Chilo partellus Swinh., C. orichalcociliella Strand (Lep., Crambidae) and Sesamia calamists Hmps. (Lep., Noctuidae) on maize in the Coast Province, Kenya

MITTEILUNGEN DER SCHWEIZERISCHEN ENTOMOLOGISCHEN GESELLSCHAFT
BULLETIN DE LA SOCIÉTÉ ENTOMOLOGIQUE SUISSE
Band 45 (1972) Heft 4

CHILO PARTELLUS SWINH., C. ORICHALCOCILIELLA STRAND (LEP., CRAMBIDAE) AND SESAMIA CALAMISTS HMPS. (LEP., NOCTUIDAE) ON MAIZE IN THE COAST PROVINCE, KENYA.

FREDERIC C. MATHEZ
Chemin de la Becque 50, 1814 La Tour de Peilz

A practical, easy and reliable method of distinguishing between *C. orichalcociliella* and *C. partellus* larvae was evolved. The best criterion is the presence of an anterior asetose tubercle on mesothorax, dorsal view, on *C. orichalcociliella* larvae which is absent on *C. partellus* larvae. The differences between the two Crambidae and *S. calamistis* are indicated in a table.

The study of some aspects of the biology of these three stalk borers on maize and sorghum was carried out from 1965 to 1969. During the main planting-to-harvest period (120 days for maize and 130 for sorghum starting in April), there are two peaks of the larval population, respectively 50 and 100 days after planting. The infestation starts very early and 100 % of the larvae are found in the funnel base 20 days after planting. This percentage decreases regularly as the stem elongates, is halved 30 days later, and nil at tasselling. No diapause was observed, but some larvae of the two main stalk borers *C. orichacociliella* and *C. partellus*, can stay alive and be active for more than 90 days on dry maize (in the field) or on soft young maize (in the laboratory). During the «dry» season (January to March), adults are still emerging from the dry old stalks of the maize planted for the second harvest of the previous year during the short rains (September to December). The wild tall Graminaceae shelter larvae all the year round and act as a reservoir during the dry season. The temperature which does not vary much, seems to be less important than the rainfall in determining the degree of infestation.

Unidentified bacterial, viral and fungal diseases are the most important factors limiting the larval populations while the parasites, mainly a *Trichogramma* sp., can kill up to 90 % of the eggs. Parasitism of larvae and pupae is usually below 10 %, although 8 larval parasites were identified.

Insecticide trials showed that is was possible to control 80 % of the stalk borers, but without obtaining a significant increase in the yield.

The conclusions of this study are that maize is unlikely to succeed in the Coast Province as a cash crop and if it is grown for local consumption, any money available must be used for weeding and the purchase of fertilizers.

I. MORPHOLOGY

It is a well known fact that a certain number of Lepidopterous larvae damage Graminaceous crops. Entomologists in various countries have already devoted considerable time to this problem. In East Africa, HARGREAVES (1939), COAKER (1956) and INGRAM (1958) in Uganda, DUERDEN (1953), SWAINE (1957) and WALKER (1961) in Tanzania, WHEATLEY (1961) and LA CROIX (1967) in Kenya, have studied some aspects of these pests, whereas NYE (1960) undertook a comprehensive study of the pests on Graminaceous crops in the three countries.

From 1965 to the beginning of 1970, the writer and his collaborators carried out, mainly at the Coast Agricultural Research Station, a study of the fluctuation of the stalk borer population damaging maize, which is the most important food crop in this part of Africa, and of the parasites of these pests. The three main species are (synonyms after BLESZYŃSKI, 1962, 1963; BLESZYŃSKI and COLLINS, 1962; BLESZYŃSKI private communication, 1969):

the Spotted Stalk Borer,	= *Chilo partellus* Swinh.,	
	= *C. zonellus* Swinh.,	
	= *Argyria lutulentalis* Tams;	Crambidae
the Coastal Stalk Borer,	= *Chilo orichalcociliella* Strand,	
	= *C. argyrolepia* Hamps.,	
	= *Chilotraea argyrolepia* Kapur,	
	= *Diatraea argyrolepia* Hmps.;	Crambidae
the Pink Stalk Borer,	= *Sesamia calamistis* Hmps.,.	Noctuidae

A second Noctuid, the Maize Stalk Borer *Busseola fusca* Fuller was found in the Taita Hills District, at Taveta (700 m) and Wundanyi (1500 m); so far, this a minor pest in the Coast Province.

Part I deals mainly with some aspects of the morphology of *C. orichalcociliella* and *C. partellus,* since *S. calamistis* is not only a minor pest, but also its eggs, larvae, pupae and imagines (WILLIAMS, 1953) are quite different from those of Crambidae (Table I).

This study required an easy and reliable method for the quick identification of eggs, larvae and pupae belonging to one of the two Crambidae species and found in dissected plants. No valid criteria for a proper identification of eggs were discovered; taking into account size, texture and colour of the *C. orichalcociliella* and *C. partellus* scale-like eggs it was decided to consider them as similar.

The two Crambidae larvae have very similar chaetotaxies, even if some differences in setal angles exist. WHEATLEY (1961) and LA CROIX (1967) consider that the two larvae cannot be separated. An easy and sufficiently reliable method was found, based on the following differences (setal nomenclature of HINTON [1946] was adopted):

1. On meso- and usually metathorax, dorsal view, an anterior asetose tubercle present (Fig. 1) . . . . *C. orichalcociliella*
– On meso- and metathorax, dorsal view, no anterior tubercle present (Fig. 2) . . . . *C. partellus*

2. On meso- and metathorax, lateral view, no asetose tubercle present posterior to the L2–SV2 line (Fig. 3). . . . . *C. orichalcociliella*
– On meso- and usually metathorax, lateral view, an asetose tubercle present posterior to the L2–SV2 line (Fig. 4) . . . . *C. partellus*

3. On first – seventh abdominal segments, lateral view, no asetose tubercle present posterior to the spiracle (Fig. 5) . . . . *C. orichalcociliella*
– On first – seventh abdominal segments, lateral view, an asetose tubercle present posterior to each spiracle (Fig. 6) . . . . *C. partellus*

For both, SD1 and SD2 are either on one or on two different tubercles.

Discussion

In order to determine these criteria and ascertain their validity for identification purposes, two individual breedings of 100 larvae each were checked every day until pupation or death of the larvae. All the 100 larvae of *C. orichalcociliella* showed on the mesothorax, dorsal view, 24 hours after hatching, the anterior asetose tubercle which in our view is their most characteristic feature, as compared to *C. partellus* larvae and 98 had this asetose tubercle on the metathorax. On the two remaining larvae, it appeared 24 hours later, before the first ecdysis. On *C. partellus,* the posterior asetose tubercle on the mesothorax, lateral view, appears on some larvae after the second ecdysis, *i.e.* approximately 6 days after hatching, but usually after the third ecdysis, *i.e.* about 9 days after hatching. In this instar, the posterior asetose tubercle on the metathorax, lateral view, begins to show.

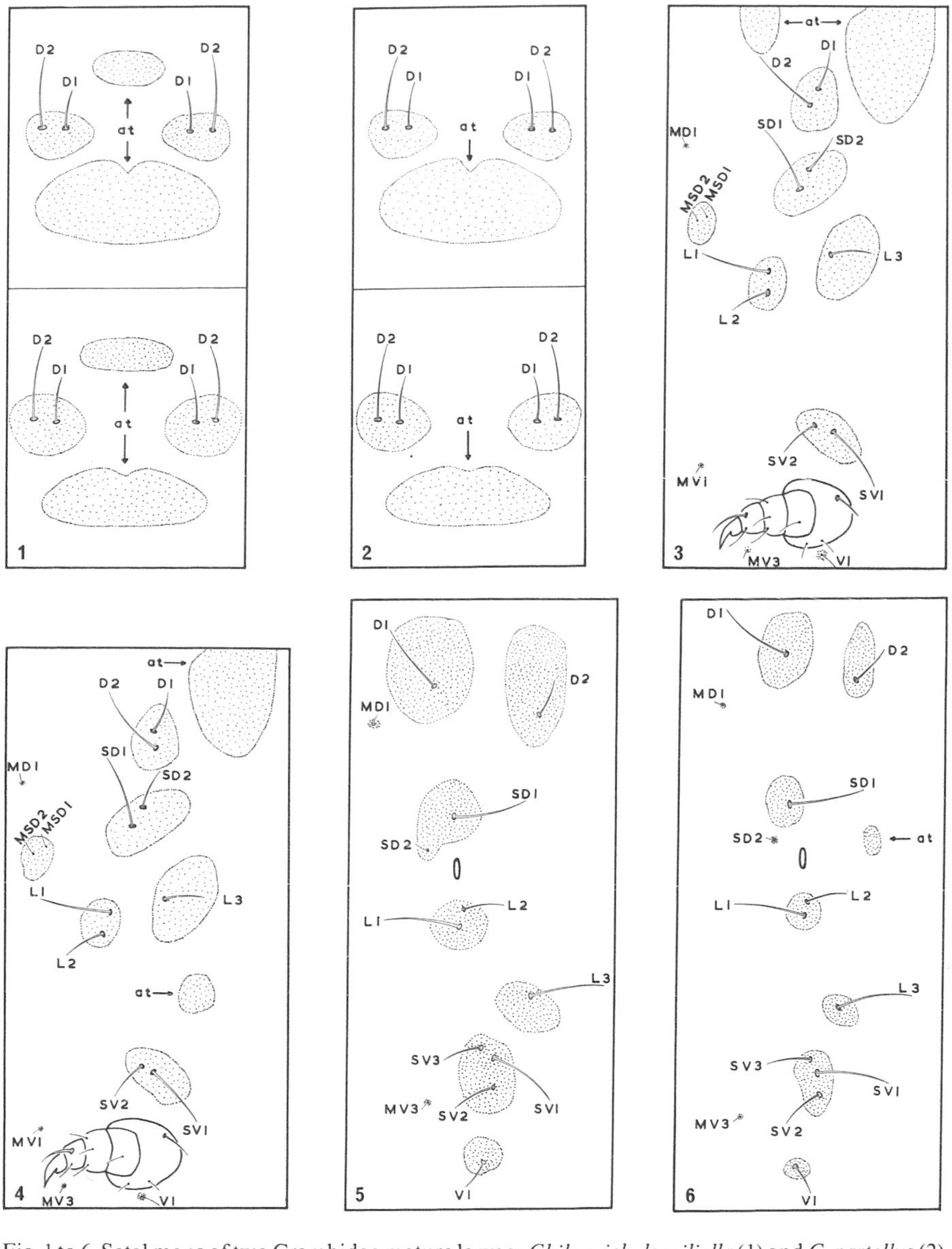


Fig. 1 to 6. Setal maps of two Crambidae mature larvae; *Chilo orichalcociliella* (1) and *C. partellus* (2) meso- and metathorax, dorsal view; *C. orichalcociliella* (3) and *C. partellus* (4) mesothorax, lateral view; *C. orichalcociliella* (5) and *C. partellus* (6) 1st abdominal segment, lateral view; at = asetose tubercle.

