus* turns out to be the only common species. Detailed information will therefore be limited to this parasite (see Section 3.5.4.).

Since the two Tachinids listed were reared from the larvae of *D. saccharalis* in rice in very low numbers only, no further attention was paid to these parasites.*

* From a *L. diadema* pupa 49 *Trichopria* sp. (fam. Diapriidae) were once reared.

However, a future study of *L. diadema* seems interesting when its frequent occurrence in *D. saccharalis* originating from *Echinochloa polystaga*, a common aquatic grass, is compared with its presence in *D. saccharalis* in rice. Biotope differences undoubtedly play an important role.

The presence of *M. mimense*, the 'Amazon Fly', in Surinam is an intriguing one. The species was first recorded by VAN DINTHER (1960a) who reared the fly from *D. saccharalis* larvae, collected in the 'Wageningen Rice Scheme', West Surinam. I again reared this parasite in limited numbers from this borer, in the same 'Rice Scheme'. Outside this area the fly has never been found. It is supposed that the Tachinid since its introduction from Brasil into the sugarcane areas in Guyana (see MYERS 1934; BENNETT 1969), has spread into the neighbouring rice area of West Surinam but failed to enlarge its territory.

3.5.3. *Pupal parasites*

ZWART (1969) reported *Spilochalcis* sp. (fam. Chalcididae) as an occasional pupal parasite of *D. saccharalis*. In the meantime this species was identified by Dr BURKS as *S. dux* (WALKER) (ZWART, pers. commun.).

During my field research *S. dux* was detected as a common pupal parasite of *Diatraea centrella* (MÖSCH.) in maize.

From D. saccharalis pupae collected from the CELOS rice fields another *Spilochalcis* species was reared in very low numbers. Its value as mortality factor is negligible.

3.5.4. *Agathis stigmaterus* (CRESSON)

Agathis stigmaterus has been recorded from *D. saccharalis* thoughout the humid tropics of America. BOX (1926) listed the species as one of the most important parasites of this borer in Guyana. Introduced on several occasions in Puerto Rico, viz. for the first time in 1924/1925, its parasitism in sugarcane fields in 1937 was 4.8% (see: MARTORELL and GAUD 1965). SCARAMUZZA (1932) reported 39% parasitism in rice fields in Cuba. MYERS (1934) mentioned the wasp as the main parasite of the Amazone region; though not common in sugarcane in Guyana, it proved abundant in grasses. In Florida *A. stigmaterus* has well been established in sugarcane since 1935, where local parasitism up to 68% has been reported (INGRAM and BYNUM 1941). In 1967, GIFFORT and MANN listed *A. stigmaterus* as the only larval parasite of *D. saccharalis* in Florida. MYERS (1932) blamed the dry climatic conditions that may prevail in certain periods of the year in the regions where the wasp has been introduced for the failure of its establishment. He also mentioned *D. lineolata* and *D. canella* as hosts of this parasite.

Although *A. stigmaterus* is a common indigenous parasite in several countries and has also been well established in a number of other regions, no further attention seems to have been paid to this beneficial insect during the last decade. The reason for this could have been that in general the role hymenopterous parasites can play as natural control agents of stem borers is not highly valued for the neotropics. In this respect BENNETT (1969) can be quoted:

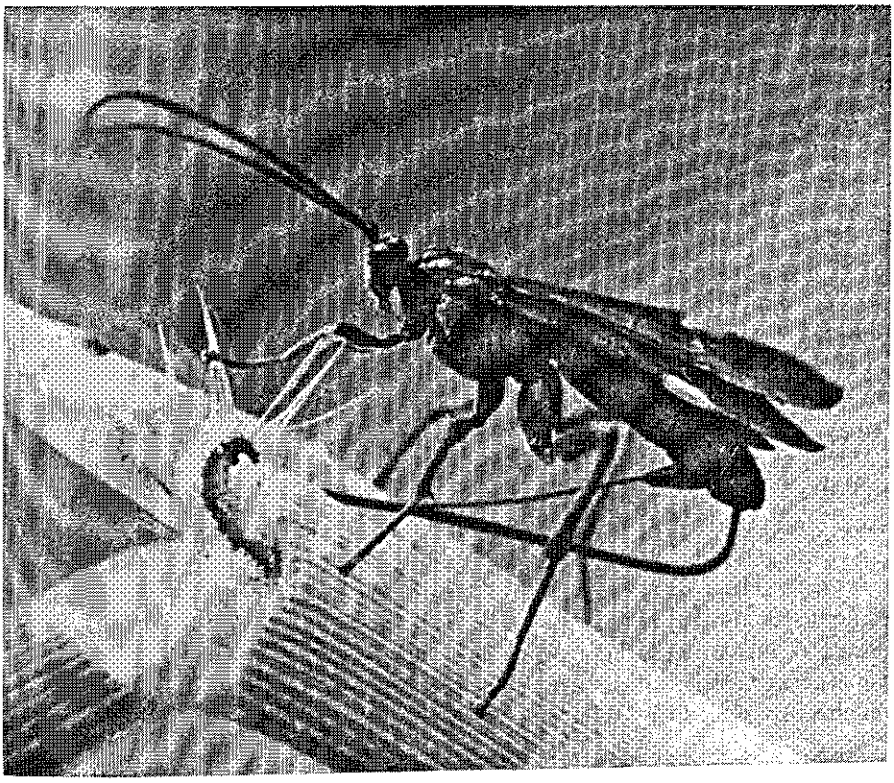

PHOTO 6. *Agathis stigmaterus* female, parasitizing.

