AN OUTBREAK OF *SPODOPTERA EXEMPTA* (WALKER) (LEPIDOPTERA : NOCTUIDAE) IN THE HIGHLANDS OF PAPUA NEW GUINEA

G.L. BAKER *

ABSTRACT

An outbreak of the moth Spodoptera exempta *(Walker), (the African armyworm), took place in pastures in the highlands of Papua New Guinea in March 1973. The outbreak is believed to have been the result of breeding by an influx of adults from lowland areas following successful breeding subsequent to the breaking of a severe drought in November 1972.*

In the invasion area, the outbreak lasted for a single generation. The collapse of the outbreak is attributed to high mortality of the pupal stage. The main factor contributing to pupal mortality was an unidentified pathological condition superficially resembling desiccation. Parasites also contributed to pupal mortality, there being several unidentified species of tachinid and two ichneumonids, Lissopimpla scutata *Krieger and* Ichneumon promissorius Er..

Because of the small area of gramineae host crops at risk and the rapid regeneration of damaged pasture, little economic loss resulted from the outbreak. Feeding by larvae on Tritonia crocosmiflora *(Lemoine) Nich. (Iridaceae) represented a new family host record.*

INTRODUCTION

Spodoptera exempta (Walker) is a widespread pest species of armyworm in the old world tropics (Commonwealth Agricultural Bureaux, 1972). Throughout its distribution it is considered a serious pest of pasture and cereal crops (Brown, 1972).

Several previous outbreaks have been recorded in Papua New Guinea (Szent-Ivany, in press). The most recent outbreaks were in 1964 and 1970. In 1964, infestations of outbreak proportions were recorded in the Northern, Central, Morobe and Southern Highland Provinces (Szent-Ivany and Stephens, 1966). In March 1970, there was a limited outbreak in the Wau-Bulolo area of the Morobe Province (Gray, 1972).

The outbreak reported in this paper took place in March and April 1973. Outbreaks of *S. exempta* also occurred in 1973 in the tropical regions of Australia adjacent to Papua New Guinea. In the Northern Territory these extended as far south as Berrimah and Katherine in March 1973 (A.J. Allwood, pers. comm.). In northern Queensland, outbreaks occurred at several western centres during March and April 1973 (T. Passlow and A.J. Allwood, pers. comm.).

S. exempta has so far been of limited economic importance in Papua New Guinea due to the rapid compensating regrowth of damaged pasture and the small area planted to susceptible cereal crops. However, as susceptible crops are planted on a larger scale than at present and as the stocking pressure on grazing land increases, the pest status of *S. exempta* will undoubtedly rise.

* Formerly Senior Entomologist, D.P.I., Kuk Tea Research Station, Mt. Hagen. Present address: Entomology Branch, Biological and Chemical Research Institute, Department of Agriculture, Rydalmere, N.S.W., 2116, Australia.

THE OUTBREAK

Bands of *S. exempta* larvae were reported from 23 centres of the Morobe, Eastern Highlands, Chimbu, Western Highlands and Southern Highlands Provinces during March and early April 1973 (*Figure 1*).

Prior to the outbreak of larvae, swarms of adult *S. exempta* are believed to have moved at night from an outbreak area in the upper Ramu Valley and Upper Markham Valley (W. Fullerton, pers. comm.) into the Eastern Highlands Province and then into the Western Highlands Province.

Unusual activity at night by adult *S. exempta* was reported from Kainantu (Eastern Highlands Province) on 5th March, 1973. An influx of adults into the town in the early evening was of such density that a Local Government Council meeting was cancelled (H. Van Leeuven, pers. comm.). On the evening of 6th March, 1973, adult *S. exempta* invaded the township of Goroka. Dead *S. exempta* adults accumulated to a depth of approximately 10cm under external lights throughout the township. On both occasions the unusual activity occurred only on a single evening. No obvious influx of adult *S. exempta* preceded outbreaks in centres further west in the Chimbu, Western Highlands and Southern Highlands Provinces.

