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CONTENTS

ABSTRACTS

HOST AND DISTRIBUTION RECORDS OF *HELOPELTIS CLAVIFER* (WALKER) (HETEROPTERA : MIRIDAE) IN PAPUA NEW GUINEA

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ERRATA

p. 34 In the last line of the first paragraph "factorail combinations" should read, "factorial combinations".

p. 38 In *Table 6* for Period 2 in column 2, the nitrogen rate "125" should read, "12.5".

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(continued overleaf)

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Dorothy E. Shaw and G.R. Kula, *Papua New Guin. agric. J.*, 29 (1 — 4) : 5 — 10

A leaf and stem disease of peanut (groundnut, *Arachis hypogaea*), is reported from New Britain. It is caused by a clamped fungus, with no perfect state known as yet, which is designated *Sclerotium* sp. at present. Large sclerotia, distinct from those of the common sclerotial species, up to 6 mm long, very irregular in shape and pale tan to orangy tan in colour, but never dark brown, were found on the surface of the soil and on moribund parts of *Xanthosoma* sp. in the field, and formed on the soil surface after inoculation and sparsely on nutrient agar. Peanut, cowpea and Poona pea (*Vigna unguiculata*), snake or yard long bean (*V. unguiculata* ssp. *sesquipedalis*), snap or dwarf bean (*Phaseolus vulgaris*) and *Crotalaria anagyroides* were susceptible when inoculated with four different isolates from the sclerotia and the peanut, while *Xanthosoma* sp. was immune.

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

G.L. Baker, *Papua New Guin. agric. J.*, 29 (1 — 4) : 11 — 26

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 contibuted 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 graminaea 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.

(continued overleaf)

INSECTICIDES AGAINST LARVAE OF THE CACAO WEBWORM *PANSEPTA TELETURGA* MEYRICK (LEPIDOPTERA : XYLORYCTIDAE)

P.T. Bailey and D.F. O'Sullivan, *Papua New Guin. agric. J.*, 29 (1 — 4) : 27 — 32

Thirty-five insecticides were screened for effectiveness against larvae of *Pansepta teleturga*, a woodborer in cacao trees. Several of the more promising insecticides were selected for field trials, using 1 or 2 of 3 methods of application:

(i) spraying onto the web,
(ii) application of systemic insecticides to the bark, and
(iii) swabbing a dilute solution onto the feeding area.

Swabbing was the only effective method. Endrin, azinophos-ethyl and dimethoate were the most effective insecticides when swabbed. Dimethoate is recommended because of its comparatively low mammalian toxicity.

YIELD OF PARA GRASS *(BRACHIARIA MUTICA)* AS INFLUENCED BY SOURCE, RATE AND FREQUENCY OF APPLICATION OF FERTILIZER NITROGEN

P.A. Chadhokar and A.E. Charles, *Papua New Guin. agric. J.*, 29 (1 — 4) : 33 — 50

Ammonium sulphate, ammonium nitrate and urea at rates of 100 and 200 kg per year were applied to a Para grass pasture in the wet tropics over three periods of about a year each. In the first period, a single initial application was compared with three splits at about 15 week intervals. In the second and third periods, comparison was between 4 splits at 12 week intervals and 8 splits at 6 week intervals.

Drymatter yields averaged 36 kg per kg N applied for ammonium nitrate, 29 kg for ammonium sulphate and 25 kg for urea. Response to frequency of application was small. There was little residual effect beyond six weeks after application. Response appeared almost linear to increasing rates up to 50 and perhaps even 200 kg per ha per application.

Nitrogen content of herbage cut at 6 to 8 week intervals averaged about 1%, with very little effect of treatments. Recovery of applied nitrogen averaged 42, 28 and 27 per cent in the three successive periods.