'Tachinids are the most important larval parasites of sugarcane moth borers in the Americas, in sharp contrast to the old world where hymenopterous parasites predominate'. The question can be posed whether this view has been accepted because mass breeding of several tachinids has become a relatively easy standard technique since the work of SCARAMUZZA (1930). Anyhow, mass breeding of native hymenopterous parasites for the biological control of stem borers has never been reported in the Caribbean area. Since I think *A. stigmaterus* has the potency of a valuable natural enemy of *D. saccharalis* I paid special attention to this wasp, the results of which are given in the next sections.

Literature about the bionomics of *A. stigmaterus* is limited to a brief report by MYERS (1932). DONDALE (1954) mentioned many data about the related *A. laticinctus* (CRESSON) a parasite of the Eye-spotted Bud moth in the orchards in Nova Scotia. SIMMONDS (1943) described in detail the allied North American species *Bracon vulgaris* (CRESSON), which was formerly listed as *Agathis vulgaris* (CRESSON).

3.5.4.1. Materials and methods

Research into the development stages, the life history and the behaviour of *A. stigmaterus* was done on specimens that were reared in large numbers from host larvae originating from *D. saccharalis* stock culture.

The intial parent material was collected in the rice fields of the 'CELOS' experimental station.

Wasps were individually stored in vials (length 10 cm, diameter 2.5 cm) where they were provided with a drop of honey.

The following rearing techniques were tested:

a. Groups of 50–100 newly hatched *D. saccharalis* larvae were placed in a 100-ml Erlenmyer flask which contained 25 g of diet. After 6–14 days the larvae (nearly all L_2, L_3) were removed by rinsing with water and transferred to 2–3 cm long stem parts of maize or *Echinochloa pyramidalis*. Five to twelve of these stem parts, each containing one host, were placed in a plastic box of 10 × 6 × 3.5 cm in which one adult female was kept. Activity of the wasp was watched and after each oviposition, the attacked host was immediately removed and transferred in numbers of 5 to vials provided with 15 g of diet or it was left in the stem parts and sectioned after 5 days.

b. *D. saccharalis* larvae reared in plastic boxes or Erlenmyer flasks on the standard diet were exposed to *A. stigmaterus*. Though successful parasitism occurred, many of the larvae escaped to the searching activity of the wasp. Superparasitism, an unfavourable factor in my wasp rearing programme, was regular observed. Due to these circumstances method b was abandoned.

3.5.4.2. Eggs

Eggs present in the ovary are first pear-shaped and show a stalk-like extension; their total length is 0.13–0.16 mm. After the moment it is laid in a host larva, the egg becomes spherical and attains a diameter of 0.25–0.35 mm (Figure 24). This phenomenon of increase in egg-volume is quite common among parasitic Hymenoptera. Volume increase in some species may even reach a maximum of 1200 times (CLAUSEN 1962).

Eclosion of the *A. stigmaterus* egg takes place within a period of 3–5 days after oviposition; only very exceptionally were eggs found on the 5th day.

3.5.4.3. Larvae

The newly emerged endoparasitic larva is hyalinous and has a length of about 0.7 mm. It shows an armoured head (0.20-0.22 mm) and a body with 13 distinct segments which tapers to the posterior end where it terminates in a short tail. Segment 2–12 each bear a pair of ventro-lateral projections ('feet') (Figure 24).

The developing larva becomes more robust and obtains a whitish appearance. After 12–25 days, when a length of about 3 mm has been attained, the growth rate increases strongly. When about 6 mm long, the larva pierces the body wall of the caterpillar and leaves its host. From this moment onwards a very voracious extoparasitic feeding starts on the host larva that hitherto looked undamaged. Within a period of three hours the parasite reaches a length of