The asetose tubercles posterior to the abdominal spiracles also appear after the third ecdysis. Using the above criteria, over 200 larvae found on maize, sorghum of wild Graminaceae were identified and then kept in individual 8x2,5 cm tubes until the imago emerged. As it is very easy to distinguish *C. orichalcociliella* adults (with a golden margin to the forewing) from *C. partellus* adults (without a golden margin), checking confirms in 100% of the cases the correctness of larval identification. The only anomalies observed up to now, were found on *C. partellus* larvae on which, in some cases, the bilateral symmetry of the asetose tubercles on the meso- and metathorax or on the abdomen, posterior to the spiracle was not respected. A few larvae were found without one or many lateral asetose tubercles on one or both sides, mainly on some abdominal segments. Usually, the missing asetose tubercles appear after the next ecdysis and in most cases the larvae will have all of them after the 4th ecdysis, that is to say about 16 days after hatching. Those which do not have them usually die before pupating (the last ecdysis is not completed properly) or the pupal case is not well formed.

On very young Crambidae larvae, the anterior and posterior asetose tubercles on the meso- and metathorax, dorsal view, (Fig. 1 and 2), are often split in half by the mesial line. On mature larvae the two parts are very seldom still separated.

The method of identification used in this work is not always valid, because of the presence among the population of the two Crambidae of a variable number of whitish individuals. The tubercles, with or without the setae, are purple-brownish until pupation, which takes place usually up to 50 days after hatching; after this period, if the larvae do not pupate, the colour of the tubercles gradually disappears, until the whole body turns whitish and it therefore becomes impossible to identify the larvae according to our criteria. This extension of larval life, which MILNER (1967) calls a «temporary facultative resting stage», can last up to 3 months on the field and also takes place with larvae fed only on

Table I. *Comparison between the 2 Crambidae and S. calamistis*

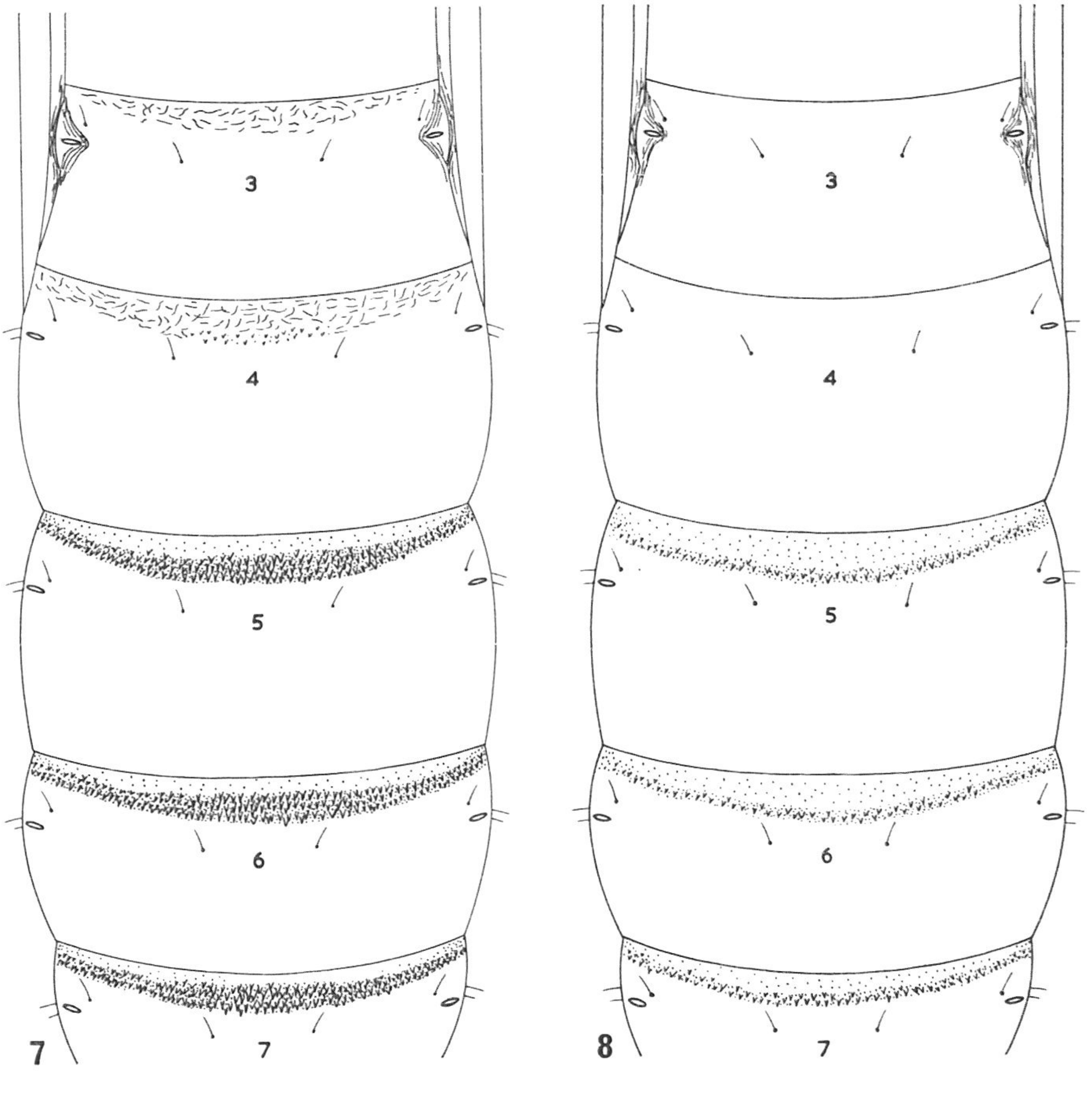
	C. orichalcociliella and *C. partellus*	*S. calamistis*
Eggs	scale-like	spherical with top flattened
Larvae		
colour	white with pourple-brown tubercles	pink
crochets on proleg*	triordinal circle uniserial	uniordial half-circle uniserial
Pupae		
colour	light brown	reddish brown
dorsal view	minute dorsal spines	no minute dorsal spines

* after Peterson (1962)

green and soft maize in the laboratory. Generally speaking, this type of larva does not seem to represent more than 5 % of the total Crambidae population on maize.

Nor is it easy to distinguish at first sight between the pupae of one species and the other. Although the minute spines present on the 5th, 6th and 7th abdominal segments, anterior region, dorsal view, are stonger and more numerous on *C. orichalcociliella* than on *C. partellus* pupae, this criterion has not been considered valid because it is too subjective; on the other hand, the *C. orichalcociliella* pupae are always lightly sculptured with sometimes a few spines on the 4th and 3rd abdominal segments anterior region, dorsal view, while *C. partellus* is quite smooth (Fig. 7 and 8). When approximately 80 pupae of the two species found on maize and sorghum were identified according to the above criteria and kept in separate tubes until the adults emerged, the identification proved 100 % correct.

7



8

Fig. 7 and 8. Pupae of *Chilo orichalcociliella* (7) and *C. partellus* (8), dorsal view.

II. BIOLOGY

In order to start a brood, larvae found in dissected maize are inserted into a hole bored in 10 cm maize cuttings and kept in breeding cages. Every 3–4 days, the food is changed and the new pupae are transferred into 8x2,5 cm tubes. The newly emerged adults are placed in a «Kilner» jar containing, against the inner surface, a paper cylinder on which the egg-masses are laid.The egg-masses are cut out of the paper and placed in dated tubes; 3 days later, 2 cm cuttings of young maize, taken at the funnel base, are added. This food is changed every morning. Thus, the larvae can eat, and in fact most of them do, as soon as they hatch out. Each larva that hatched during the past 24 hours is inserted into a small hole bored in a short piece of 7–8 weeks old maize stalk. Using this technique, and provided the larva is kept under observation during the few minutes following its transfer, it remains inside the maize.

Eggs and egg-masses

In the laboratory, the pre-oviposition period of the two Crambidae is 1–3 days and the females lay 200–300 eggs during 1–3 nights before dying. The scale-like oval eggs of *C. partellus* and *C. orichalcociliella* look alike; they are creamy-whitish and translucent. Their centre becomes brown (= head capsule of the young larva) about 36 hours before hatching; through the dissecting microscope, the chorion texture appears reticulated. JEPSON (1954) gives the following measurements of Crambidae eggs: 0,7 to 0,9 mm x 0,65 mm. In the Coast Province, the egg-masses of the two species are usually constituted by 3–6 overlapping imbricated rows and are laid on the leaves (about 70 %), under the leaves (25 %), on the upper external part of the leaf-sheath (5 %); on or under the leaves, they are mainly found close to the midrib. *S. calamistis* eggs, which are spherical, flattened on top and creamy-whitish, are always laid side by side on the inner side of the lateral upper part of the leaf-sheath.
For the 3 species, no egg-mass was found on the husk of the cob. In the field, the mean number of eggs per egg-mass is higher for *S. calamistis* (27 eggs) than for the Crambidae (18 eggs), but the extremes overlap for both full and empty egg-masses. In the laboratory, for 34 egg-masses laid by 5 females of both Crambidae species, the mean number of eggs was 26. Although the incubation period is shorter for *C. orichalcociliella,* being 4–6 days against 5–7 days for *C. partellus* (LA CROIX, 1967), the life-cycle of the former is longer.