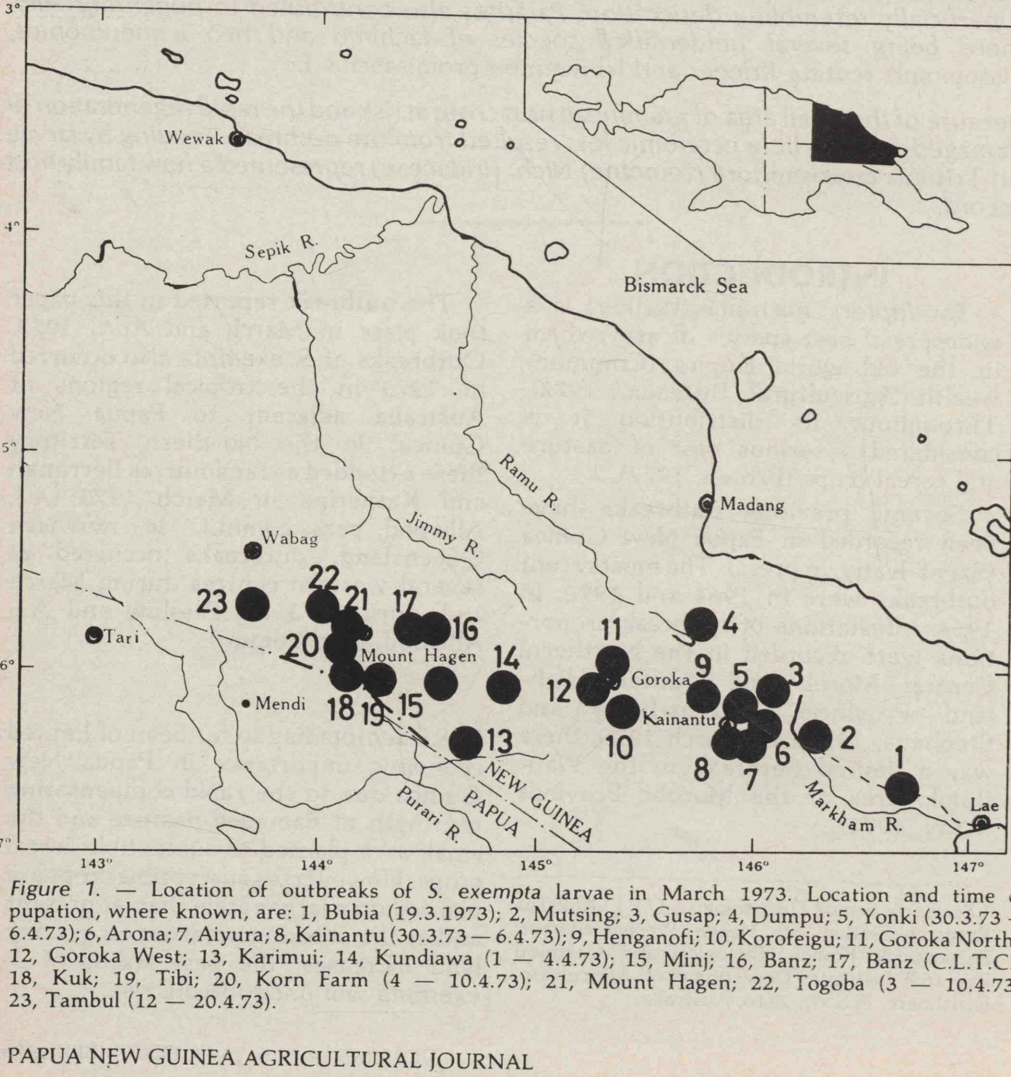

Figure 1. — Location of outbreaks of *S. exempta* larvae in March 1973. Location and time of pupation, where known, are: 1, Bubia (19.3.1973); 2, Mutsing; 3, Gusap; 4, Dumpu; 5, Yonki (30.3.73 — 6.4.73); 6, Arona; 7, Aiyura; 8, Kainantu (30.3.73 — 6.4.73); 9, Henganofi; 10, Korofeigu; 11, Goroka North; 12, Goroka West; 13, Karimui; 14, Kundiawa (1 — 4.4.73); 15, Minj; 16, Banz; 17, Banz (C.L.T.C.); 18, Kuk; 19, Tibi; 20, Korn Farm (4 — 10.4.73); 21, Mount Hagen; 22, Togoba (3 — 10.4.73); 23, Tambul (12 — 20.4.73).

LARVAL DEVELOPMENT

At the time when reported, most bands had attained the 5th and 6th instar. Frequency distribution histograms of head capsule width are drawn for larvae collected in mid-March 1973 from several centres. The results (*Figure 2*) show there was a marked tendency for samples from more eastern locations (Kainantu and Yonki) to be at a later stage of development than those samples taken from more western locations (Banz, Korn Farm and Togoba). However, subsequent samples taken from five bands at widely separate locations on 29th March, 1973 were all in the final instar (*Figure 2*) indicating a fair degree of synchronous development throughout the outbreak area.