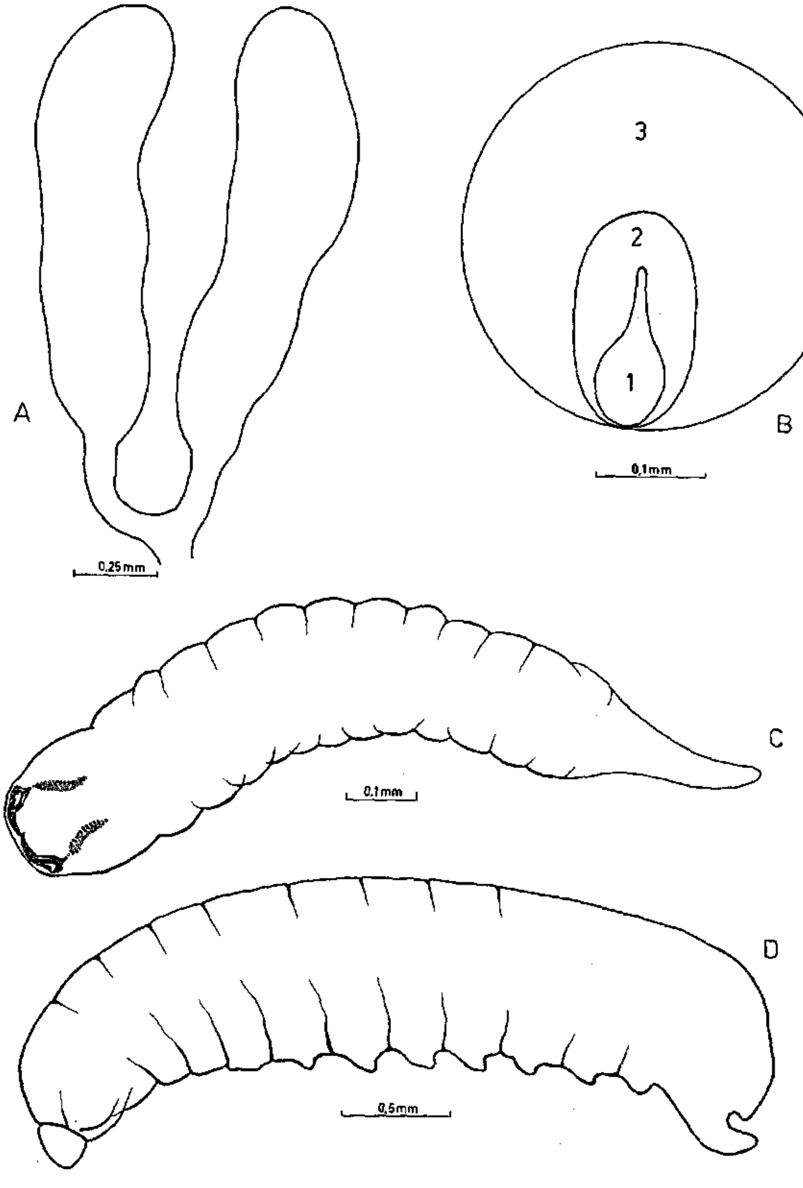

FIG. 24. *Agathis stigmaterus*, ovaries, eggs and larvae.
A. Ovary of 22-day-old female; oviposition has not yet started.
B. Eggs: 1. in ovary
2. 1–2 days old
3. full-grown, 3–5 days old.
C. Larva, about 4 days old, 1.1 mm.
D. Larva, about 17 days old, 3.6 mm.

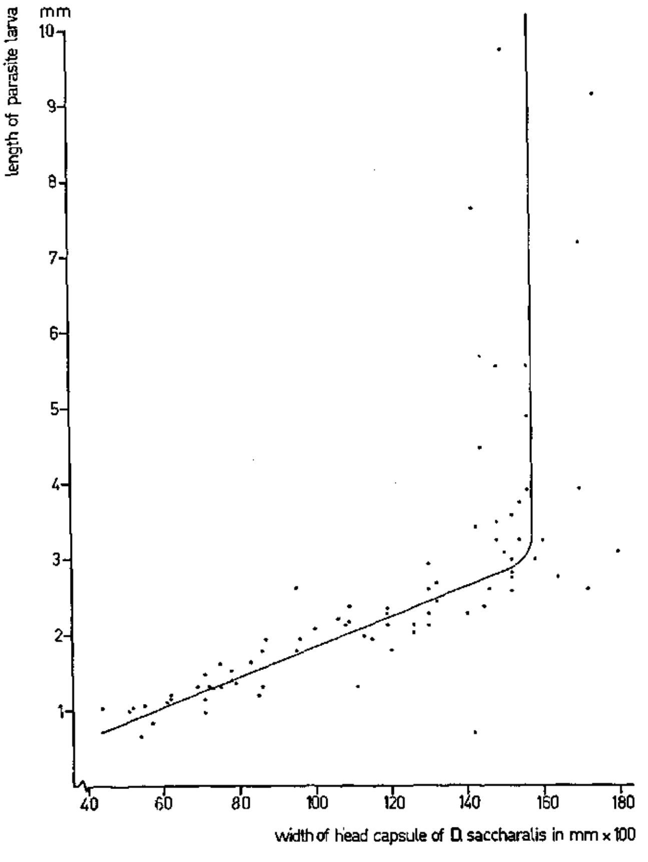

FIG. 25. Relation between larval length of *A. stigmaterus* and host size.

about 10 mm (Figure 25) and becomes light yellowish.

The mean total developmental duration of the larval and egg stage together is 24 days (range 16–80 days; n = 474). I did not observe a period of arrested larval growth as mentioned by SIMMONDS (1943) and ASKEW (1971). Neither could I confirm the information of PLANK (1929) that sometimes *A. stigmaterus* leaves its host after pupation.

Only one parasite develops from one host. Although up till 12 larvae were found in one host – high numbers are reached when only a few host are offered to a wasp – I never found more than one larva alive after some days.

3.5.4.4. Pupae

Pupation takes place within an almost cylindrical cocoon. The posterior end is round, the anterior end more truncated and filled at its top with fluffy, white silk threads. The whitish, transparent cocoon has the appearance and texture of tissue-paper and measures 17 by 3.5 mm (MYERS 1932).

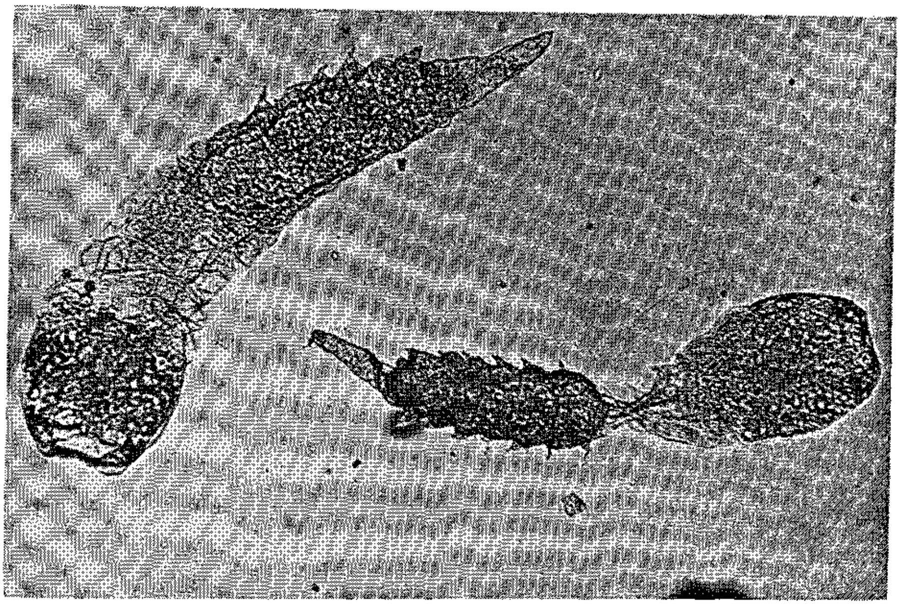

PHOTO 7. Two *Agathis stigmaterus* larvae, about one day old, recovered out of one host. One has destroyed the other. (Photo A. J. Jansen.)