Longer life larvae

One hundred larvae bred from 5 *C. orichalcociliella* pairs and one hundred from 4 *C. partellus* pairs were kept in individual tubes until the imagal stage. The 5 cm long and 7–8 weeks old maize cuttings were changed every day after a careful examination of the larvae and the newly-bored burrow, in order to search for any cast off skin and head capsule. The effect of daily handling on the larvae can be considered negligible; their larval life is perhaps extended by 1–2 days, as compared with the natural variations observed for the hatching-pupation period. The temperature was practically the same during both broods. The most important fact is the presence in 3 cases– *C. partellus* larvae which later became females and *C. orichalcociliella* larvae which became males and females – of larvae which have a much longer life span and in most cases more ecdyses (up to 9). These longer life larvae gradually start losing their tubercular pigmentation about 50 days after hatching and not suddenly after a particular ecdysis. A few whitish larvae of both species were found, for instance in 1966, on very old maize and sorghum respectively 150 and 130 days after the last full egg-masses had been seen on the leaves. These egg-masses were laid about 120 days and 140 days after planting of maize and sorghum respectively. Pant, Pathak and Pant (1962) noticed that *C. partellus* larvae survive differently if fed on different varieties of maize. In the Coast Province, the «P.P.» maize, the «Serena» sorghum and some wild Graminaceae shelter longer life larvae; furthermore, the age of the food does not seem to affect greatly the larval life of the two Crambidae. In both broods, a few larvae fed exclusively on 7–8 weeks old maize remained alive for a very long period (4 larvae pupated after more than 80 days; maximum 98 days). As the larval life extends, the feeding activity diminishes, not only on dry old maize and sorghum, but also on soft young ones. However, since feeding and moulting continue at least in the laboratory, the longer life larvae cannot be considered as having a diapause. In the laboratory and in the field, the pupation period does not seem to be affected by the length of the larval life. All adults of 64 pupae, found on maize stalks over 200 days old, emerged in the laboratory, within a maximum of 9 days; the pupation period is the same for longer life larvae collected from these old stalks and then bred in tubes. In the field, it is hard to assess the percentage of longer life larvae, because pupation takes place at any time, and it is difficult to distinguish between normal and longer life larvae, except by considering the colour of the tubercles. On a 50 stalk sample, taken say 100 days after harvest, all the larvae found will be longer life and the percentage 100. But considering the overall larval population feeding on 50 plants, ranging from 15 days after planting to the complete destruction of the stalks, perhaps only 5 % are longer life larvae.

At the end of 1969, longer life larvae were collected on dry maize, 80 days after the harvest, and kept up to the imagal stage in the insectary; out of this population, 7 mass broods, 3 of *C. orichalcociliella* and 4 of *C. partellus*, showed that the percentage of longer life larvae did not increase in the first generation, when the parents were longer life larvae, collected when whitish in colour and over 75 days old.

Larvae

On average, larvae of future males tend to have fewer ecdyses and shorter larval lives than future females. The *C. partellus* larvae which will become females have roughly the same larval life and the same number of ecdyses as the *C. orichalcociliella* larvae which later became males. Theoretically, for both species, perhaps half of the males cannot mate, because they start emerging about 10 days earlier than the females, but in fact this gap is of little importance for the Crambidae population, since males and females fly practically all the year round.

During breeding experiments, cases of semi-ecdysis (casting of the skin only, while the head capsule remains; the opposite is exceptional) were observed from time to time; two ecdyses in less than 48 hours may also occur.

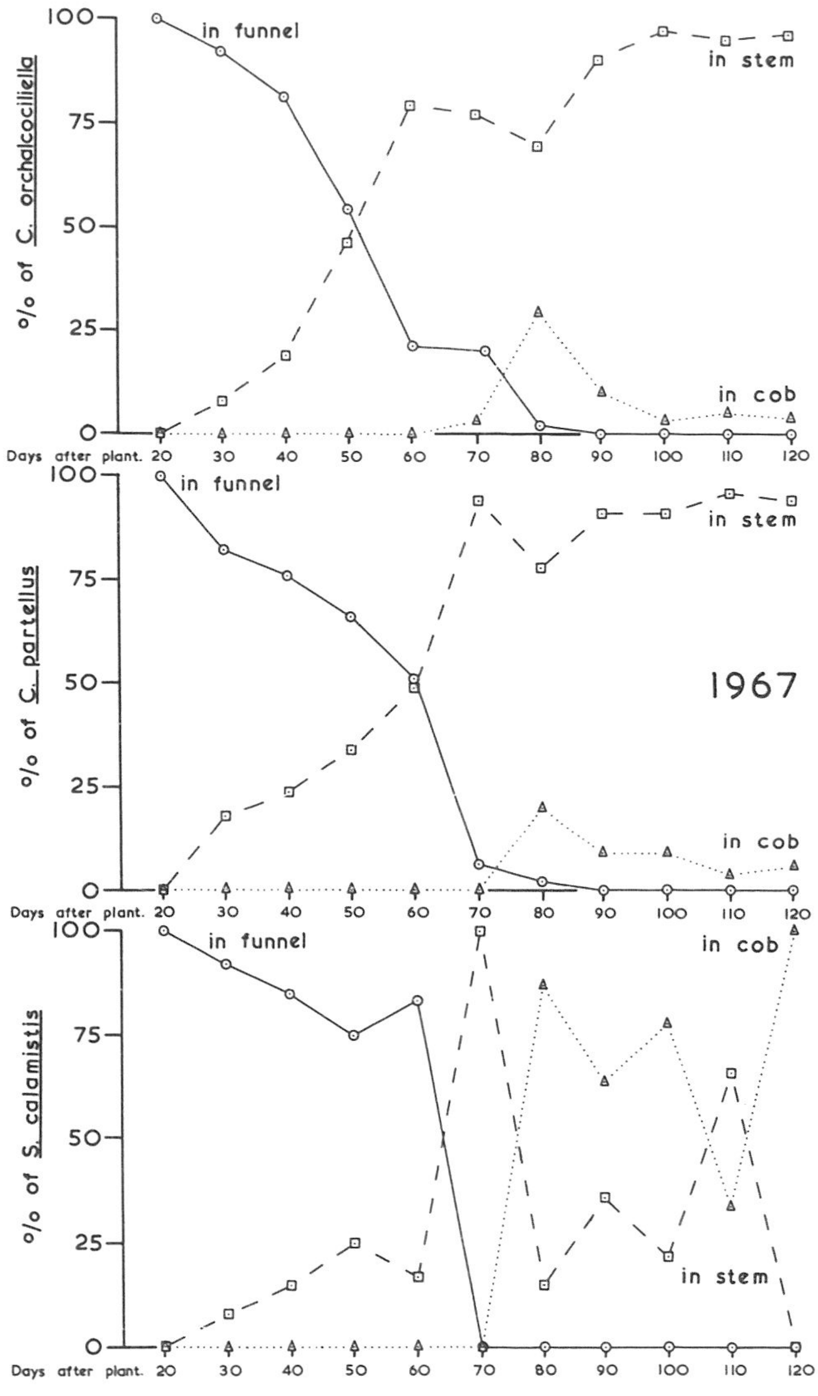


Fig. 9. Distribution of 3 stalk borer larvae on 50 maize plants up to harvest; average for 4 samples of 50 plants at 10 days intervals.

In broods, newly hatched out larvae feed well on yellowish cuttings of maize, taken at the funnel base, and in most cases the very young larvae start to feed immediately. In the field, on young maize and sorghum, a leaf to funnel migration takes place after eclosion. The larvae of all 3 species move from the leaves, or for *S. calamistis,* from under the sheath into the funnel base of the plant. On maize, very few larvae feed on the midrib or under the sheath; on sorghum however, the larval population damaging these two parts of the plant is higher. A comparison between the number of empty unparasitized eggs found on the plants and the number of living larvae, shows that up to 100% of the larvae may disappear during the migration from the leaf to the funnel or to the stem, when climatic conditions are unfavourable. The rain, by washing away the larvae, seems to be the main factor reducing the stalk borer population during the first instar.

Almost all the larvae found 20 days after planting are in the funnel, and about 30 days later 50 % of them are still there. The 3 species show the same behaviour (Fig. 9), although the number of *S. calamistis* larvae is much lower than that of *C. orichalcociliella* and *C. partellus.* Feeding on the yellowish rolled up leaves at the funnel base , the larvae cause 2 types of damage: either they bore right through practically all the leaves, leaving a hole that is perpendicular to the plant axis, or they eat one epidermis and the parenchyma, often leaving the other epidermis intact; when these leaves spread out, they have either small holes and/or «windows», parts of the leaf where, usually, only a transparent epidermis remains. The tassel or male inflorescence, is also damaged; in the funnel, peduncles, pedicels and staminate spikelets are eaten, but pollination does not seem to suffer. From 20 to 30 days after planting up to tasselling, about 40 days later, the percentage of larvae in the funnel decreases, because the first arrivals have moved into the stem and because more and more of the newly hatched larvae do the same. Very few mature larvae and no pupae of the 3 stalk borers were found in the funnels. The cobs become more or less heavily infested 60–70 days after planting (Fig. 9). After five years of observations and despite a usually extremely low population of *S. calamistis,* there can be no doubt that the larvae of this species are more attracted by the cob than by the stem. At the early stage of cob growth, some styles (= silks) and female spikelets are destroyed, and later the formation of seeds is disturbed by larvae boring holes into different parts of the cob.

At harvest time, about 120 days after planting, the stalk borer population in the cobs may still be important. Between the middle of June and the middle of August 1965 (harvest), rainfall was below average, and more stalk borers went into the cobs later than in a normal year; at harvest time, about 40 % of the larval population were in the cobs and in the axillary branches supporting the cobs, against 8 % in 1967 and 14 % in 1968.

From silking, 70 days after planting, to harvest the larval population in the stalks can be divided into two groups: larvae found below the cob and larvae found above it; the results, based on 750 dissected plants, show a fifty-fifty distribution. After harvest, the stalks dry and rot; naturally they do not fall simultaneously. There are more larvae on the erect stalks, because the fallen stalks are more rotten and the ants more numerous on them. In 1966, 4 longer life larvae were found on 50 very old maize plants, lying on the ground and planted 269 days earlier.