HOST AND DISTRIBUTION RECORDS OF *HELOPELTIS CLAVIFER* (WALKER) (HETEROPTERA : MIRIDAE) IN PAPUA NEW GUINEA

E.S.C. SMITH *

ABSTRACT

A total of 25 plant species, representing 15 families are recorded as hosts of the mirid Helopeltis clavifer *(Walker) in Papua New Guinea. Seventeen of these are new records.*

The host plant feeding damage and distribution of H. clavifer *is also outlined.*

Although the insect is at present a serious pest of only two crops (cocoa and tea) in certain areas of this country, it is possible that as agricultural development continues, it may develop into a pest of other crops grown here.

INTRODUCTION

Members of the genus *Helopeltis* (Heteroptera: Miridae) are widely distributed throughout the old world tropics, and are responsible for serious damage to at least 30 species of agriculturally important tropical plants. For example, *H. chinchona* Mann, distributed in Indonesia and South East Asia, has been recorded from more than 60 different host plants (Lever 1949) while Miller (1941) listed a total of 38 host plants of *H. antonii* Sign. and *H. theivora* Waterhouse.

Cocoa (*Theobroma cacao* L., Fam. Sterculiaceae) is attacked by various *Helopeltis* species wherever it is grown in the old world. *H. clavifer* (Walker) is one of the most important cocoa pests on the mainland of Papua New Guinea (Smith 1973), in Irian Jaya, Indonesia (Simon Thomas 1962) and in Sabah, Malaysia (Conway 1971), but little has been published on alternate host plants of this pest. Simon Thomas (1962) listed *Ipomoea batatas* (L.) Lam. (Fam. Convolvulaceae) (sweet potato) and *Leucaena leucocephala* (Lam.) de Wit (as *L. glauca*) (Fam. Fabaceae) as hosts of *H. clavifer* in Irian Jaya, while in Sabah, *Psidium guajava* L. (Fam. Myrtaceae) (guava) and *Anacardium occidentale* L. (Fam. Anacardiaceae) (cashew nut) are known to be attacked (Conway 1971). In Papua New Guinea, the mirid has been reported to damage *Flemingia strobilifera* (L.) R.Br. (Fam. Fabaceae) (Anon. 1971), and Szent-Ivany (in press) has recorded six other host plants, namely *Camellia sinensis* (L.) O. Kuntze (Fam. Theaceae) (tea), *Centrosema pubescens* Benth. (Fam. Fabaceae), *Ipomoea hederifolia* L. and *I. batatas* (Fam. Convolvulaceae), *Mimosa invisa* var. *inermis* Adelb. (Fam. Mimosaceae) and *Pueraria phaseoloides* Benth. (Fam. Fabaceae).

This paper records additions to the existing information on alternate hosts of *H. clavifer* in Papua New Guinea. Host plant families are arranged following Hutchinson (1973).

PLANT DAMAGE

Plant feeding mirids, to which group *H. clavifer* belongs, have mouthparts capable of piercing deeply into plant tissue and sucking out the cell contents. Goodchild (1952) studied the digestive

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system of *H. bergrothi* Reut., and proposed that host plant damage was caused mainly by the chemical affects of an injected toxic saliva, rather than the mechanical effects of feeding.

The typical feeding damage caused by *H. clavifer* is a necrotic area of cell tissue called a lesion. While the insect is still feeding, a water soaked area develops around the point of entry of the mouthparts, and the area becomes well defined within one hour, rapidly becoming dark brown to black due to death of plant cells caused by the toxic saliva. Lesions are particularly obvious on green stems and shoots where they are elongate in shape, but on fruits the lesions are generally circular. Feeding damage to flush shoots and soft leaves (where secondary veins are generally attacked) causes malformation and curling of the shoot and leaf, or in severe cases, death of the terminal bud and shoot. If terminal shoot growth is affected, secondary and occasionally tertiary lateral shoot proliferation occurs, thus creating a deformed and stunted plant.

When very young fruits are attacked, they frequently shrivel and die, while older fruits may be reduced in size, malformed, pitted or scabbed, due to *H. clavifer* feeding action.

NEW HOST RECORDS

Acalypha caturus Bl. (Fam. Euphorbiaceae). Adults and nymphs observed feeding on young flush tissue of this secondary regrowth tree. Garaina, Morobe Province.