The larva spins its cocoon in 1–2 days. After another 1–2 days a white pupa is formed. The wasp emerges 6.1 days (range 5–7 days; n = 53) later.

The mean total time from leaving the host till wasp emergence was 8.7 days (range 7–11 days; n = 160).

3.5.4.5. Adults

The adults are reddish brown, the head and abdomen being somewhat darker. The wings are more or less smoky and show a yellow stigma. The average lengths of body, ovipositor and antennae were 10, 11 and 7 mm, respectively.

Each ovary consists of 8 ovarioles which are surrounded by a red membrane (Figure 24).

The lifespan of wasps that were offered hosts daily, ranged form 6–19 days, with an average of 11 days (n = 27); when no hosts were offered adults lived 0–28 days, with an average of 14 days (n = 289).

3.5.4.6. Host-parasite synchronization

The total time of development of *A. stigmaterus* from egg to adult ranged from 23–90 days, but only in 4% of the cases was it longer than 50 days. The mean duration amounted to 31.5 days (n = 474).

The total life cycle of *D. saccharalis* which last about 40 days equals the life cycle of *A. stigmaterus* when the adult lifespan of the parasite is included. From this it is concluded that an adequate synchronization exists between host and parasite.

3.5.4.7. Sex ratio

Of some 660 *A. stigmaterus* adults reared in the laboratory only about 1.5% were males. From field samples another 230 wasps were reared of which 2% were males.

A. stigmaterus shows an obligate thelytoky; copulation was not be observed in those few cases where a male and a female wasp were placed together in a rearing cage. The unmated females produced also males, although these are rare and perhaps functionless.

Also in *A. diversicus* (MUESEBECK) males were almost lacking (ALLEN et al. 1940). About 48% of the reared *A. laticinctus* were females (DONDALE 1954). CLAUSEN (1962) said that in the Braconidae an exceptional number of species yield a preponderance of male progeny and that only a small number have a large majority of female progeny.

3.5.4.8. Searching and parasitizing behaviour

When searching for a host, the wasp moves over the stem, keeping the tops of the antennae slightly curved upwards. As soon as a stem perforation gnawn by the host is detected, the wasp inserts its highly movable and flexible ovipositor.

During oviposition the insect remains motionless, its antennae protruding straight forward. The actual time needed for egg-laying ranges from 8–50 seconds as a rule. Only very exceptionally does this period last 1–2 minutes.

Observations starting with newly emerged wasps kept in cages that contained maize stems infested by *D. saccharalis*, revealed that the searching and parasitizing activity started on the 3rd or 4th day of their stay in the cages. The number of consecutive searching and parasitizing rounds could be very large. Up to 113 in a four hour period were observed. However they were not always successful, as witnessed by the absence of an egg or larva on dissection of the host 5 days later. In one instance even all the final 18 rounds of a total of 73 proved to be failures. Sometimes in one oviposition act two eggs were laid (2% of the cases).

As to the sizes of the hosts fit to be parasitized it was found that there were no clear limits. In the laboratory, experiments remained confined to hosts of at least 5 days (L_2, 3–4 mm long), because recovery of younger and smaller larvae from the stem parts proved too tedious. In the fields parasitized second instar larvae were collected. There was no evidence of an upper limit, except that the big larvae were able to creep away from the ovipositor or bite it. When thus attacked the wasp hastily pulled back its ovipositor.

It was found that the wasp did not recognize hosts that had already been parasitized, but avoided stem parts she had walked over several times.

3.5.4.9. Egg production

The egg production capacity was studied by offering the wasps from the day of emergence daily as many hosts as they could parasitize. When the wasp did not parasitize during 15 minutes, it was removed and saved for the next day.

TABLE 28. Number of daily *A. stigmaterus* attacks on *D. saccharalis* larvae (L_2, L_3 in stem parts) during life-span of the wasp. (– = no hosts offered)

No. wasp	Day of life 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
1	0	0	0	0	0															0
2	0	0	0	0	0	0														0
3	–	0	0	0	0	0	0													0
4	0	0	0	0	0	0	0	0	0	0	0	0	0							0
5	0	0	0	0	7	0	0													7
6	–	8	5	0	0	3	1	6	0	1	0									24
7	0	0	15	10	0	0	0	0	–	–	–									25
8	0	0	0	26																26
9	0	0	0	26	6	1	0	5	0	0	1	0	0	0	0					39
10	0	0	0	12	21	8	0													41
11	0	0	1	1	10	5	17	9	0	0										43
12	0	0	0	0	2	21	13	10												46
13	0	0	0	2	10	9	5	1	11	8	7	9	2	2						66
14	0	0	0	0	0	0	16	2	13	4	0	9	–	6	8	1	1	2	10	72
15	0	0	0	0	0	0	3	–	39	11	21	1	0	2						77
16	0	0	0	37	36	13														86
17	0	0	0	0	0	3	2	7	–	0	–	8	38	14	19	3	0	1	0	95
18	9	0	2	4	1	1	0	79												96
19	0	0	4	29	20	21	3	8	13	1	7	–								106
20	0	0	0	55	40	20														115
21	0	0	0	37	49	17	20	25	3											151
22	0	0	0	29	19	56	44	29												177
23	0	0	0	0	59	92	49	0												200
24	0	11	15	31	20	21	1	40	69											208
25	0	31	35	13	33	9	8	77	5	–	–	–								211
26	0	0	37	21	37	20	43	53												211
27	0	0	0	1	64	13	18	129	escaped											225
28	0	0	57	69	85	16	15	0	13											255
29	0	0	0	0	9	56	60	62	12	–	–	–	87	0	1	0	0	0		287
30	0	0	0	73	36	77	90	15												291
31	0	3	0	0	62	5	10	9	84	58	83	–	–	–	0	0				314
32	0	0	0	29	12	7	19	49	77	1	129	103	50	63	89	66	0			694

The hosts were either reared in groups of 5 on an artificial diet or kept in the stem parts. In the last case they were dissected after 5 days.