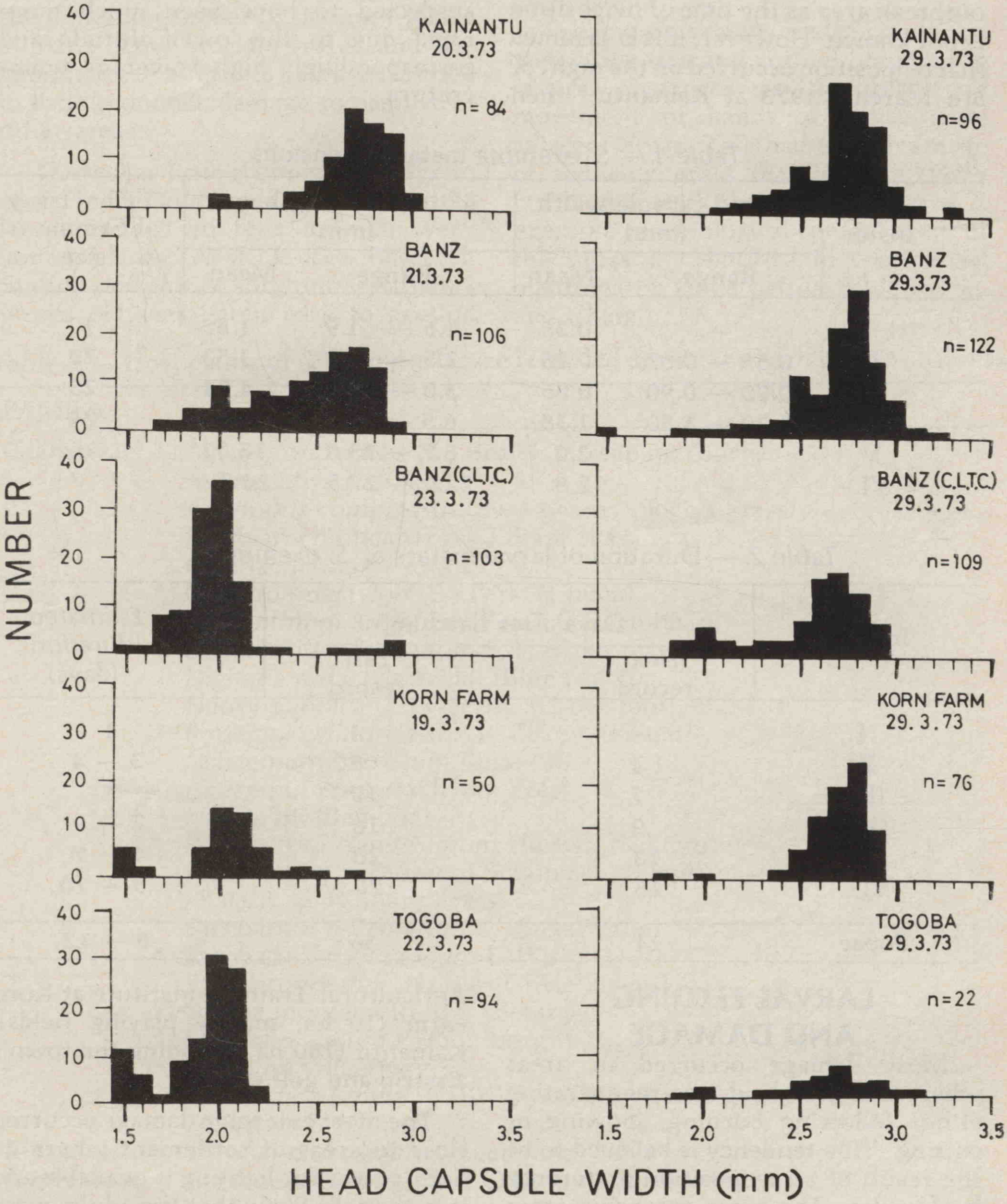

Figure 2. — Frequency distribution histograms of the head capsule width of *S. exempta* larvae sampled during the outbreak. (For location of sites refer to *Figure 1*).

The head capsule dimensions of the six instars were determined by rearing larvae in the laboratory at Kuk Tea Research Station. The results are given in *Table 1* for comparison with those given in *Figure 2.*

Only circumstantial evidence is available on the combined egg and larval development period in the highlands outbreak area as the time of oviposition is not known. However, if it is assumed that oviposition occurred on the night of 5th March, 1973 at Kainantu, then combined egg and larval development in that area took 25 to 32 days, pupation having taken place between 30th March, 1973, and 6th April, 1973. The duration of the larval stage for larvae bred in the laboratory at Kuk Tea Research Station in the Western Highlands Province in May 1973, is given in *Table 2.* Development in the Markham and Ramu Valleys is suspected to have been much more rapid due to the lower altitude and correspondingly higher average temperature.

Table 1. — *S. exempta* instar dimensions

Instar	Head capsule width (mm)		Body length (mm)		Sample size
	Range	Mean	Range	Mean	
I	—	0.35	1.6 — 1.9	1.80	10
II	0.55 — 0.67	0.58	2.5 — 4.0	3.53	20
III	0.70 — 0.90	0.85	3.0 — 7.0	4.74	25
IV	1.30 — 1.50	1.38	6.5 — 14.0	9.64	24
V	—	2.0	8.7 — 23.0	15.33	16
VI	—	2.8	22.0 — 27.5	24.5	7

Table 2. — Duration of larval instars of *S. exempta*

Instar	Days after hatching		*Estimated duration* (days)
	First record	*Last* record	
I	—	4	4
II	4	8	3 — 4
III	7	10	3
IV	9	18	2 — 9
V	13	20	4 — 7
VI	18	28	5 — 10
Pupae	24	36	8 — 12

LARVAL FEEDING AND DAMAGE

Most damage occurred in areas where the grassland was regenerating either following burning, mowing or cutting. This tendency is believed to be the result of an oviposition preference by females. The most extensive areas denuded were at the Highlands Agricultural Training Institute at Korn Farm (10 ha, mainly playing fields), Kainantu (150 ha, including the town's airstrip and golf course).

The most extensive damage occurred close to areas of settlement where 24 hour power for lighting is available and it is thought likely that the adults were attracted to such areas partly through the abundance of areas of maintained grass and partly due to the attraction of lights during the evening. Areas carrying short grass in a state of regeneration but not near settlements were not utilised to any great extent.

Damage to improved pasture was of economic importance in one instance only, where limited pastures were available for a large herd of dairy cows at the Christian Leaders Training College at Banz. Low stocking rates and the abundance of alternate pasture resulted in little economic damage to pasture in other areas.

There was little economic damage to cereal fodder and food crops. *S. exempta* larvae tended to feed only on very young plants. At Kuk Tea Research Station one plot of sorghum less than 2 weeks old was eaten back to ground level whilst an adjacent crop, 6 weeks old, was relatively unaffected. Gray (1972) observed similar results when larvae were presented with a choice between young and old *Imperata cylindrica* (L.) P. Beauv.. Due to lack of large scale commercial plantings and the non-synchronous planting of cereal crops in indigenous food gardens, very few cereal crops were at risk during the outbreak.

Feeding on grasses under plantation tree crops (tea and coffee) occurred in several instances as the result of movement of bands of larvae from adjacent areas. This had the advantage of reducing grass maintenance. Gray (1972) discusses the potential use of *S. exempta* as a biological control agent of the grass *I. cylindrica* in commercial plantings of *Pinus patula* Schlechtend. and Cham..

Table 3. — Host plants of *S. exempta* larvae recorded during the March 1973 outbreak

FAMILY		SPECIES
Gramineae:	*	*Agropyron repens* (L.) Beauv. (Creeping couch)
		Avena sativa L. (Oats)
		Axonopus compressus (Sw.) Beauv. (Sogeri grass)
	*	*Brachiaria mutica* (Forsk.) Stapf (Para grass)
		Coix lachryma — Jobi L.
	*	*Cynodon dactylon* (L.) Pers. (Couch)
	*	*Dichanthium aristatum* (Poir.) C.E. Hubbard
	*	*Dichanthium fecundum* S.T. Blake
		Digitaria didactyla Willd. (Blue couch)
		Eleusine indica (L.) Gaertn. (Crowsfoot)
	*	*Imperata cylindrica* (L.) P. Beauv. (Kunai)
		Ischaemum barbatum Retz.
		Ischaemum polystachyum Presl.
		Nastus sp. (Bamboo)
	*	*Pennisetum clandestinum* Hochst. (Kikuyu)
		Pennisetum purpureum Schumach. (Elephant grass)
		Phalaris sp. (Canary grass)
		Saccharum officinarum L. (Sugar cane)
	*	*Saccharum spontaneum* L. (Pit-pit)
		Saccharum edule Hassk. (Edible Pit-pit)
		Setaria montana Reeder (Setaria)
	*	*Sorghum almum* Parodi (Sorghum)
	*	*Sorghum vulgare* Pers.
		Themeda australia (R. Br.) Stapf (Kangaroo grass)
	*	*Zea mays* L. (Corn)
Iridaceae:		*Tritonia crocosmiflora* (Lemoine) Nich.
Cyperaceae:		*Cyperus cypercides* (L.) O.K.