Anacardium occidentale (Fam. Anacardiaceae) (cashew nut). Adults and nymphs were observed to attack flush growth of five year old trees, causing the death of some growing points and subsequent ramification below the damaged tissues. Developing fruits were malformed and showed sunken feeding scars, while flower shoots were often severely damaged. Eggs were found embedded in the leaf petioles. Attack to the growing points of young seedlings has also been reported (Hartley 1974). Popondetta Agricultural College (P.A.C.), Popondetta, Northern Province.

Annona reticulata L. (Fam. Annonaceae). Adults noted feeding on developing fruits. Garaina, Morobe Province.

Annona squamosa L. (Fam. Annonaceae) (custard apple). Nymphal stages were observed to cause moderate damage to soft flush growth and very young fruits. P.A.C., Popondetta, Northern Province.

Bixa orellana L. (Fam. Bixaceae) (annatto dye). Adults and nymphs were reported to feed on veins of flush leaves, particularly those shaded from the sun, causing the death of adjacent tissue and leaf crinkling. Bubia Agriculture Research Centre and Wau, Morobe Province.

Cassia fistula L. (Fam. Caesalpiniaceae) (Indian laburnum). Adults and nymphs were seen feeding on flush growth and causing minor damage. P.A.C., Popondetta, Northern Province.

Eucalyptus deglupta Bl. (Fam. Myrtaceae) (kamerere). Adults and nymphs were observed attacking flush growth and causing moderate damage and ramification. Lejo Experiment Station, North Sangara, Northern Province.

Flemingia sp. prob. *congesta* Roxb. (Fam. Fabaceae). Adults and nymphs were observed feeding on flush tissue, and eggs were found embedded in leaf petioles of plants used as temporary shade for young cocoa trees. Lejo Experiment Station, North Sangara, Northern Province.

Gliricidia sepium (Jacq.) Stewd. (Fam. Fabaceae). A single adult was observed feeding on flush tissue of a cocoa shade tree. P.A.C., Popondetta, Northern Province.

Ixora chinensis Lamk. (Fam. Rubiaceae). Adults were seen feeding on soft flush growth and flower shoots,

causing distortion. Eggs were found embedded in soft flush tissue. P.A.C., Popondetta, Northern Province.

Leucaena leucocephala (Fam. Fabaceae). On several occasions, adults were observed feeding on flush growth of cocoa shade trees. P.A.C., Popondetta, Northern Province.

Mangifera indica L. (Fam. Anacardiaceae) (mango). Distortion of shoot growth and proliferation of young shoots resulted from the feeding of adults and nymphs. Damage was occasionally severe. Popondetta, Northern Province.

Mangifera sp. (Fam. Anacardiaceae) ('bush' mango). Adults and nymphs were observed feeding on flush growth of a small tree and caused minor damage. Sangara, Northern Province.

Passiflora edulis Sims (Fam. Passifloraceae) (passion fruit). Adults and nymphs were reported to feed on flush tissue of a vine, causing minor damage only. Wau, Morobe Province.

Polyscias sp. poss. *fruticosa* (L.) Harms. (Fam. Araliaceae). Moderate damage was caused when nymphs and adults fed on flush growth. Eggs were found embedded in flush tissue. This shrub, which grows to a height of 2 — 3m is much used as a hedge and border plant around Northern Province villages. Popondetta, Northern Province.

Persea americana Mill. (Fam. Lauraceae) (avocado). Adults and nymphs were observed to attack soft flush growth and flower shoots, causing distortion and death of tissue. P.A.C., Popondetta, Northern Province.

Psidium guajava (Fam. Myrtaceae) (guava). Adults and nymphs were seen to attack soft flush tissue, causing moderate to severe damage and proliferation of side shoots. Insect feeding attack also caused scabbing on developing fruits. Eggs were found embedded in ripening fruits. P.A.C., Popondetta, Northern Province.