Part of the data collected during the work are given in Table 28. Four of the 32 wasps studied (12%) did not parasitize at all. Each of the remaining 28 performed on the average 150 times the searching and parasitizing behaviour.

Table 29 gives information on the egg production as ascertained by dissection of the hosts of 18 parasitizing wasps. Not considering the dead and lost hosts, 71% of all living host larvae were actually parasitized. If we assume that the parasitizing percentages of the dead, lost and living hosts were identical, the average wasp performed 104 successful acts of parasitizing, thereby laying 107 eggs. The highest egg production by one wasp amounted to 230.

Rearing the parasitized host larvae in groups of 5 on an artificial diet proved difficult (Table 30). More than half of them died before pupation or emergence of a parasite. Of the remaining hosts 71% were parasitized. Many *A. stigmaterus* died after leaving the host, mainly because they were destroyed by the other *D. saccharalis* larvae in the group. Therefore the number of hosts per vial should have been smaller to obtain an optimum production of parasites.

The daily egg production varied strongly (Table 28). There was no difference in the degree of success of the act of parasitizing between the start and the end of the oviposition period.

TABLE 29. Egg production of *A. stigmaterus*. Data obtained by dissecting *D. saccharalis* larvae 5 days after being attacked.

Number of parasites studied	18		
Number of larvae attacked	2574		
Number of found progeny	1752		
Data of larvea attacked:			
Dead	6%		
Lost	3%		
Living	91%		
living larvae containing:		1 living parasite	63%
		2 parasites, usually one alive	2%
		1 dead parasite	6%
		no parasite	29%

TABLE 30. Egg production of *A. stigmaterus*. Host larvae attacked while in stem parts were immediately transferred to the standard diet.

Number of parasites studied	10	
Number of larvae attacked	1614	
Data of larvae attacked:		
dead larvae		58%
emerged moths		12%
dead parasites (full-grown larvae and pupae)		6%
emerged parasites		24%

According to DONDALE (1954), *A. laticinctus* may parasitize as many as 15–20 hosts, laying one egg per host. He mentioned that 48% of the reared wasps were females. Thus a female has a progeny of not more than 10 females.

3.5.4.10. Discussion

A. stigmaterus, being well adapted to its host was observed in all rice growing areas in Surinam. Also in other countries this wasp is common. Mass breeding followed by field release of this parasite is likely to yield good results against *Diatraea* spp. As the number of ovipositions per day varies considerably and heavy superparasitism occurs, mass breeding could be performed as follows. A few wasps older than 3–4 days confined in a cage measuring about 50 × 40 × 40 cm are provided with host larvae in stem parts of maize. A person working with his arms through sleeves that give access to the cage continuously replaces the parasitized material. After several days the host larvae are transferred to an artificial diet, awaiting the emergence of the adult parasites. This method is equally or less time-consuming than the rearing technique of tachinids which is practised in a number of neotropical countries.

3.6. PREDATORS

In the Paramaribo area the group of the predators of *D. saccharalis* seemed to be limited to the ladybird beetle *Coleomegilla maculata* (De Geer) (Coccinellidae) and the ant *Paratrechina* (*Nylanderia*) sp. (Formicidae).

3.6.1. *Coleomegilla maculata* (DE GEER)

SZUMKOWSKI (1952) who studied *Coleomegilla maculata* under laboratory conditions, listed this ladybird beetle as an important predator of eggs and larvae of *D. lineolata* and other insects in Venezuela.

I rarely found this insect in rice fields of the Paramaribo area. In the laboratory the beetle was very voracious. Usually a single individual consumed daily more than 90 *D. saccharalis* eggs for several consecutive days.

3.6.2 *Paratrechina (Nylanderia)* sp.

In the literature ants were frequently mentioned as predators of *D. saccharalis*. In Puerto Rico, WOLCOTT and MARTORELL (1937) found that *Monomorium carbonarium ebinium* (FOREL), nesting in the leaf sheaths and old burrows of *D. saccharalis*, is an important egg predator. According to MEADOWS (1938) an unidentified ant eats both eggs and larvae but especially pupae of *D. saccharalis* in maize and sugarcane in Lousiana. Also in Louisiana, HENSLEY et al. (1961) and NEGM and HENSLEY (1969) showed that application of heptachlor against *Solenopsis saevissima v. richteri* (FOREL), the annoying fire ant, reduced the beneficial natural enemy complex of *D. saccharalis* so that borer infestation increased. HENSLY et al. (1961) and NEGM and HENSLY (1967) mentioned *Paratrechina* sp. (Formicidae) as one of the predators in cane fields.

In the CELOS rice fields *Paratrechina* (*Nylanderia)* sp. was a common predator of young *D. saccharalis* larvae.

3.6.2.1. Life cycle

Ant nests, made of clay and organic material are constructed between the stems of a rice hill, just above the water surface. A change in water level caused the ants to move their nests; eventually they may nest in soil cracks when plots became dry. Some nests were small and situated between the leaf sheaths, whereas others, occupied nearly all the space between the stems of a rice hill, and were more than 10 cm high.