* Previously reported as host plants in Papua New Guinea (T.L. Fenner, pers. comm.)

The most commonly attacked species of grass was *Pennisetum clandestinum* Hochst.. However, as this species is preferentially planted in areas where the grass is frequently cut, the frequency with which it was attacked does not necessarily imply a feeding preference. Other grasses frequently attacked were *Digitaria didactyla* Willd. and *Cynodon dactylon* (L.) Pers..

Reports of damage to improved pasture most frequently involved *Setaria montana* Reeder and *Pennisetum purpureum* Schumach.

The only damage to food crops in indigenous gardens was to *Saccharum edule* Hassk. and *Zea mays* L. Despite the movement of bands through mature plantings of *Saccharum officinarum* L., no feeding was observed. Damage to young *S. officinarum* was reported to have occurred at several centres in the highlands.

Of the host plants recorded (*Table 3*) the only new record of interest is that of *Tritonia crocosmiflora* (Lamoine) Nich. (Iridaceae) which was observed being extensively eaten at Kainantu. Previous records of host plants have indicated that feeding by *S. exempta* is confined to the families Gramineae and Cyperaceae (Brown, 1972).

LARVAL BIOLOGICAL CONTROL AGENTS

The only previous record is of a eumenid wasp preying on larvae at Garaina in the Morobe Province (Gray, 1972).

Specimens of the toad, *Bufo marinus* L., collected from an area heavily infested by larvae of *S. exempta* at Natava Plantation in East New Britain Province in March 1973, were found to contain numerous *S. exempta* larvae in their gut (P. Bailey, pers. comm.). Pippet (1975) discussed the diet of *B. marinus* in relation to the control of harmful insects in Papua New Guinea.

Black starlings, possibly *Aplonis metallica*, were reported feeding on late instar larvae of *S. exempta* at Loani airstrip in the Milne Bay Province in March 1973 (D. Underwood, pers. comm.).

Platynopus Sp. (Hemiptera: Pentatomidae) was observed preying on final instar *S. exempta* larvae at Kainantu in the Eastern Highlands Province. Four instances of predation were noted in the space of 45 minutes (*Plate 1A*).

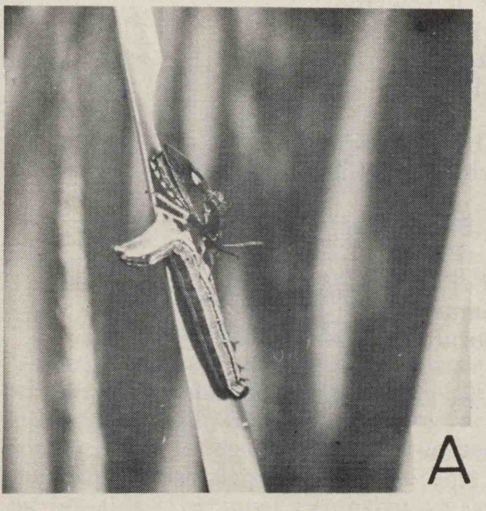

Plate 1. — A. ***Platynopus*** sp. attacking final instar *S. exempta* larvae.

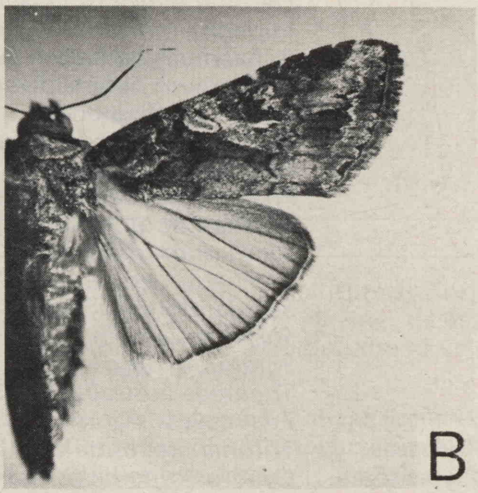

Plate 1. — B. Adult female *S. exempta*.

Microplitis sp. (Hymenoptera : Braconidae) is a suspected parasite on the larval stage. A cocoon of *Microplitis* sp. was collected on grass in association with a dead fourth instar *S. exempta* at Togoba, Western Highlands Province, on 6th April, 1973.

Diadegma sp. (Hymenoptera : Ichneumonidae) was bred from a cocoon collected in the soil in association with *S. exempta* pupae at Togoba in the Western Highlands Province in April 1973. Its association with *S. exempta*, if any, is unknown.

Trichionotus sp. (Hymenoptera : Ichneumonidae; Anomalominae; Gravenhorstiini) is possibly a larval parasite of *S. exempta*. Adults were attracted to bands of *S. exempta* larvae at Kainantu, Eastern Highlands Province, in March 1973. Also in March 1973, an adult was bred from a cocoon collected from the soil at Yonki, Eastern Highlands Province in association with *S. exempta* pupae.

Adults of the ichneumonids *Netelia* sp., *Echthromorpha insidiator* (Smith), *Echthromorpha* sp. nr. *insidiator* (Smith) and *Ischnojoppa luteator* F. were collected at Kainantu, Eastern Highlands province, seemingly attracted to bands of final instar *S. exempta* larvae. However, there was no confirmation that any of these species parasitised *S. exempta* larvae.