The immature stages of *H. clavifer* are soft-bodied, delicate insects which are liable to desiccation (Smith 1973) and consequently are very rarely found away from a host plant. Since immature stages were found, it is very probable that the mirid would breed on all of these newly reported host plants, with the exception of *G. sepium* and *L. leucocephala*. Feeding on these two species of cocoa shade trees was probably incidental.

DISTRIBUTION WITHIN PAPUA NEW GUINEA

Szent-Ivany (in press) has reported that the distribution of *H. clavifer* within Papua New Guinea was the Central, Northern, Morobe, Eastern Highlands and New Ireland Provinces, and ranged from sea level to approximately 1,670m (5,500 ft.). Recently, *H. clavifer* has been recorded on cocoa in the Madang and Milne Bay Provinces, and since the insect is found in several localities along the North Coast of Irian Jaya, it is likely that its distribution ranges into the Sepik, Gulf, Western and some of the Island Provinces of Papua New Guinea.

In October 1978, adult and nymphal specimens of *H. clavifer* were collected from an as yet unidentified plant growing in the lower story of primary forest in the Burit area of the Baining Mountains, East New Britain Province (elevation about 450m). This is only the second record from the island region of Papua New Guinea, the first being from cocoa pods at Matakan Plantation, Namatanai District, New Ireland Province during March 1965.

It is possible that other infestations of *H. clavifer* have not yet been recorded because they may occur on flush tissue of tall trees in virgin forest. In Indonesia, Leefmans (1920) has reported that *Helopeltis* infestations of this type may only occasionally descend from the forest canopy, and are therefore rarely observed.

DISCUSSION

These records increase the number of plant species on which *H. clavifer* has been recorded in Papua New Guinea by 17, and bring the total number of hosts to 25 species, representing 15 plant families. At present, the mirid is a serious pest of only two cash crops, cocoa and tea, but extensive damage can result to many other plant species due to the toxic effects of feeding.

In other countries, species of *Helopeltis* may attack a wide range of fruit and nut crops (e.g. apple, grapes, rambutan), spices (chillies, cinnamon, pepper), fibre and beverage crops (coffee, cotton, kapok), shade trees (*Albizia, Sesbania, Tephrosia*) timber trees (camphor, *Eucalyptus*, mahogany) and ornamentals (*Gardenia, Begonia, Fuchsia*). Some of these species are already growing in this country, and some others may be considered as cash crops in the future. It could therefore be expected that *H. clavifer* will become a major pest of other crops in Papua New Guinea as agricultural development continues.

ACKNOWLEDGEMENTS

I am grateful to Dr W.C. Gagné of the Wau Ecological Institute for permission to publish the *P. edulis* host record, and to Dr J.J.H. Szent-Ivany and my colleagues in the Department of Primary Industry for their comments on the manuscript. I am also indebted to Mr E.E. Henty, Senior Botanist, Division of Botany in the Office of Forests at Lae who identified the botanical specimens.

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A DISEASE OF SOME LEGUMES IN PAPUA NEW GUINEA CAUSED BY *SCLEROTIUM* SP.

Dorothy E. Shaw* and G.R. Kula*

ABSTRACT

A leaf and stem disease of peanut (groundnut, Arachis hypogaea*), is reported from New Britain. It is caused by a clamped fungus, with no perfect state known as yet, which is designated* Sclerotium *sp. at present. Large sclerotia, distinct from those of the common sclerotial species, up to 6 mm long, very irregular in shape and pale tan to orangy tan in colour, but never dark brown, were found on the surface of the soil and on moribund parts of* Xanthosoma *sp. in the field, and formed on the soil surface after inoculation and sparsely on nutrient agar. Peanut, cowpea and Poona pea* (Vigna unguiculata), *snake or yard long bean* (V. unguiculata *ssp.* sesquipedalis), *snap or dwarf bean* (Phaseolus vulgaris) *and* Crotalaria anagyroides *were susceptible when inoculated with four different isolates from the sclerotia and the peanut, while* Xanthosoma *sp. was immune.*