In recently planted lowland rice plots only workers were observed, single or in groups of only a few individuals. Several weeks after transplanting the first small nests occurred. At first these nests contained rarely or never males. However, at maturity of the crop males were present in all nests. Only once was a winged queen found.

It was not clear whether a hill contained more than one nest or one nest more than one queen. When the ants extracted from one hill were placed together in an artificial nest of plaster, often 2–3 queens were found together.

In these artificial nests both eggs and young larvae of *D. saccharalis* were offered. The ants immediately caught the larvae but hardly ever took notice of the eggs.

An inventory of the ant colonies was made for a number of hills in maturing rice fields. As shown in Table 31 ant numbers per hill varied considerably, and were not determined by the size of the hill.

TABLE 31. Numbers of ants, *Paratrechina* sp., per hill in a mature rice field.

hill	egg	larvae	pupa	male	worker	queen	total per hill
1	48	106	98	89	92	–	433
2	658	219	310	20	317	2	1526
3	–	270	–	72	201	1	544
4	2079	1733	834	111	787	7	5551
5	–	149	–	96	84	–	329
6	–	113	1	16	34	1*	165
7	–	55	–	36	34	–	125
8	–	–	–	29	10	–	39
9	406	409	1	51	155	3	1025

* winged queen

3.6.2.2. Fluctuations of numbers

Ant counts were made both at the 'CELOS' experimental station and in two small holders' rice plots nearby. Ant nests containing eggs and/or larvae and/or pupae were registered. On the 'CELOS' station two plots (A and B) were checked weekly. Each survey included about 850 hills. In two small holder plots (C

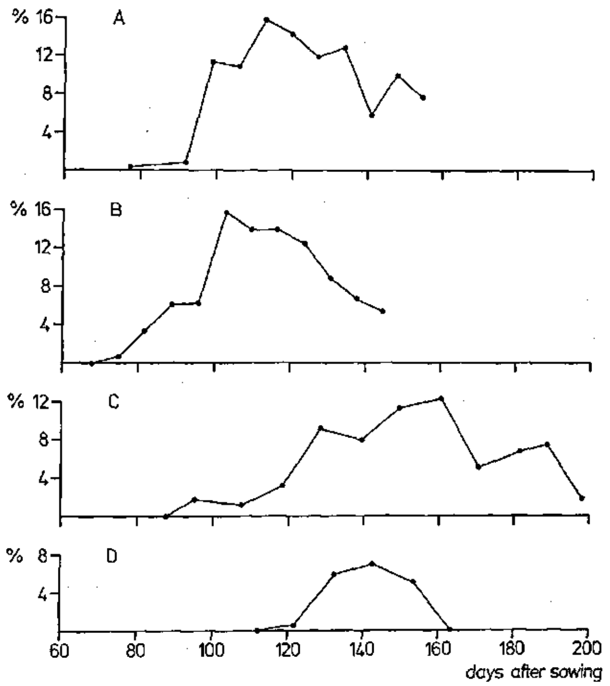

FIG. 26. Percentage of rice hills (variety Holland) with ant nests. Plot A, B: experimental station. Plot C, D: small holder fields.

and D) about 450 hills were searched for ants every 10 days. The results are presented in Figure 26. In the plots A and B colonization clearly started at the border, about 10 weeks after sowing. The colonization of plots C and D began much later probably because of the smaller size of the hills at their early stages.

The data for the experimental station were all obtained between September 1970 and February 1971. No other surveys were made until September 1971 when it became evident that the ant population had completely disappeared. According to monthly observations after that date, which were continued until November 1972, ants remained absent, although crop and soil were never treated with pesticides. A survey of small holders' rice fields in August 1972, however, showed many ant infested hills.

3.7. IMPORTANCE OF THE BORER

The importance of *D. saccharalis* as a pest of sugarcane in the neotropics and the Southern States of the USA is well known from many literature data. In contrast to this, information on the occurrence of this borer in rice is far more limited.

For Louisiana DOUGLAS and INGRAM (1942) listed a total rice stem infestation of 32%, caused by two rice borers, one of which was *D. saccharalis*. In Venezuela, ANGELES (1960) observed a 20–25% infestation of *D. saccharalis* in rice. In the 8000 hectares 'Wageningen Rice Scheme', Surinam, where two crops are grown annually, local *D. saccharalis* erruptions that remained limited to a number of fields do occur. Losses of 50% and over have been noticed especially during the first years after reclamation (DE WIT 1960). VAN DINTHER (1960b) studied the rice borer in this area during 1958/1959 and mentioned that the mean total infestation by *R. albinella* and *D. saccharalis* varied from 7–27% for the fields grouped in weekly intervals of the sowing period. The higher percentages referred to fields sown during the last weeks of the sowing period. He found a *Rupela/Diatraea* ratio of 22:1 during 1958 and he postulated that *Rupela* will far outnumber *Diatraea* in other years. VAN DINTHER (1971) reported that the following practices proved valuable in restricting borer damage in the Wageningen area: the separation of the periods of sowing and harvesting; stubble-burning and clean cultivation. Local eruptions, of *D. saccharalis* seem to occur randomly, making the prediction of the outbreak difficult and complicating chemical control.

Rice was cultivated continuously on ¼ ha at the 'CELOS' research centre during 1970, 1971 and 1972, and stem infestation was very low. The first year it was about 1½% and the last year not even 1%. Also in the small holder plots near Paramaribo the infestation was negligible (<1%). *D. saccharalis* was hardly ever found in samples I took in West Surinam.