Sampling and results

The trials concerning the stalk borer population were carried on from 1965 to 1969 and their fluctuations were established from observations made on maize, sorghum and wild Graminaceae. The food crops were planted sometimes twice a year; sampling started about 15 days after planting and a variable number of 50 plant samples were taken at random every 2–4 days. The figures obtained during 10 or 15 days were therefore added and divided by the number of samples collected during this period. In the present work, each figure or point represents 50 plants and constitutes a mean of a certain number of dissected samples. For every dissected plant, any information concerning all three species was recorded: number of eggs and egg-masses, full or empty, parasitized or not; number of living or dead larvae, parasitized or not, and on which part of the plant (funnel, tassel, midrib, cob, stalk) they were found; number of full or empty pupae parasitized or not and where they were found. The same information was collected for the parasites.

A two year experiment

From 15th April 1965 to 15th April 1967, 1/80 hectare plots of maize were planted twice a month , *i.e.* on 15th and 30th. These plots were watered when necessary and always fertilized. One sample of 50 plants was dissected 46, 48, 53 and 55 days after planting and thus the average of eggs and larvae at 50 days was established. Full eggs, parasitized or not, were found practically all the year round for Crambidae, while *S. calamistis* eggs were not present in June, at the beginning of July and in October 1965 nor during May–June 1966 and 1967 (Fig. 10). *C. orichalcociliella* larvae were always present; *C. partellus* were practically

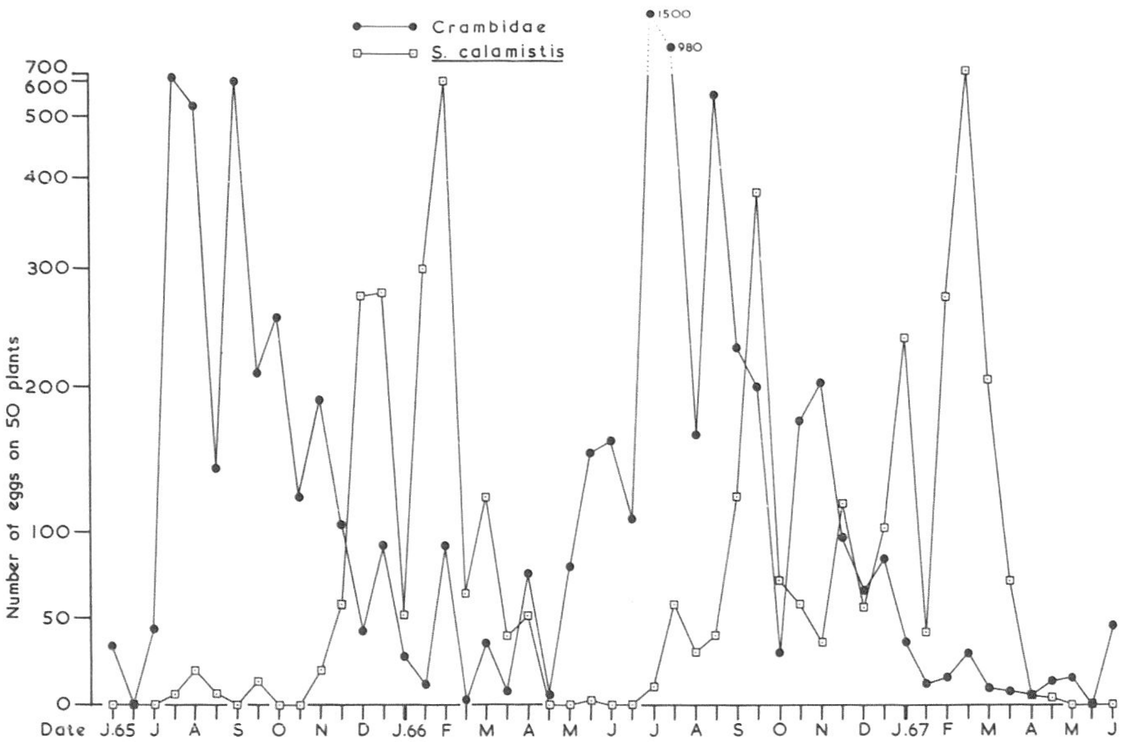


Fig. 10. Mean number of eggs found on 50 plants (average for 4 samples of 50 plants) 50 days after planting.

absent up to the beginning of September 1966 and later their numbers vary greatly as they do for the 2 other stalk borers (Fig. 11). The low overall number of *S. calamistis* larvae as compared with the very high number of eggs (Fig. 10) was due to the egg parasites, which in this type of breeding system become well established and reduce the larval population of the stalk borer by more than half.

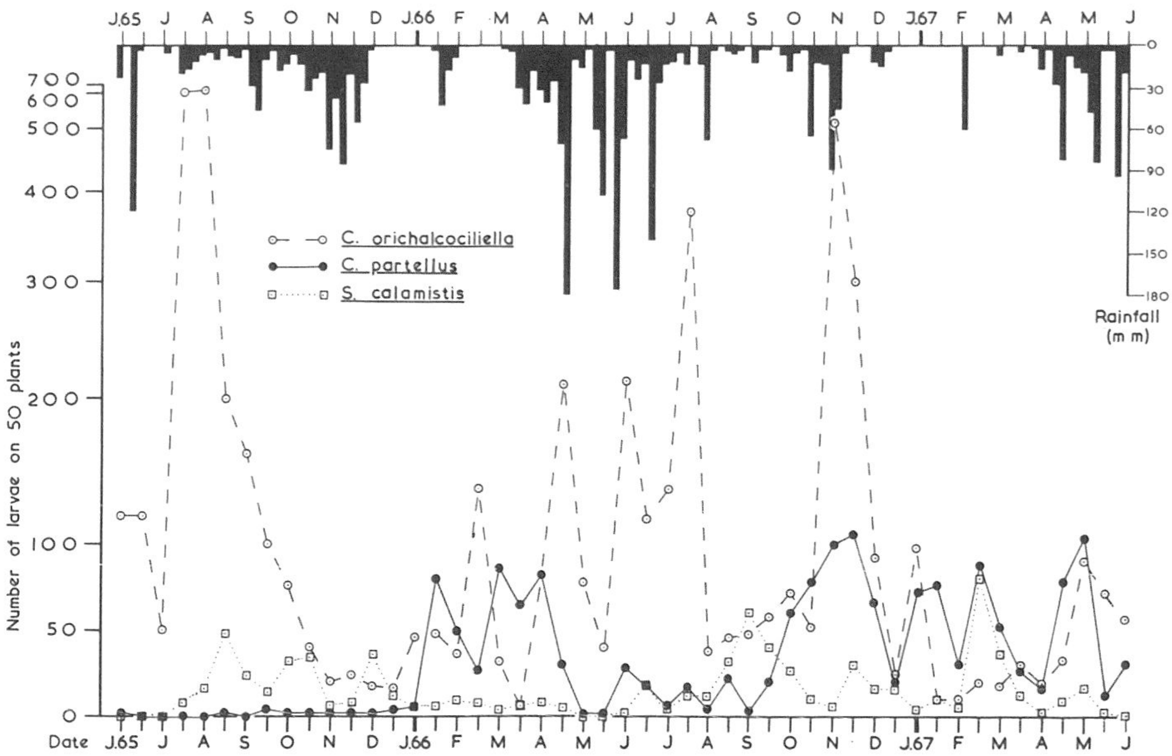


Fig. 11. Mean number of larvae found on 50 plants (average for 4 samples of 50 plants) 50 days after planting.

Annual experiments

Not only does the larval population vary greatly during a continuous experiment of 2 years, but it also varies from year to year when maize is planted at the right time, *i.e.* at the beginning of the long rains. Fig. 12 shows the fluctuation of the stalk borer populations and indicates that peaks are reached approximately 50 and 100 days after planting. *C. orichacociliella* in 1965, 1967 and 1968 and *C. partellus* in 1966 and 1968 present these features. In 1969, the graph indicates an abnormally low population because the long rains did not break in the middle of March.

The average number of plants infested by stalk borers varies according to the larval population and consequently the rate of infestation (number of larvae/number of infested plants) varies too. About 110 days after planting 80 % of the stalks are damaged by 4 larvae each. The rate of infestation, however, is usually higher (up to 6.7 larvae) a few weeks after planting, when fewer plants are infested. Both the number of infested plants and rate of infestation decrease after the harvest, but the dispersion of the larval population is higher than at the beginning of the crop growth. The highest number of larvae on one plant was 98 *C. orichalcociliella,* 28 *C. partellus* and 43 *S. calamistis* during the two year experiment, and 45, 31 and 20 during the yearly experiments.