Adult tachinid flies were commonly observed associated with bands of *S. exempta* larvae, but in the majority of cases they were parasites of the pupal stage and eggs oviposited on the larvae did not hatch until the final moult. Only one species (Baker, in preparation) was an obligatory parasite of the larval stage. This species was rare with only four instances of parasitism by the species being recorded during the outbreak.

A spore-forming bacillus possibly caused the death of a larva collected adhering to a blade of grass at Yonki in the Eastern Highlands Province on 29th March, 1973. Other specimens of larvae collected dead in the field were heavily infected by fungi.

A nuclear polyhedrosis virus (D. Compson, pers. comm.) infected larvae held in the laboratory at Kuk Tea Research Station. No instances of viral death were noted in the field and the virus (PNG 8829) may have been the result of a cross infection from other diseased insect material held in the laboratory.

A non-occluded virus (PNG 9991) was contained in the body of a single larva bred from the egg stage in the laboratory. Microsporidia were commonly found associated with dead larvae bred from eggs in the laboratory (D. Compson, pers. comm.).

No attempt was made to determine mortality of larvae under field conditions. However, the small number of observations made of predators and the few observations of diseased larvae would indicate there was low mortality of the larval stage.

PUPAL STAGE

In the Markham Valley pupation commenced prior to 22nd March, 1973 (D. Sands, pers. comm.). Larvae collected at Yonki on 29th March, 1973 and retained in the laboratory commenced pupating on 30th March, 1973 and all had pupated by 6th April, 1973. In the Western Highlands Province no viable larvae were found at either Togoba or Korn Farm after 10th April, 1973.

The density of pupae in the soil varied with soil type. In loose friable soil cultivated for a food garden at Togoba, the number of pupae per 0.5 m^2 ranged from 180 to 347 (mean 225; n = 5). In heavier clay soil supporting a grass cover at Korn Farm, the number of pupae per 0.5 m^2 ranged from 48 to 89 (mean 64.8; n = 5). When pupation took place in heavy clay soils the anterior end of the pupae usually projected 2 — 4 mm above the soil surface. Pupae, even at some depth, were characteristically vertically orientated in clay soils. In loose friable soils the tendency for the pupae to be orientated vertically was not as obvious and a more random orientation was found. Where loose friable soils were mixed with heavier soils there was a higher density in the more friable soil.

The duration of the pupal stage under laboratory conditions ranged from 8 to 12 days (*Table 2*). The time of pupation of larvae in the field was difficult to assess and the pupal period can only be approximately determined. At Togoba, pupation commenced on 28th March, 1975. Most larvae had entered the soil to pupate by 5th April, 1975. Peak adult emergence took place between 14th and 19th April, 1975 (*Figure* 3), giving a pupal period of from 9 — 21 days.

PUPAL BIOLOGICAL CONTROL AGENTS

A species of *Pheidole* (serial number 446) was observed at Togoba preying on prepupae and pupae. In one sample, 20 out of 47 pupae had been preyed upon by *Pheidole* sp. 446. A nest of the ant was located in the soil in association with the sample.

Elaterid larvae were often found in the soil during sampling, and two instances of predation upon pupae were noted.

Ichneumon promissorius Er. (Hymenoptera : Ichneumonidae) was frequently recorded as a parasite of *S. exempta* pupae in the Western Highlands Province and to a lesser extent in the Eastern Highlands Province. In Papua New Guinea, *I. promissorius* is also a parasite of pupae of the noctuids, *Tiracola plagiata* (Walk.) and *Agrotis ipsilon* (Hufnagel) (Baker, 1974).

Lissopimpla scutata Krieger (Hymenoptera : Ichneumonidae) was infrequently encountered as a parasite of *S. exempta* pupae, being bred only from *S. exempta* pupae collected at Togoba in the Western Highlands Province in March 1973. At this location it was considerably less abundant than *I. promissorius*, only 8 specimens being bred from samples which yielded 103 *I. promissorius*. *L. scutata* is also a parasite of the pupae of *T. plagiata* (Baker, 1974).

A complex of tachinid parasites was found parasitising the pupal stage of *S. exempta* during the outbreak. The complex involves at least four species (R. Crosskey, pers. comm.), all of which lay macrotype eggs on the final instar larvae which hatch at the time of the final moult. The fully developed tachinid larvae emerge from the host pupae approximately 6 days after the time of pupation of the host. The pupal period is approximately 14 days.

The complex of parasitic tachinids was of slightly greater importance as biological control agents of *S. exempta* pupae than the Ichneumonid species complex (*L. scutata, I. promissorius*).

Although numerous non-viable pupae were collected in samples taken from field infestations, they contained no dectectable micro-organisms which may have contributed to their death, but frequently were heavily bacterially contaminated (D. Compson, pers. comm.). The symptoms of the condition were a loss of flexibility by pupae and an elongation of the abdominal segments. The contents of pupae dried out to a corky material, often with a central cavity. Desiccated pupae are of similar internal appearance, however shrivelling of the pupal case was invariably associated with desiccation.

FIELD ASSESSMENT OF PUPAL MORTALITY

The viability of all *S. exempta* pupae found in a soil sample of 0.5 m^2 by 10 cm deep was assessed at several times during the pupal development period at two sites in the Western Highlands Province. The results are shown in *Table 4*.

The most frequent cause of pupal

mortality was a pathological condition of unknown identity. The incidence of the condition increased towards the end of the pupal development period at both sites to levels between 20 and 30 per cent of pupae (*Table 4*).

Table 4. — Viability of *S. exempta* pupae in 0.5 m^2 soil samples at two locations in the Western Highlands Province.

Location	Date	Per cent of samples: Viable	Adults emerged	Preyed upon	Parasitised*	Dead (cause unknown)	Sample size
Togoba	6.4.73	87.3	0	12.7**	0	0	220
	10.4.73	92.8	0	2.7	2.2	2.2	179
	13.4.73	82.9	2.5	0	6.2	8.3	194
	18.4.73	43.2	26.7	2.3	5.1	22.7	176
	25.4.73	68.5	12.2	2.2	3.3	13.8	181
Korn Farm	6.4.73	94.8	0	2.5	0	2.5	77
	10.4.73	89.6	0	0	0	10.3	58
	13.4.73	71.4	0	0	0	28.6	42
	18.4.73	51.0	21.2	0	0	27.6	47
	25.4.73	63.7	8.6	0	0	27.5	58

* Empty pupae from which parasite had emerged.