My conclusion is that heavy stem infestations will be scarce and that the borer is not of economic importance in the small holder rice areas. It appears that the Surinam climate is too wet for *D. saccharalis* since I hardly found any in maize and sugarcane.

4. SUMMARY

In many tropical countries, lepidopterous stem borers are major pests of the rice crop. Study of the rice borers in Surinam, *Rupela albinella* and *Diatraea saccharalis*, was made in the Paramaribo area, at the experimental station 'CELOS' during 1971, 1972 and 1973, since data on the ecology and economic importance of these borers were incomplete and almost lacking for the small holders rice areas. Special attention was paid to the role of the parasites of these borers.

I. *R. albinella*

This 'white rice borer' deposits its scale-covered egg masses on the leaves. Newly hatched larvae disperse in a very active way both on plants and on the water surface and they may also use the flow of water. They bore into the stem cavity within 24 hours after hatching. Development to maturity takes place inside one internode. There are five larval instars and only the last two can not be separated by head capsule width. The full-grown larva cuts an exit opening in the stem wall for escape of the adult. The duration of the different developmental stages was determined.

Normally the percentage of larvae which entered diapause proved to be very low. It was not clear which factor was reponsible for diapause induction. A correlation with a slightly higher temperature (about 2 °C) was detected but the data are still too limited to accept the temperature as a basic factor.

Moths are active during darkness and are attracted by ordinary incandescent light, but are seldom captured during the period of full moon.

Since *Rupela* requires an adequate stem cavity for its development, rice plants become vulnerable to attack only 60 days after sowing when a proper internodal space may be present. Rice varieties having a total growth period of only 105 days automatically possess an 'escape resistance', because the larval and pupal development takes about 50 days.

Generally *R. albinella* is well adapted to the rice plant. Crop losses are very small since the stem tissue is only attacked superficially.

Four parasites of *R. albinella* were found, viz.:

1. *Telenomus* sp., an egg parasite with a short life cycle. This insect was not further studied.
2. *Venturia ovivenans*, an egg-larval parasite with a high reproduction capacity, parasitizes the eggs. The growth of the parasite larva is moderate until the host is full-grown. Rapid growth follows and the larva leaves its host and pupates inside the stem.

Development of host and parasite are well sychronized, both in non-diapause and diapause situations. The average time of emergence of the wasp is two days earlier than of the moth.

The species is very common throughout Surinam.

3. *Strabotes rupelae*, a larval and pupal parasite, deposits its eggs near the full-grown host larva or pupa. The wasp even crawls into the water in search for hosts. The ectoparasitic larva grows very rapidly and sucks out its host. The duration of the life cycle is one third that of the host. The adult life span may be as long as two months.

The parasite was quite common at the 'CELOS' research centre with its continuous rice cultivation program.

4. *Heterospilus* sp., a gregarious and ectoparasitic wasp, lays its eggs in the stem cavity near a full-grown host larva. Larval growth is very rapid and the total life cycle is one third of that of its host.

The parasite was common at the 'CELOS' research centre.

The interactions between *R. albinella* and its parasites are schematically given in Figure 15.

The greatest mortality occurs in the L_1 during dispersal and penetration of the host plant. Later on, the effect of parasites as well as pupal mortality are important.

The succession of the generations of the borer and its parasites under the 'CELOS' continuous rice cultivation system is given in Figure 18. Over a period of slightly more than two years, borer infestation slowly increased whereas parasitization of the borer slowly decreased. The percentage composition of the parasitic complex remained stable in these two years.

II. *D. saccharalis*

An existing aseptical diet for the 'brown borer' was improved and made it possible to rear large numbers of borers. The following good rearing results were obtained: total developmental time (35–38 days), pupal weights (males 75 mg, females 125 mg) and egg production (400 eggs/female). A clear correlation was found between pupal weight and egg production.

It was not possible to accurately separate the 6 larval instars by means of head capsule width. The behaviour of the larvae was followed. Moths emerged before midnight and sometimes copulated the same night. A male copulates once a night and at most, three successive nights. Copulation always occurs late in the night. The first eggs are laid the night after mating.

Larval and pupal mortality was very high under field circumstances.

Agathis stigmaterus was the only important parasite. It was reared in large quantities in host larvae feeding on the diet mentioned above. The wasp deposits its eggs in 6–14 day-old hosts. An average of 100 hosts were parasitized per wasp. The parasite first grows slowly; it then leaves the nearly full-grown host and sucks it out within a few hours. There is a good synchronization between the host and the parasite. Only 2% of the wasps were males.

Ant nests were present in about 15% of the rice hills. These ants, *Paratrechina* sp., feed on the young borer larvae.

Although *D. saccharalis* incidentally may cause some local losses, the overall damage is negligible.

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6. SAMENVATTING

In vele tropische landen behoren stengelboorders van de orde Lepidoptera tot de belangrijkste plagen van de rijst. Aangezien gegevens over de ecologie en het economisch belang van *Rupela albinella* en *Diatraea saccharalis*, de twee in Suriname voorkomende rijstboorders, onvolledig waren en voor de klein landbouw nagenoeg geheel ontbraken, werden beide boorders in de streek rondom Paramaribo op het 'Centrum voor Landbouwkundig Onderzoek in Suriname' (CELOS) gedurende de jaren 1970–1972 bestudeerd. Speciale aandacht is hierbij besteed aan hun belangrijkste parasieten.

I. *R. albinella*

R. albinella, de witte rijstboorder, legt met schubben afgedekte eihoopjes op de bladeren. De uitkomende rupsen verspreiden zich actief zowel via de planten als via het wateroppervlak, en maken daarbij ook gebruik van stromingen in het water van de sawah. Via de bladscheden boren zij zich in de stengelholte, waar ze na één dag aanwezig zijn. Het gehele verdere leven van de rijstboorder wordt in één internodium voltooid. Van de 5 larvale stadia die voorkomen, zijn de laatste twee niet met behulp van de kopkapselbreedte te onderscheiden. De rups die op het punt staat zich te verpoppen, vreet eerst een opening ('venster') in de stengelwand waardoor de vlinder de stengel kan verlaten. De duur van de verschillende ontwikkelingsstadia werd bepaald.