In January 1976, Mr S. Rangai, an officer at the Lowlands Agricultural Experiment Station, Keravat, New Britain (P.N.G.), forwarded a deteriorated corm of *Xanthosoma* sp. (Araceae) to Konedobu for examination. It was found to have sclerotia about 2 mm in diameter on the rotted tissue, some on the outside of the corm, and many on the dead leaves. Apparently the sclerotia were first noticed on the material in the field by Dr C. Prior. Sclerotia were surface sterilized with mercuric chloride (1: 1000), washed in sterile water and after plating on potato dextrose agar (PDA), the fungus was obtained in culture (PNG 10090) by Mr W.A. Layton. The sclerotial fungus was not obtained from surface sterilized tissue taken from the margin of the rotted and the symptomless tissue of the corm.

In March 1976, Mr Rangai forwarded another unthrifty *Xanthosoma* plant from the same area, and a culture (PNG 10131) was established by G.R.K. from sclerotia loosely attached to the corm.

In the same month, Mr Rangai found sclerotia on the surface of the soil around healthy *Xanthosoma* plants at Site U in another part of the Gazelle Peninsula of New Britain, and from these, culture PNG 10140 was established by G.R.K.

The sclerotia received from the field were up to 6 mm long, very irregular and angular (*Plate* I), pale tan to orangy tan in colour, not becoming brown at any stage, and therefore differing from sclerotia of *Sclerotium rolfsii* in shape, size and colour.

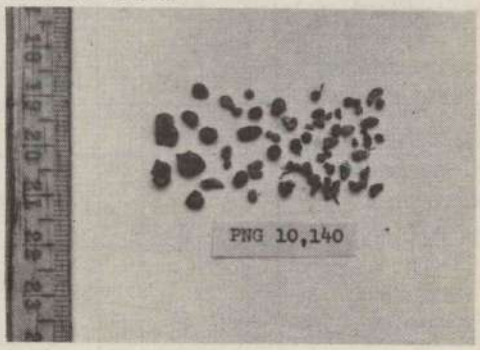

Plate I Sclerotia from the surface of the soil around healthy *Xanthosoma* plants in the field

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Mr Rangai was asked by the senior author to check other crops at Site U and in late March 1976, forwarded diseased peanuts (*Arachis hypogaea* L.) from that site. He had noted that the leaves were chlorotic and necrotic and that the stems were dying off above ground level, and that sclerotia were present in large numbers on affected stems. When examined, the plants were found to have a rot at the collar and on some leaves, with white mycelium evident to the naked eye, especially on the collar. No perfect state was present on the material. Culture PNG 10164 was established by D.E.S. from diseased stem tissue after alcoholic dip.

All the isolates from the above accessions were similar or nearly so in culture, having vigorously growing white mycelium, slightly fluffy and somewhat stringy on PDA and with clamps. On PDA small sclerotia (1 to 2 mm diameter) formed in isolates PNG 10090 and 10140, formed sparsely in 10164, and did not form in isolates 10140 and 10164 in later subcultures; no perfect state formed in any isolate.

Inoculations were carried out on healthy *Xanthosoma* sp., and on taro (*Colocasia esculenta* (L.) Schott) (both Araceae) and on coconut (*Cocos nucifera* L.) using isolates PNG 10090 and PNG 10131 (both derived from sclerotia loosely attached to unthrifty *Xanthosoma* plants) and PNG 10140 (derived from sclerotia from the surface of the soil around healthy *Xanthosoma*). The inoculum consisted of pieces (about 5 mm square) cut from young vigorously growing cultures on PDA, applied to the base of the petioles, and on to the surface of the soil, and incubated under plastic for 48 hours after spraying with tap water; controls were inoculated with PDA pieces without fungus and incubated, while other control plants were untreated in any way.