** Exceptionally high level of predation in vicinity of an ant's nest (*Pheidole sp.*).

No pupae from which tachinid parasites had emerged were recorded at the Korn Farm site although tachinid pupae were found in the soil (*Table 5*). Parasitism at the Togoba site was generally less than 6 per cent (*Table 4*). Tachinid pupae were also more abundant at the Togoba site than at the Korn Farm site (*Table 5*). Adult tachinids had emerged from all pupae found on 25th April, 1973. Predation was insignificant at both sides.

Table 5. — Number of tachinid puparia found in 0.5 m^2 soil samples at two locations in the Western Highlands Province

Date (April 1973)	7	10	13	18	25
Togoba	2	4	14	11	19*
Korn Farm	0	0	3	1	4*

** Adults had emerged.*

LABORATORY ASSESSMENT OF PUPAL MORTALITY

At irregular time intervals during the pupal development period large samples of pupae were randomly collected at Togoba and Korn Farm in the Western Highlands Province. The pupae were held in the laboratory at Kuk Tea Research Station in large paper bags partially filled with soil. The number of adult *S. exempta* and adult parasites to emerge was recorded daily. Details are shown in *Figures 3* and *4*, and *Table 6*.

Table 6. — Emergences from field collected *S. exempta* pupae

Location	Date Sampled	Emergences as per cent of sample: Adult *S. exempta*	*I. promissorius*	*L. scutata*	tachinids	% Dead	Sample Size
Togoba	6.4.73	66.1	0.9	0	10.9	21.9	546
	10.4.73	32.9	0.9	0.1	14.4	51.5	728
	13.4.73	33.3	0.8	0.3	1.4	64.0	690
	18.4.73	7.6	5.7	0.2	0.1	86.3	1,337
	25.4.73	0	2.2	0.5	0	97.2	404
Average		25.1	2.7	0.2	4.7	67.0	Total 3,705
Korn Farm	5.4.73	41.3	3.0	0	6.7	48.8	133
	6.4.73	33.6	5.0	0	5.5	55.6	413
	10.4.73	15.6	0	0	0	84.4	83
	13.4.73	12.7	1.4	0	2.1	83.6	141
	18.4.73	0	13.6	0	1.5	84.8	66
	25.4.73	0	0	0	0	100	37
Average		25.7	4.1	0	4.1	65.9	Total 773

By far the most important cause of mortality was the pathological condition which has been previously discussed.

In samples taken prior to significant adult emergence between 20 and 50 per cent of pupae succumbed to the condition. The incidence of the condition increased in samples taken late in the larval development period. In samples taken subsequent to peak adult emergence, the majority of pupae had been killed by the condition (*Table 6*). Samples taken after peak adult emergence are however necessarily biased in favour of the collection of non-viable pupae. There is an apparent inverse relationship between the incidence of the condition and the length of time pupae were retained in the laboratory. This suggests that a causal factor in the field was absent in the laboratory. This, however, is not necessarily the case. In order to obtain samples of comparable size greater areas were searched over at later samplings when adult emergence had lessened the availability of pupae. As previously stated such samples are invariably biased to favour collection of non-viable pupae.

Parasitism by tachinids was the second most important cause of mortality (*Table 6*). Parasitism rates were much higher for samples collected early in the pupal development period than late in the development period (*Table 6*). In several instances no tachinids were recovered from samples of pupae taken after *S. exempta* adult emergences commenced (*Figures 3 and 4*). This is due to the fact that fully developed tachinid larvae usually emerge from host pupae within six days of pupation of the host. As a result, samples of host pupae taken after this time rarely contain tachinid larvae.