Het percentage rupsen dat in diapauze gaat is gewoonlijk zeer klein. Het is niet duidelijk welke factor de diapauze induceert. Er is een correlatie gevonden met een iets hogere temperatuur (ca 2 °C), maar de gegevens zijn te summier om de temperatuur als regulerende factor te kunnen aanwijzen.

De vlinders zijn 's nachts actief en worden door gewoon lamplicht aangetrokken; tijdens volle maan worden zij echter nauwelijks gevangen.

Omdat de rupsen voor hun ontwikkeling een stengelholte nodig hebben, zijn de planten pas ca. 60 dagen na zaaien geschikt om te worden aangetast. De larvale en pupale ontwikkelingsduur is ca. 50 dagen, zodat de rijstrassen met een totale groeiduur van slechts 105 dagen een 'ontsnappingsresistentie' hebben.

In het algemeen is *R. albinella* zeer goed aan de rijstplant aangepast. De veroorzaakte schade is slechts gering doordat het stengelweefsel alleen oppervlakkig wordt aangevreten. Opbrengstverliezen zijn gering.

Vier parasieten van *R. albinella* zijn gevonden, nl.:

1. *Telenomus* sp., een eiparasiet met een korte cyclusduur. Hieraan is verder geen aandacht besteed.
2. *Venturia ovivenans*, een 'ei-larve' parasiet met een groot reproductievermogen, die haar ei in een gastheerei legt. De parasietlarve groeit slechts langzaam tot het moment waarop de gastheerrups volgroeid is. Dan volgt een zeer snelle groei, waarna de gastheer verlaten wordt en een verpopping in de stengel plaats vindt.

De ontwikkeling van gastheer en parasiet zijn zeer goed gesynchroniseerd, ook wanneer de gastheer in diapauze gaat. De wesp komt gemiddeld twee dagen eerder uit dan de vlinder.

De parasiet is in geheel Suriname algemeen.

3. *Strabotes rupelae*, een larve- en popparasiet, die haar ei bij de volgroeide gastheerrups of pop legt. De wesp gaat zelfs onder water om haar gastheer te zoeken. Tijdens een zeer snelle groei zuigt de ectoparasitaire larve de gastheer leeg. De totale cyclusduur is ca. één derde van die van de gastheer. De levensduur van de volwassen wesp kan ruim twee maanden zijn.

De parasiet was zeer algemeen op het 'CELOS' onderzoek centrum met permanente rijstverbouw.

4. *Heterospilus* sp., een gregaire ectoparasiet, die haar eieren in de stengelholte bij de volgroeide rups legt. De larvale groei is zeer snel en de totale cyclusduur is één derde van die van de gastheer.

De parasiet was algemeen op het 'CELOS' terrein.

De interacties tussen *R. albinella* en haar parasieten wordt schematisch in Figuur 15 weergegeven.

Aantalsafname van de boorder wordt grotendeels veroorzaakt door de mortaliteit tijdens de verspreiding en het inboren van de L_1. Daarna spelen parasieten en popmortaliteit een grote rol.

De opeenvolging van de generaties van de boorder en de parasieten bij permanente rijstverbouw op het CELOS is schematisch in Figuur 18 weergegeven. Over een periode van ruim twee jaar nam de boorderaantasting langzaam toe en de parasitering van de boorder langzaam af. In deze twee achtereenvolgende jaren bleef de procentuele samenstelling van het parasietencomplex gelijk.

II. *D. saccharalis*

Voor *D. saccharalis*, de bruine boorder, werd een reeds bestaand aseptisch dieet verbeterd waarmee de volgende bevredigende resultaten werden bereikt: ontwikkelingsduur (35–38 dagen), popgewichten (mannetjes 75 mg, wijfjes 125 mg) en eiproductie (400 eieren/wijfje). Tussen popgewicht en eiproductie bestaat een duidelijke correlatie. Het dieet is geschikt voor de vermeerdering van de boorder op grote schaal.

Het gedrag van de rupsen werd nagegaan. De zes larvale stadia zijn niet of nauwelijks aan de hand van kopkapselbreedten te scheiden. De vlinders komen in de vooravond uit en copuleren voor een deel dezelfde nacht. Een mannetje paart éénmaal per nacht en maximaal in drie opeenvolgende nachten. Paring vond altijd tegen de morgen plaats. De eerste eieren werden gelegd in de nacht volgend op de nacht van paring.

Onder veldomstandigheden werd een hoge mortaliteit bij de larven en poppen waargenomen.

Agathis stigmaterus was de enige parasiet van belang. Zij werd in grote aantallen gekweekt op rupsen die op dieet leefden. De wesp legt haar ei in 6–14 dagen oude rupsen. Per wesp worden gemiddeld ruim 100 gastheren geparasiteerd. De larve, die eerst langzaam groeit, verlaat de bijna volgroeide rups en zuigt deze in enige uren geheel leeg. Er is een goede synchronisatie tussen gastheer en parasiet. Bijna 2% van de wespen zijn mannetjes.

In ca. 15% van de rijstpollen werden mierennesten aangetroffen. Deze mieren, *Paratrechina* sp., zijn roofvijanden van de jonge rupsen.

Hoewel *D. saccharalis* incidenteel plaatselijke schade veroorzaakt, is de totale schade te verwaarlozen.

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