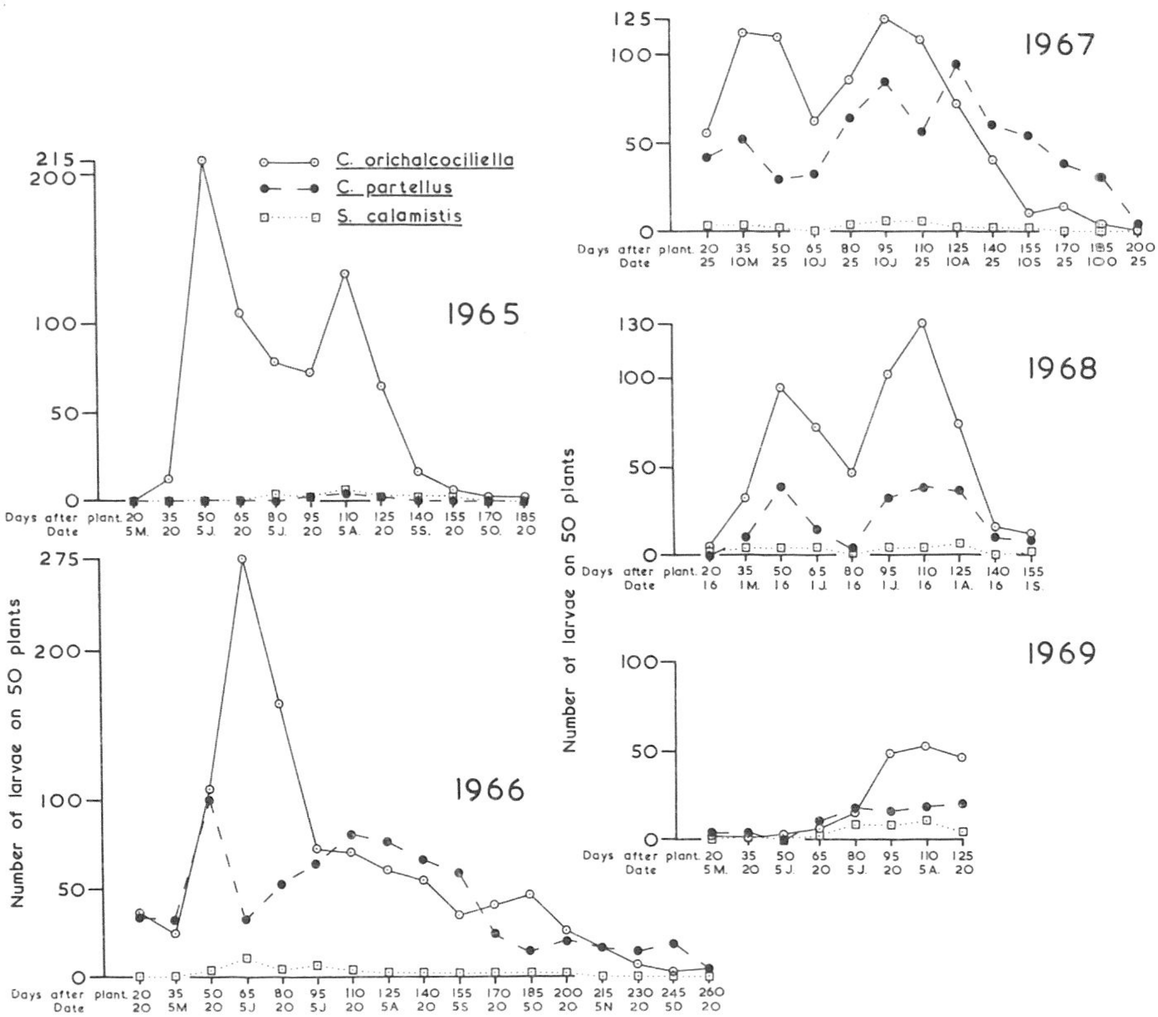


Fig. 12. Fluctuation of the population of 3 stalk borers.

In 1966, maize and sorghum were interplanted twice on 1/2 ha plots at the same dates. During the long rains, *C. partellus* larvae on sorghum were 2.25 times more numerous than *C. orichalcociliella* (1895 against 844; 70 samples of 50 plants for each crop) while the latter species was 1.46 more numerous on maize than *C. partellus* (1025 against 698) (Fig. 13). Planting during the short rains was done about one month too late; on sorghum, the *C. partellus* population was very high (over 150 larvae per sample) up to 140 days after planting while this same stalk borer was numerous (over 200 larvae) on maize during the first 40 days and then decreased rapidly, very few egg-masses being laid on this crop. These four experiments show that *C. partellus* is more attracted by sorghum than by maize and that the tillering of the first crop seemed to increase the overall population of stalk borers, which consisted mainly of *C. partellus*.

Pupae

Pupation takes place in different parts of the plant, but never in the funnel. Before harvest, 95 % of the Crambidae pupae are found in the stem; the remainig 5 % are either in the husk, on the cob (2–3 %) or under the sheath (1–2 %). The proportion of *S. calamistis* pupating in these three parts is slightly higher. The

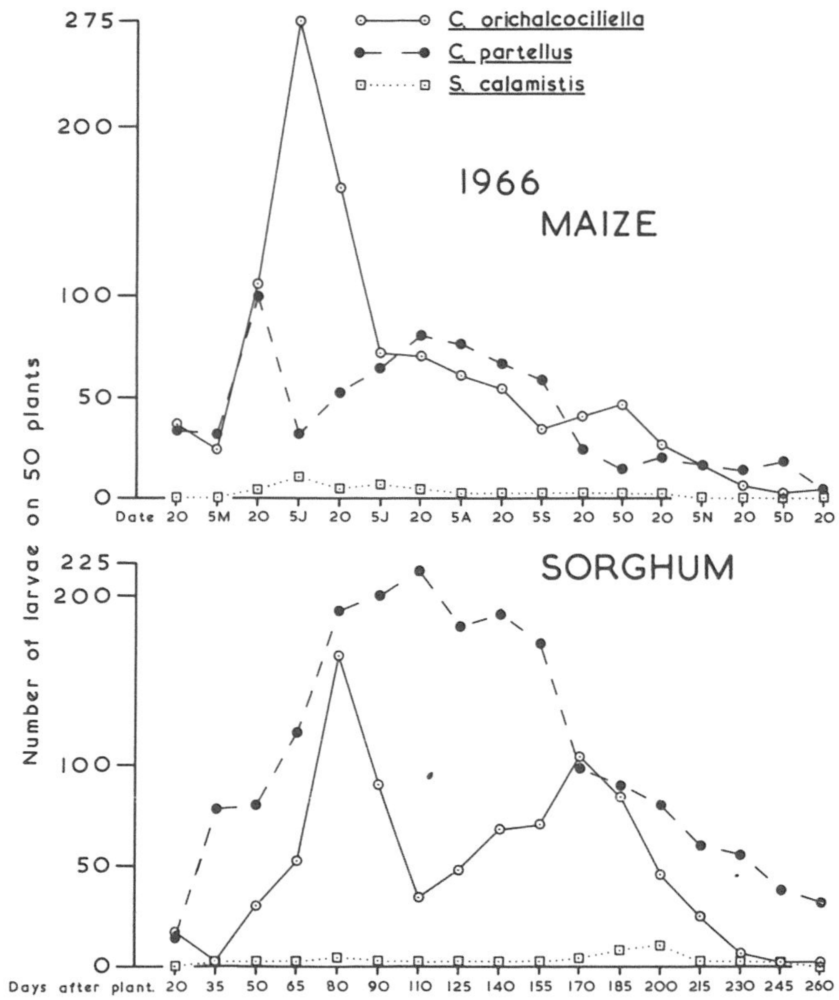


Fig. 13. Number of stalk borer larvae found on maize and sorghum interplanted.

first pupae found on maize and sorghum are *C. partellus* males, followed by *C. partellus* females a few days later, usually 40–50 days after planting. Except on maize planted during the short rains (October 1966), the highest numbers of full pupae of the 3 stalk borers are found about 90 days after planting (max. 47 pupae on 50 maize plants; min. 14 pupae), and full pupae of the 3 species can be present well over 200 days after planting. There is no significant difference between the numbers of male and female pupae, full or empty of the 3 species. In 1966, on maize and sorghum, 2/3 of the empty pupae collected up to the end of sampling (260 days) were found after the harvest.

Alternative host plants

Host plants other than maize and sorghum were dissected from 1965 to 1969 at different seasons during each year. The recording system used for the stalk borer population was the same as that for the two food crops, except that the dissected samples usually consisted of 100 stalks. The great variations observed in the numbers of eggs, larvae and pupae found, are due to four major factors: the species of the host plant considered, its diameter, where it has grown (in the bush or near a maize plot) and when it was dissected (during the dry or the rainy season). As it is on maize, *C. orichalcociliella* is the most common and numerous

Table II. *Occurrence of stalk borers on plants other than maize and sorghum*

host plants	*C. orichal cociliella*	*C. partellus*	*S. calamistis*
Saccharum officinarum	E, L, P ♂ + ♀	E, L, P ♂	–
Pennisetum purpureum	E, L, P ♂ + ♀	–	–
Panicum maximum	E, L, P ♂ + ♀	E, L	E, L
Sorghum brevicarinatum var. *swahilorum*	E, L	E, L, P ♂ + ♀	L
Hyparrhenia rufa	L	–	–
Pennisetum polystachyon	-	–	L
Cyperus rotundus ssp. *tuberosus*	L	–	–

E = eggs; L = larvae; P = pupae.

species. It may be due to the fact that *Panicum maximum*, a wild Graminaceae, is too very common, while *C. partellus*, which prefers *Sorghum brevicarinatum* var. *swahilorum* has less opportunity to breed because the latter is less common (Table II). The *S. calamistis* population is very low not only on food crops, but also on the other host plants. During any one year the variations of the 3 stalk borers populations occurred at about the same time on maize and sorghum as on the other host plants. The only difference observable was that the 3 stalk borers were much more numerous on food crop samples of equal size.

Distribution of stalk borers in the Province

Due to transport difficulties it was not possible to carry out systematic investigations all over the Province. Only a few samples from different places were dissected in 1967 and 1968 (Table III). The overall impression is that in most cases, *C. partellus* seems just as important as *C. orichalcociliella*, and is sometimes more numerous as at Taveta and Mwakiki. *S. calamistis* is dominant at Wundanyi (altitude 1,500 m).

It appears that the fluctuations of the population and the rate of infestation were the same as those observed at the Coast Agricultural Research Station. However, in one particular case, at Bamba, in Kilifi District, 1095 *C. partellus* larvae were found on 50 maize plants. This outbreak was the most important one observed during this study.

Discussion

In contrast with the erratic rainfall, the temperature does not vary much during the first maize crop of each year which usually grows from April to August (Figs. 14 and 15). Having no diapause, *C. orichalcociliella* and *C.*

Table III. *Relative importance of 3 maize stalk borers in the Coast Province*

Locality	Altitude	District	No. of samples*	*C. orichalcociliella*	*C. partellus*	*S. calamistis*
Taveta	800 m	Taita Hills	11	+	+++	++
Wundanyi	1500 m	Taita Hills	11	0	0	+++
Mwakiki	700 m	Taita Hills	8	+	+++	++
Shimba Hills	140 m	Kwale	19	+++	+++	+
Matuga	120 m	Kwale	31	+++	+++	+
Mariakani	200 m	Kwale	8	+++	++	+
Kibarani	40 m	Kilifi	11	+++	+++	+
Msabaha	30 m	Kilifi	11	+++	+++	+
Bamba	270 m	Kilifi	12	++	+++	+
Lamu	10 m	Lamu	4	++	+++	0

* Number of samples of 50 plants each.