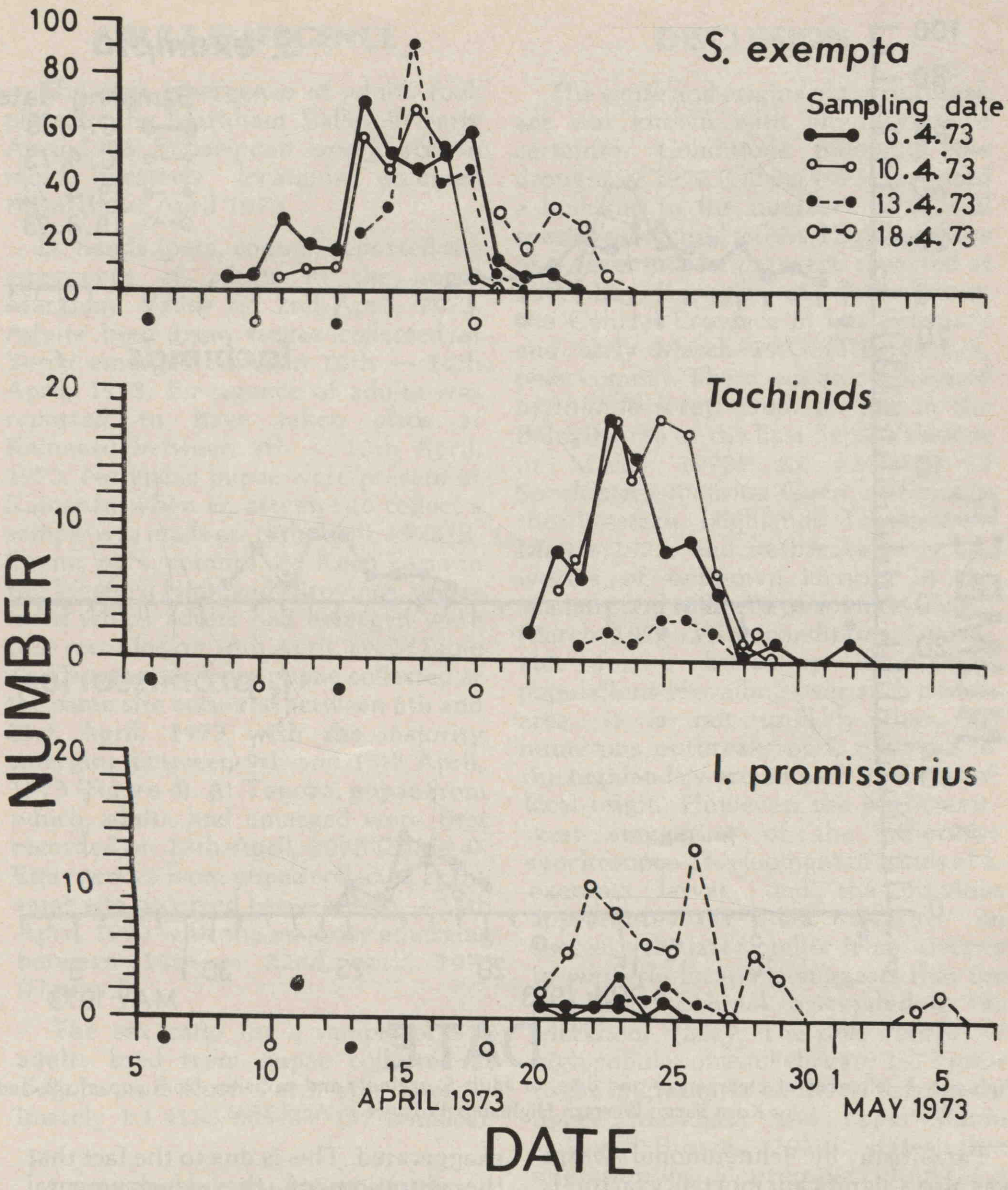

Figure 3. — Number of emergences and date, of adult *S. exempta* and parasites from pupae collected at Togoba, Western Highlands Province in April 1973.

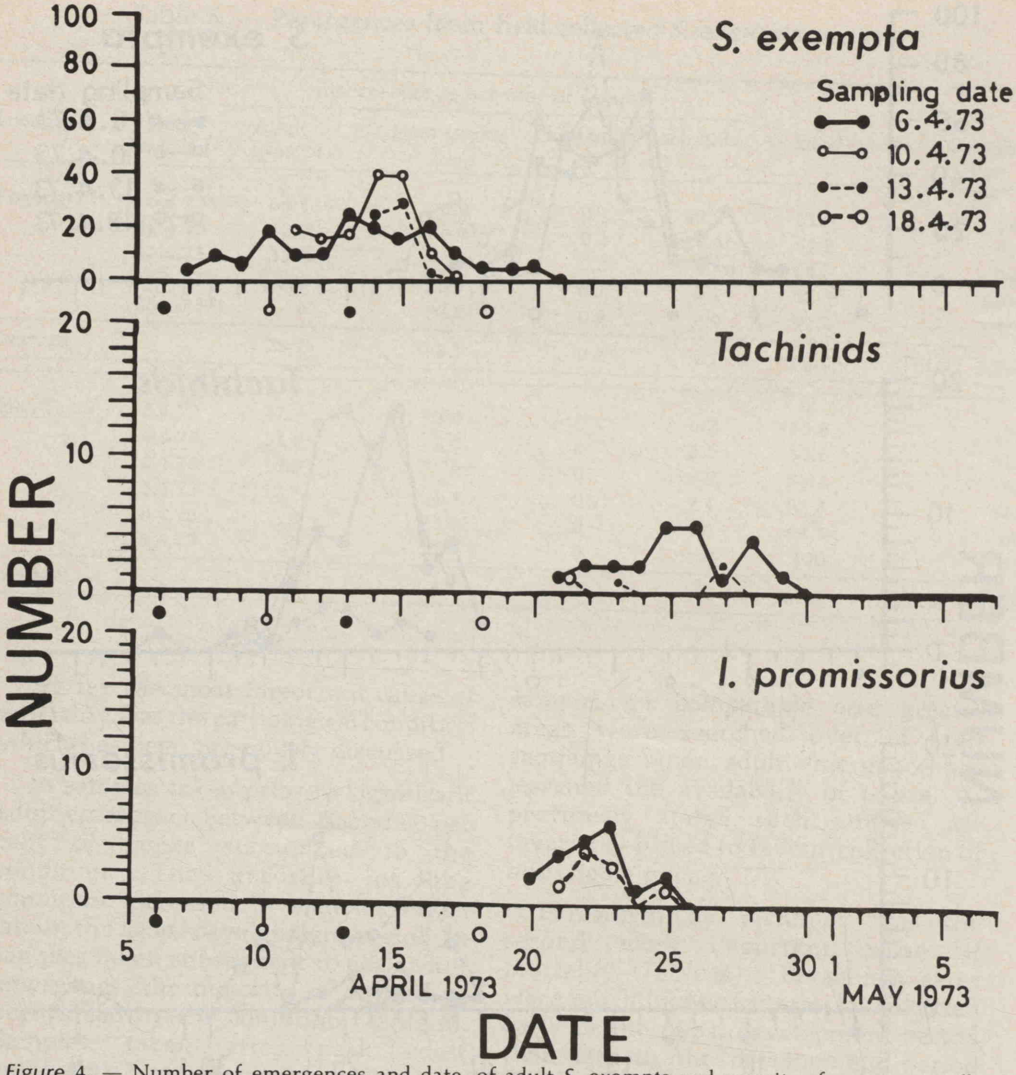

Figure 4. — Number of emergences and date, of adult *S. exempta* and parasites from pupae collected at Korn Farm, Western Highlands Province in April 1973.