partellus emerge at any time from old maize stalks remaining on the field after the harvest of the second crop planted in September–October the previous year, or from the wild tall Graminaceae growing all the year round. The life of moths being rather short (2–4 days), they are unable to fly very far from the point of emergence, except perhaps when a strong wind is blowing during the night. Infestation of the young plants starts very early, in most cases 10 to 15 days after planting. The number of adults flying in April depends mainly on the weather conditions prevailing during the preceding months. Most farmers plant maize twice a year without burning or burying the stalks after the first harvest. There is a direct and usually high infestation from these old stalks to the second crop. After the second harvest, by the end of the year approximately, stalks remain undestroyed on the field and moths emerge continuously during the «dry» season (December–March), as they also do from the wild Graminaceae. Theoretically, if the period directly preceeding the first planting after the «dry» season is moderately wet and the rainfall well-distributed, the infestation ought to be high soon after germination because the stalk borer population will be more numerous at the end of the second crop on old stalks or on wild Graminaceae. More larvae from newly laid egg-masses will have a chance to survive on healthy, well-watered wild Graminaceae. In actual fact, the period during which the data were collected was too short (1965 to 1969) and the variations too great to confirm this theory satisfactorily. If the total rainfall during the main planting-to-harvest period and the total number of larvae or the total number of larvae of the 3 species found during the same period are considered, again the

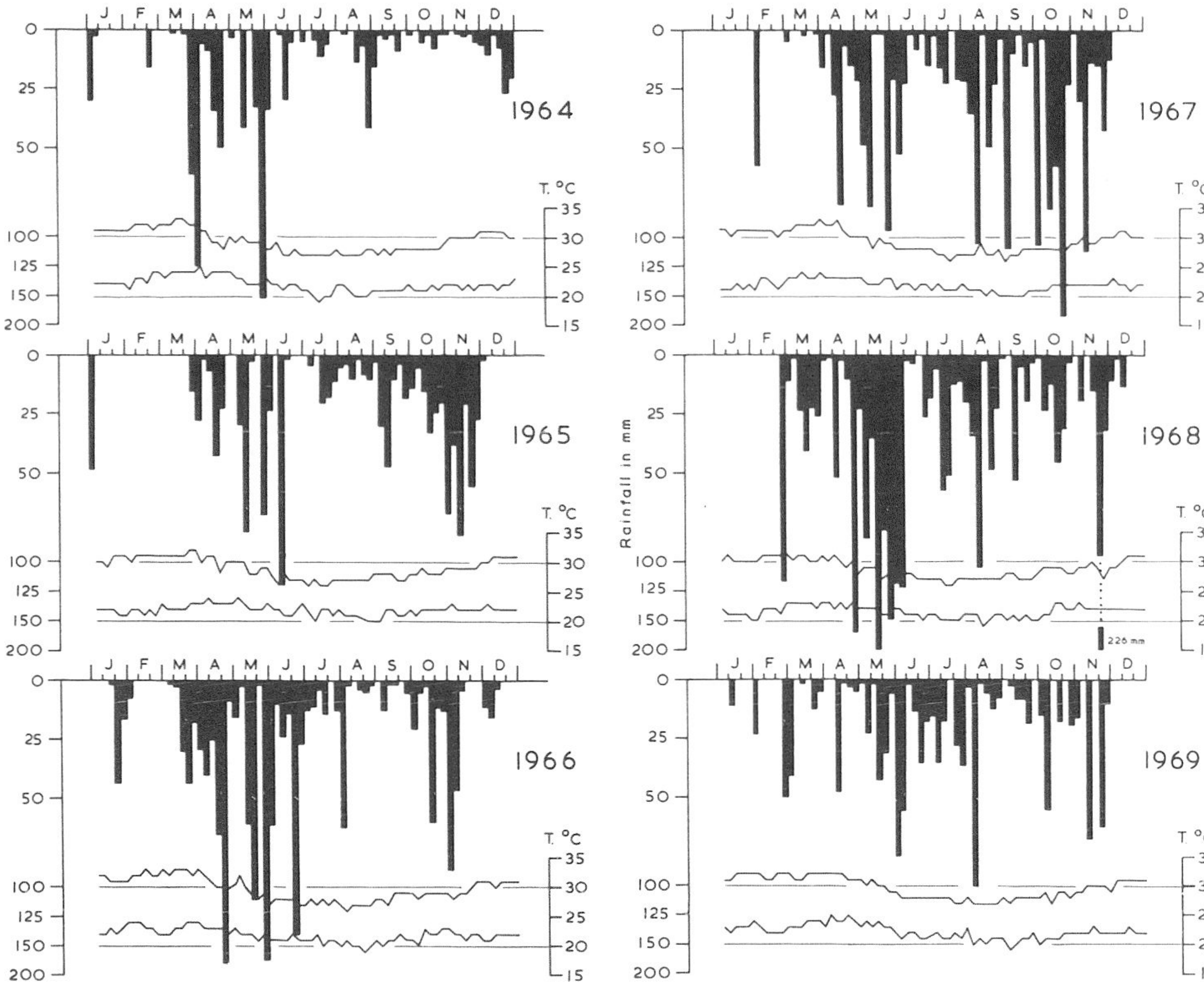


Fig. 14 and 15. Rainfall and temperature at 5 day intervals at the Coast Agricultural Research Station.

figures do not lead to any conclusion. For instance in 1966, 1055 mm fell during the 120 days of the maize growth and 1695 larvae were found (2/3 of *C. orichacociliella);* in 1967, with half the rainfall, practically the same amount of larvae was found.

It may be possible to explain the fact that usually 100 % of the stalk borer larvae are found in the funnel base 20–30 days after planting by the early timing of egg-laying. The stem is practically non-existent 15 days after planting. However, it represents more than 90 % of the space where the larvae can feed after tasselling (cob less than 10 %). The increase of the stem volume and the diminishing percentage of the larvae found in the funnel base suggest that the probability of a larva entry to the stem increases with the growth of the plant.It is, however, possible that the mortality of the larvae is higher when they have to bore into the stem instead of moving into the soft funnel base.

III. PARASITES AND INSECTICIDES

Many natural agents acting at different stages cause mortality in an insect population. Bacterial, viral and fungal diseases, metabolic disorders, predators and parasites are normally present so that even less than 5% of the eggs may produce adults which die of old age. In the present work, the causes of adult mortality were not taken into account and those responsible for egg, larval and pupal mortality were divided in two groups: bacteria, viruses, fungi and metabolic disorders on one hand, predators or parasites on the other hand.

The Coast Province being a cotton area, where applications of DDT 75 % and Carbaryl (Sevin) 85 % are officially recommended, the action and the persistence of these two insecticides were also tested.

Egg mortality

The number of fertile eggs that do not hatch due to unknown reasons is below 5 % for the 3 species in both field and laboratory. The activity of egg predators in the field appeared to be nil. In the laboratory, some unidentified ants were found feeding on egg-masses during the dry season. At least 3 species of egg parasites were reared: *Telenomus* sp.? *dignus* (GAH.) and a *Trichogramma* sp. ex-Crambidae, *Platytelenamus busseola* (GAH.) and a *Trichogramma* sp. ex-S. *calamistis*. It is possible that the two *Trichogramma* are only one species, because very few of them emerged from *S. calamistis* eggs. Out of 19 Crambidae egg-masses totaling 215 eggs, 509 *Trichogramma* sp. emerged (mean 2.3; extremes 1–4) while there was always one *Telenomus* sp. per egg (87 eggs checked). The *Trichogramma* sp. must be regarded as the most important egg parasite of the Cramidae during our research work.

During the two year experiment (see p. 276), the mean parasitism for 4 samples reached 92 % for the Crambidae (Fig. 16) and 97 % for the *S. calamistis* (Fig. 17). These graphs show the typical increases in the number of parasitized eggs, which after a few weeks outnumbered the unparasitized eggs and then declined to very low numbers for a few months.

On yearly planted maize the population fluctuated greatly, as with the preceeding two year trial. In 1965, 1968 and 1969 no parasitized eggs were found

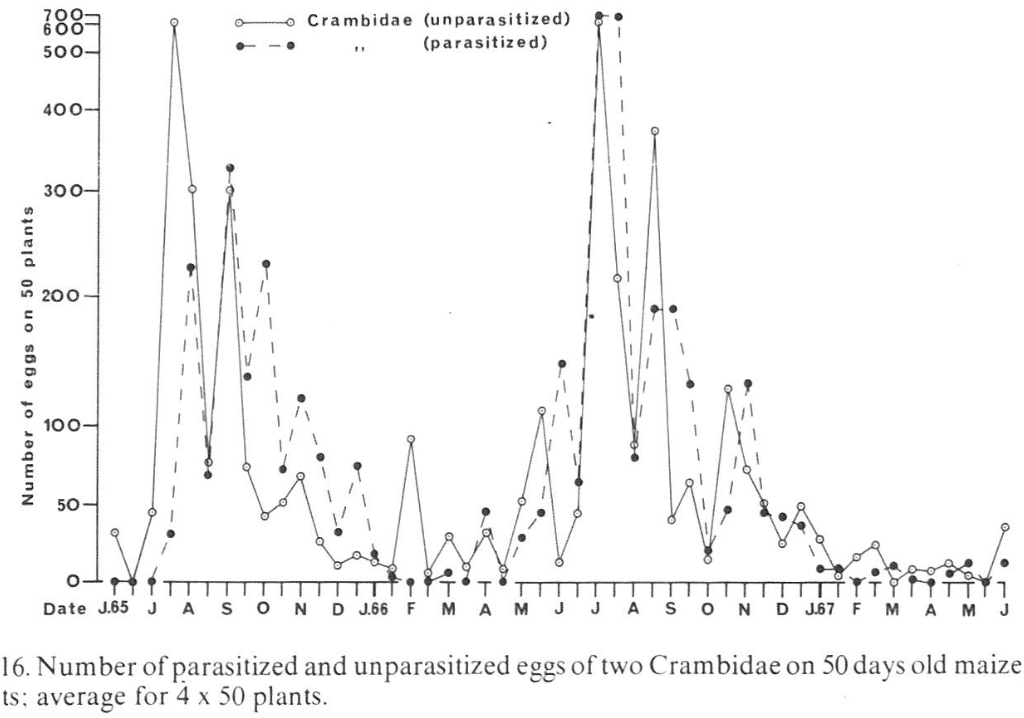


Fig. 16. Number of parasitized and unparasitized eggs of two Crambidae on 50 days old maize per 50 plants; average for 4 x 50 plants.