Parasitism by Ichneumonid wasps was also a significant mortality factor. *L. scutata* was not recorded from the Korn Farm site and was only of slight importance at the Togoba site where the highest parasitism rate recorded was 0.5 per cent (*Table* 6). *I. promissorius* was considerably more important, with the highest parasitism rate recorded being 13.6 per cent for a sample collected at Korn Farm late in the host's pupal development period (*Table* 6). Parasitism rates by Ichneumonids recorded for samples collected late in the pupal period of the host tend to be much exaggerated. This is due to the fact that the duration of the developmental stages of the Ichneumonid within the host is greater than the duration of the host's pupal stage. Samples of *S. exempta* pupae collected at Korn Farm after 18th April, 1973 and at Togoba after 25th April, 1973 yielded no *S. exempta* but numerous *I. promissorius*. Baker (1974) observed a similar trend with Ichneumonid parasites of *Tiracola plagiata* (Walk.) during an outbreak in the Western Highlands Province in 1970.

ADULT EMERGENCE

The first emergence of adults took place in the Markham Valley in early April 1973. Subsequent emergences in more westerly locations occurred throughout April 1973.

D. Sands (pers. comm.) reported the emergence of adults in the upper Markham Valley on 2nd April, 1973. Adults bred from larvae collected at Yonki emerged between 10th — 14th April, 1973. Emergence of adults was reported to have taken place at Kainantu between 9th — 13th April, 1973. No viable pupae were present at Kainantu when an attempt to collect a sample was made on 14th April, 1973 (R. Carne, pers. comm.). At Korn Farm in the Western Highlands Province, pupae from which adults had emerged were first recorded on 18th April, 1973 (*Table 4*). Emergences from pupae collected at the same site occurred between 6th and 21st April, 1973 with the majority emerging between 9th and 15th April, 1973 (*Figure 4*). At Togoba, pupae from which adults had emerged were first recorded on 13th April, 1973 (*Table 4*). Emergences from pupae collected at the same site occurred between 9th — 24th April, 1973 with the majority emerging between 14th — 22nd April, 1973 (*Figure 3*).

The sex ratio for a sample of 315 adults bred from pupae collected at Togoba and Korn Farm was approximately 1:1 (158 males : 157 females).

FAILURE OF OUTBREAK TO CONTINUE

There were no reports of unusual activity at night by adult *S. exempta* at the time when emergences were taking place.

There were no sightings or reports of larvae or damage to field crops at the time when a further generation of larvae was expected in May 1973.

DISCUSSION

The cause and origins of the outbreak are not known with any degree of certainty. Conditions following the drought of 1972 (Gibbs, 1973) favoured a build up in the numbers of several species of noctuid moths. High numbers of *S. exempta* larvae were reported at Idlers Bay, Kapogere and Patikalana in the Central Province in late February and early March 1973 (T.L. Fenner, pers. comm.). There was an outbreak of *Mythimna loreyi* Dup. on rice in the Bainyik area of the East Sepik Province in March 1973; an outbreak of *Spodoptera mauritia* Guen. at Banz in the Western Highlands Province in March 1973, and outbreaks of armyworms of unknown identity in the Madang and Milne Bay Provinces also in March 1973. With conditions favourable for a build up in noctuid populations prevailing over such a wide area, it is not unlikely that the numerous outbreaks of *S. exempta* in the highlands were, in each instance, of local origin. However, the slight east-west staggering of the otherwise synchronous development of bands of *S. exempta* larvae, and the previous appearance of adult swarms on successively later nights from easterly to westerly locations suggests that the highlands outbreak originated in the Markham Valley. The only records of high populations in February 1973 prior to the migration of adults were from the upper Markham and upper Ramu Valleys. Brown (1972) states that migration by *S. exempta* adults is a dominating biological feature in the life of the adult and that movement is downwind. In East Africa such migrations result in large scale movement of extensive moth populations, which may concentrate more or less simultaneously in a distant area of wind convergence. The movement is by night and usually unobserved, and the moths breed to produce larvae at high densities and often closely synchronised in development (Brown, 1972). However, there is only fragmentary evidence to support the contention that a similar course of events took place prior to the outbreak of March 1973.

The low rainfall throughout Papua New Guinea in 1972 may have been indirectly responsible for the outbreak of March 1973. A reduction in the population of *S. exempta* during the drought would have been expected because of the limited availability of young regrowth for larval development. In certain areas badly affected by the drought this could have resulted in population levels falling below the threshold for the maintenance of parasite populations. The upper Markham Valley was one area severely affected by the drought. With the resumption of favourable conditions, highly successful breeding, in the absence of the restraint imposed by parasites, may have led to the explosive increase in numbers in the upper Markham Valley in late February, 1973. This was almost certainly the sequence of events in an outbreak at Bulolo in 1970 where Gray (1972) found a noticeable absence of parasites.

Breeding by the migrant population in their Highlands invasion area was unsuccessful, despite the initial production of larvae in outbreak proportions. This collapse in the population was due to high mortality of pupae. The principal pupal mortality factor was a pathological condition, the cause of which was not identified. No pathogenic organisms were consistently associated with the condition. The relatively indiscriminate nature in which pupation sites are, by necessity, selected and utilised by large banded populations of larvae, may have resulted in pupation at sites physically unsuitable for pupal development. There is an obvious need for further investigation to identify the cause of this prevalent mortality factor.

Parasitism of pupae by a complex of ichneumonids and tachinids was unexpectedly high for the first generation of progeny by a large immigrant population. The parasitism rates recorded indicate the base population of *S. exempta* or alternate hosts present in the highlands, prior to the influx of *S. exempta*, had been ample to maintain a large reserve of parasites. Parasites, however, appear to have been a relatively minor factor in the sequence of events which led to the population decline.

The collapse of the outbreak in the upper Markham Valley would have been contributed to by the proposed migration of a large proportion of the population to the Highland Provinces in early March 1973. No observations were made on mortality factors in the residual population's progeny.

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