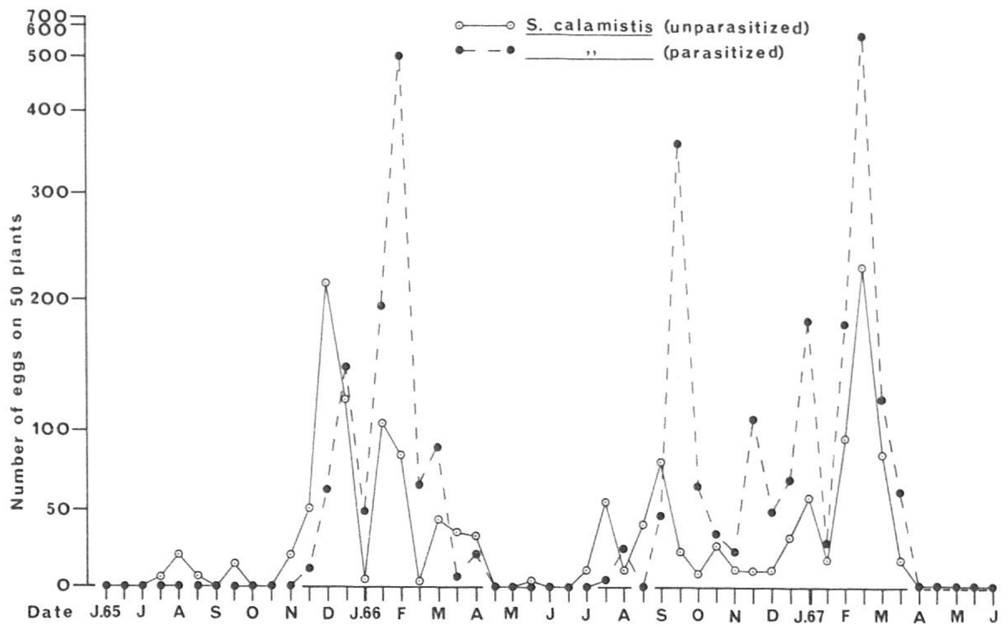


Fig. 17. Number of parasitized and unparasitized eggs of *S. calamistis* on 50 days old maize per 50 plants; average for 4 x 50 plants.

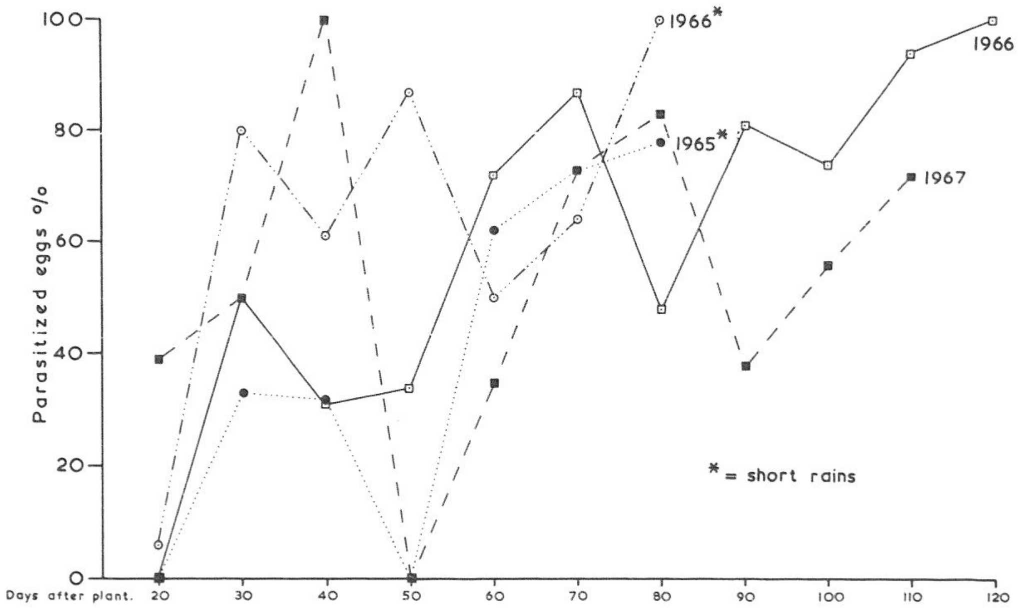


Fig. 18. Percentage egg parasitism during the planting-to-harvest period per 50 plants; average for 4 x 50 plants.

on crops planted during the long rains (March–July), although stalk borer eggs were abundant in both 1965 and 1968. On the crop planted during the short rains (October–December) in 1965, on the two following crops in 1966 (long and short rains) and on the first in 1967, the parasitism sometimes reached a high level (Fig. 18). As indicated above for 1965 and 1969, an abundance of stalk borer eggs is not the only factor necessary for the presence of parasite population; climatic conditions can act favourably or adversly.

Larval mortality

Different causes of larval mortality may be considered. In the laboratory, 15–20 % of the larvae pupated and the mortality due to diseases and physiological disturbances was apparent. In the field, the remains of the larvae that died during the 3 first instars vanished very quickly, washed away by the rains, so that mortality is difficult to estimate. Nevertheless, concealed and apparent mortality must be taken into account. For the former, no reliable figures can be given, but it may well reach 100 %, because very often no larvae are found on the plant although empty unparasitized egg-masses remain 2–3 days on the leaves. It seems that the concealed mortality was the most important and that it was not due to lack of food or to any disease associated specifically with over-populated plants. A possible explanation is that a proportion of the larvae are unable to survive on certain plants that have particular characteristics, as already noticed by PANT, PATHAK and PANT (1962).

The apparent mortality was reckoned on the basis of dead larvae found on the plants, and was usually due to two causes: diseases and physiological disturbances on one hand, and parasites on the other. The incidence of Nematode parasites and ant predators was negligible. The two major causes were about equally important. They were almost insignificant on young plants, but by harvest time had killed a total of about 10 % of the larvae on maize planted in the long rains and 15 % on maize planted during the short rains. After the harvest, as the stalk borer population decreased, the percentage mortality due to the parasites became higher, whereas that due to bacteria, viruses, fungi and physiological disturbances remained constant.

At least 8 true larval parasites were found. None of them was sufficiently active to influence the stalk borer population. Furthermore, in some instances none were found during many months (*Goniozus* sp.) although a great number of maize stalks were dissected (Table IV). As already mentioned for the egg parasites, climatic conditions would also act favourably or adversly on larval parasites.

There are doubts about the real status of two Muscidae, *Atherigona* sp. and *Phaonia* sp. and three Chloropidae, *Scoliophtalmus trapezoides* (BECK.), *Polyodaspis* sp. ? *robusta* (LAMB.) and *Anatrichus erinaceus*(LOEW).More than half the total number of these 5 insects was found very close to the remains of stalk borer larvae, but none of them were observed feeding on moribund larvae, as was the case for the other true parasites. They may well be saprophagous insects rather than parasites.

Pupal mortality

During the survey, less than 10 % of the pupae were prevented from reaching the adult stage by diseases and physiological disturbances. This included some pupal cases which were not well formed so that the emerging adults were unable to fly and died within a few hours. The action of the predators seemed very low, although a few pupae on about 250 days old maize were found half eaten by ants.

Pediobus furvus (GAH.) a Eulophidae, was the most common parasite of the three stalk borers. The first parasitized pupa was usually found 80 days after

Table IV. *Parasites found on maize in 1965 to 1968*

Family	Name of parasite	Status	*C. orichalcociliella*	*C. partellus*	*S. calamistis*	No. of parasites* on 354 x 50 plants
Braconidae	*Apanteles* sp. *laevigatus* gp.	parasite	+	−	+	3**
Braconidae	*A. sesamiae* Cam.	parasite	+	+	+	218
Braconidae	*Bracon (Glabrobracon)* sp.	parasite	+	+	−	145
Braconidae	*Glyptomorpha* sp.[0]	parasite	+	+	−	37
Braconidae	*Rhaconotus* sp.	parasite	+	+	+	53
Braconidae	unidentified sp.	parasite?	+	−	−	1
Ichneumonidae	*Syzeuctus* sp.	parasite	+	−	−	1
Bethylidae	*Goniozus* sp.	parasite	+	+	+	88
Tachinidae	*Sturmiopsis parasitica* Curr.[0]	parasite	+	−	−	3
Muscidae	*Atherigona* sp.	parasite?	+	+	+	446
Muscidae	*Phaonia* sp.	parasite?	+	−	−	5
Chloropidae	*Scoliophthalmus trapezoides* Beck.	parasite?				
Chloropidae	*Polyodaspis* sp.? *robusta* Lamb.	parasite?	+	+	+	44
Chloropidae	*Anatrichus erinaceus* Loew	parasite?				

* including empty pupae.
** figures include the parasites found on or near unidentified dead larvae.
[0] found also by La Croix (1967).

maize planting and about 100 days later, when the pest populations were very low, parasitism sometimes reached 100 %. Up to maize harvest, about 1481 pupae were examined from 1965 to 1969 and only 19 of them were parasitized by *P. furvus.*

Very few specimens of a Braconidae, *Chelonus (Microchelonus)* sp. and an Ichneumonidae, genus near *Isotima* sp. were found ex-Crambidae pupae.

Insecticide trials

During the long rains in 1967, an insecticide trial was set up on maize. DDT 75 %, Carbaryl (Sevin) 85 % and BHC 20 % were sprayed into the funnel of each plant either 20 or 20 and 27 days after planting. There were five replications

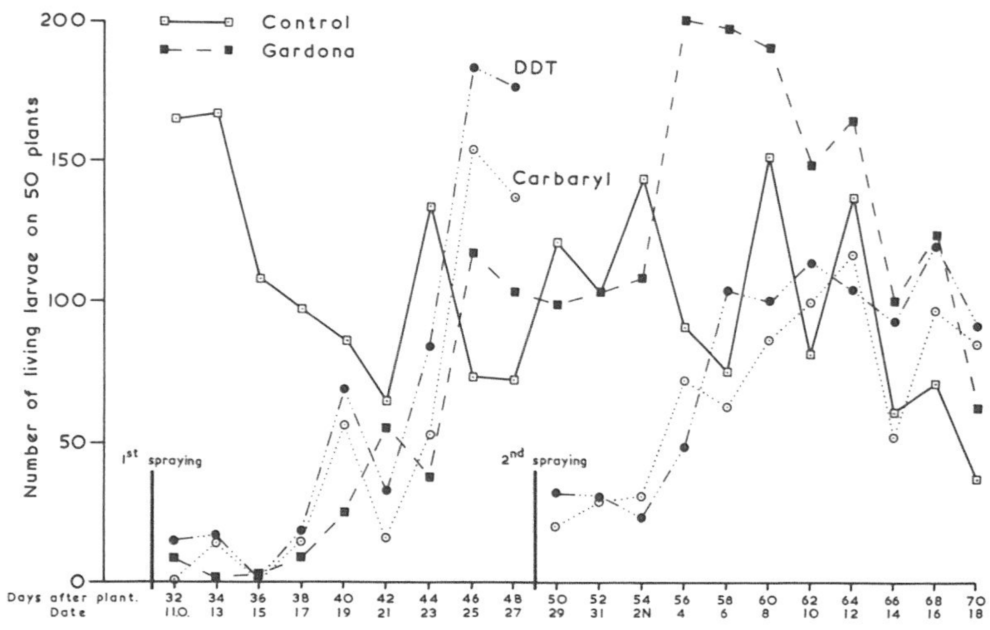


Fig. 19. Living larvae per 50 plants during an insecticide trial.

per treatment. The results showed no significant difference in yield (13 bags of 200 lb/acre, or 3000 kg/ha) either between the sprayed plots and the controls or between the three insecticides, whether applied once or twice.

After this unsuccessful attempt, DDT, Carbaryl and Gardona were sprayed during the short rains in 1967 on a new trial, in order to ascertain their effectiveness and persistence. BHC was omitted because it had caused scorching of the plants in the previous trial. The rate was 2.5 x the rate used for the first trial, *i.e.* in ounces per 20 gallons of water per acre (= kg/225 litres/ha) 52.5 oz (3.750 kg) for DDT 75 %, 47.5 oz (3.350 kg) for Carbaryl 85 % and 70 oz (4.950 kg) for Gardona 50 %. The first sprayings were done on ½ acre plots each, 31 days after planting and the second (DDT and Carbaryl) 18 days later. One sample of 50 plants per treatment and control plot was collected at random every 2 days and dissected in the laboratory. On sprayed plants, the larval mortality figure was over 80 %, as compared to the control, during the 7 days after the first spraying, but was lower after the second spraying, because in the meantime more larvae had gone into the stem (Fig. 19). Carbaryl seemed to be more active and persistent than DDT. Gardona was the best, but unfortunately the supply was insufficient for a second treatment.

At the end of the 1967 short rains Carbaryl 85 % was sprayed on 42 days old maize at the following rates: 19 oz/8 gall/acre (1.350 kg/90 l/ha), 28.5 oz/12 gall/acre (2 kg/135 l/ha) and 38 oz/16 gall/acre (2.700 kg/180 l/ha). One sample of 50 plants was dissected every two days after spraying. The three treatments gave about the same mortality figures during the 16 following days: 78 %, 84 % and 79 %. The persistence was very good but was favoured by the absence of rain.

Another trial was carried out at the end of the short rains in 1967. The insecticides applied on 33 days old maize were DDT 5 % dust, DDT 5 % dust and sand and Carbaryl 20 % granulate. They were poured once into the funnel with a coffee spoon at a rate of 1 spoon for DDT 5 % dust, 2 spoons for DDT 5 % plus sand and 1/4 spoon for Carbaryl 20 %, so that the quantity of active ingredient was about the same. The 3rd and 4th days after the treatment 31 mm of rain fell. but this did not seem to affect the mortality figures which were 79 % for DDT, 84 % for DDT plus sand and 95 % for Carbaryl granulate during the following days.

Discussion

Maize has been grown for centuries in the Coast Province as a subsistence crop. Very often planted twice a year, this crop has exhausted most of the soils which already were not very fertile because of their geological origin and the climatic conditions. Today, neither manure nor fertilizers are applied and maize is still almost exclusively a food crop for family and local consumption. In 1969, only 323 bags were sold to the Maize and Produce Board for the whole Province (Ministry of Agriculture, 1969).

With over 40 in (1000 mm) of rain during the planting-to-harvest period,the following yields have been recorded: farmers (average for the Province) 3–4 bags/acre (675–900 kg/ha); Research Station (commercial 8–10 bags (1800–2200 kg); Research Station (fertilizer trials) up to 16 bags (3800 kg); in all cases no insecticides were applied. With only half the rain, the yield is reduced by half on the farmers' land, by one third only on the Research Station (commercial), and by one fourth on the Research Station (fertilizer trials).

Allan (1968) showed the role of good husbandry (early planting, correct population, clean weeding until tasselling), hybrid seeds and fertilizers as essential factors increasing the maize yield in the Western Province of Kenya. At the Coast Agricultural Research Station, on land that is not outstandingly fertile but is included in a normal rotation (4 years rest as temporay pasture, then one year maize or cotton and one year sunflower or sesame) the yields reached about 10 bags/acre (2200 kg/ha) with good husbandry, «P.P.» maize variety (resistant to *Puccinia polyrosa* rust) and fertilizers; this figure is hardly greater than the yield in the Western Province with bad husbandry (planting late, low population, one late weeding) unimproved seeds and no fertilizers (Allan, 1968). This comparison shows that the cost of production of maize grown in the Coast is very high, even under the most favourable conditions, *i.e.* on soils which are not exhausted, and that climate and soil fertility are, in most cases, unfavourable to this crop grown for a market economy.

The stalk borer is the last adverse factor. When plants are small and weak the importance of pest damage is much greater. A strong and tall plant can tolerate say 5 larvae inside the stalk; the seed production may be reduced by about 10 %. The same 5 larvae on a weak and short plant will reduce the seed number per cob by at least 60 % or may even kill the plant. In fact, the stalk borer population, per sample of the same size, is usually lower on poor growth plants than on healthy ones but the resulting damage is much greater.

Despite a good control (about 80 %) of the stalk borers by means of insecticides, the yield did not increase because either these pests are in most cases not important, due to the low yield of our trials as compared to the Western Province, or the 20 % unkilled larvae are those which reduce the yield; or because of the combination of these two factors. The use of Carbaryl 85 % at a rate of 30 oz/12 gall/acre (2.150 kg/135 l/ha) can be recommended 25, 35 and 45 days after planting only if the potential yield reaches at least 12 bags/acre (2.700 kg/ha) with good husbandry, «P.P.» maize variety and fertilizers. Below this figure, only field sanitation, destruction of the stalks by immediate burning after harvest, regular slashing of the wild Graminaceae all the year round and planting of maize only once a year, during the long rains, will help to reduce the stalk borer population. The efficacy of this indirect control would be greatly increased if sanitation measures were applied over large areas, say at location level, by people who believe in its usefulness.

Acknowledgements

The work described above was carried out at the Coast Agricultural Research Station and is published by permission of the Ministry of Agriculture, Kenya, and the Delegate for Technical Cooperation, Switzerland.

I am greatly indebted to Dr. D.J. Greathead, C.I.B.C., Kampala, for the identification of the parasites, and to Dr. S. Bleszyński, who identified the Crambidae.

Special thanks are due to Mr. M.T. Locke and Mr. J.A.MacFarlane for their helpful criticism of the manuscript. I am most grateful to my Technical Assistant, Mr. Malio Enock, who during five years was in charge of insect breedings, maize dissecting and observation recording.

REFERENCES

ALLAN, A.Y., 1968. *Maize diamonds. Kenya Farmer,* 138, 18–19.

BLESZYŃSKI, S., 1962. *Studies on the Crambidae (Lepidoptera). Part 36. On some species of genus* Chilo *Zinken. Acta zool. Crac., Krakow, 7,* no. 7, 107–133.

– 1963. *Studies on the Crambidae (Lepidoptera). Part 40. A review of the genera of the family Crambidae with data on their synonymy* and types. *Ibid., 8,* no. 3, 91–132.

BLESZYŃSKI, S., COLLINS, R.J., 1962. *A short catalogue of the world species of family Crambidae (Lepidoptera). Acta zool. Crac.,* Krakow *7,* no. 12, 197–389.

COAKER, T.H., 1956. *An experiment on stem borer control on maize. E. Afr. agric. for. J., 21,* 220–221.

DUERDEN, J.C., 1953. *Stem borer of cereal crops at Kongwa, Tanganyika, 1950–52. Ibid., 19,* 105–119.

HARGREAVES, H., 1939. *Notes on some pests of maize and millets in Uganda. Ibid., 5,* 104–109.

HINTON, H.E., 1946. *On the homology and nomenclature of setae of Lepidopterous larvae, with some notes on phylogeny of Lepidoptera. Trans. R. ent. Soc. Lond., 97,* 1–37.

INGRAM, W.R., 1958. *The Lepidopterous stalk borers associated with Gramineae in Uganda. Bull. ent. Res., 49,* 367–383.

JEPSON, W.E., 1954. *A critical review of the world literature on the Lepidopterous stalk borers of tropical Graminaceous crops. London, C.I.E.,* 127 pp.

LA CROIX, E.A.S., 1967. *Maize stalk borers in the Coast Province of Kenya. E. Afr. agric. for. J., 33,* 49–54.

MILNER, J.E.D., 1967. *Final report on a survey of parasites of Graminaceous stem-borers in East Africa. Kawanda, Commonw. Inst. Biol. Control, 159* pp. (cyclostyled).

MINISTRY OF AGRICULTURE (Kenya), 1969, *Economic review of agriculture. October – December and Annual Summary,* 58 pp.

NYE, I.W.B., 1960. *The insect pests of Graminaceous crops in East Africa. Colon. Res. Stud., 31,* 48 pp.

PANT, N.C., PATHAK, M.D., PANT, T.C., 1962. *Resistance to* Chilo zonellus *Swin. in different host plants. I. Development of the larvae on different hosts. Ind. J. Ent., 23,* 128–136.

PETERSON, A., 1962. *Larvae of insects. Part I. Lepidoptera and Hymenoptera. Ohio State Univ. Colombus,* 315 pp.

SWAINE, G., 1957. *The maize and sorghum stalk borer* Busseola fusca *Fuller, in peasant agriculture in Tanganyika Territory. Bull. ent. Res., 48,* 711–722.

WALKER, P.T., 1961. *Insecticide studies on the maize stalk borer,* Busseola fusca *Fuller, in East Africa. Ibid., 51,* 321–351.

WHEATLEY, P.E., 1961. *The insect pests of agriculture in the Coast Province of Kenya. V. Maize and sorghum. E. Afr. agric. for. J., 27,* 105–107.

WILLIAMS, J.R., 1953. *The larvae and pupae of some important Lepidoptera. Bull. ent. Res., 43,* 691–701.