The results of the inoculations are summarized in *Table 1*. Mycelium from the inoculum pieces grew vigorously, especially from those on the surface of the soil; mycelium from the latter also produced sclerotia similar to the largest

Table 1. — Summary of results of first inoculation test carried out with sclerotial isolates

Plant species inoculated	Number of plants						Rating
	Controls*+	Inoculated				Infected	
		Isolates#					
	Total	PNG 10090	PNG 10131	PNG 10140	Total	Total	
Xanthosoma sp.	14	6	2	2	10	0	Immune
Colocasia esculenta (taro)	4	2	2		4	0	Immune
Cocos nucifera (coconut)	4	2			2	0	Immune
	22	10	4	2	16	0	

* Controls included plants inoculated with PDA only and incubated, and others without any treatment or incubation

\+ No infection occurred on any control plant

\# See text for origin of isolates

forwarded from the field. However, neither the *Xanthosoma*, nor the taro, nor the coconut became infected with any of the three isolates. It was concluded, therefore, that the sclerotial fungus had probably been growing as a saprophyte on the dead leaves in the field, and was not a pathogen of the *Xanthosoma*. (Studies on the unthriftiness of the *Xanthosoma* are being reported elsewhere.)

In the second inoculation experiment, two of the isolates used above (PNG 10090 and PNG 10140) and isolate PNG 10164 from diseased peanut tissue were inoculated on to *Xanthosoma* sp., peanut, cowpea and Poona pea (*Vigna unguiculata* (L.) Walp.), snake or yard long bean (*V. unguiculata* ssp. *sesquipedalis* (L.) Verdc.), snap or French dwarf bean (*Phaseolus vulgaris* L.) and *Crotalaria anagyroides* H.B. & K.. The inoculation procedure was similar to that of the first experiment, except that the pieces were usually about 3 x 3 mm square, and some were placed directly on the upper surface of the leaflets.

The results are shown in *Table 2*. *Xanthosoma* sp. was again immune to all three isolates. Cowpea and Poona pea, snake bean, snap bean, and *Crotalaria anagyroides* were classed as very susceptible; peanut, which did not wilt in this test, although it developed leaf lesions, was classed as moderately susceptible.

Table 2. — Summary of results of second inoculation test carried out with sclerotial isolates

Plant species inoculated	Number of leaflets								Rating
	Controls*+	Inoculated				Infected			
		Isolates#							
	Total	PNG 10090	PNG 10140	PNG 10164	Total	Total	%	Comments	
Xanthosoma sp.	6	2	2	3	7	0	0	no infection	Immune
Vigna unguiculata (cowpea)	16	8	7	4	19	19	100	all wilted	Very susceptible
V. unguiculata (poona pea)	10	30	15	18	63	63	100	all wilted	Very susceptible
V. unguiculata ssp. *sesquipedalis* (snake or yard-long bean)	25	10	13	10	33	33	100	wilted 27; with lesions 6	Very susceptible
Arachis hypogaea (peanut)	21	5	5	5	15	15	100	with lesions (none wilted)	Moderately susceptible
Phaseolus vulgaris (dwarf bean) "Royal Windsor"	10	10	10	10	30	30	100	all wilted; some basal infection of stems	Very susceptible
Crotalaria anagyroides	18	7	4	3	14	14	100	all wilted	Very susceptible
	106	72	56	53	181	174	96.1		

* Controls included plants inoculated with PDA only and incubated, and others without any treatment or incubation

\+ No infection occurred on any control plant

\# See text for origin of isolates

The mycelium from the inoculation pieces grew very vigorously on susceptible hosts, and on the surface of the soil, appearing as cobwebby to ropy white strands (*Plate* II, B) and on the soil produced sclerotia, large (up to 5 mm long) and irregular in shape, pale tan to orangy tan, similar to those originally received from the field.

The reaction on the most susceptible hosts was so severe that wilt of the leaves and stems occurred even within 48 hours (*Plate* II, A). On peanut, or on the other susceptible hosts where the inoculum piece had been placed on the leaflets, round, slightly zonate lesions up to 5 cm diameter occurred in the laminae (*Plate* III).

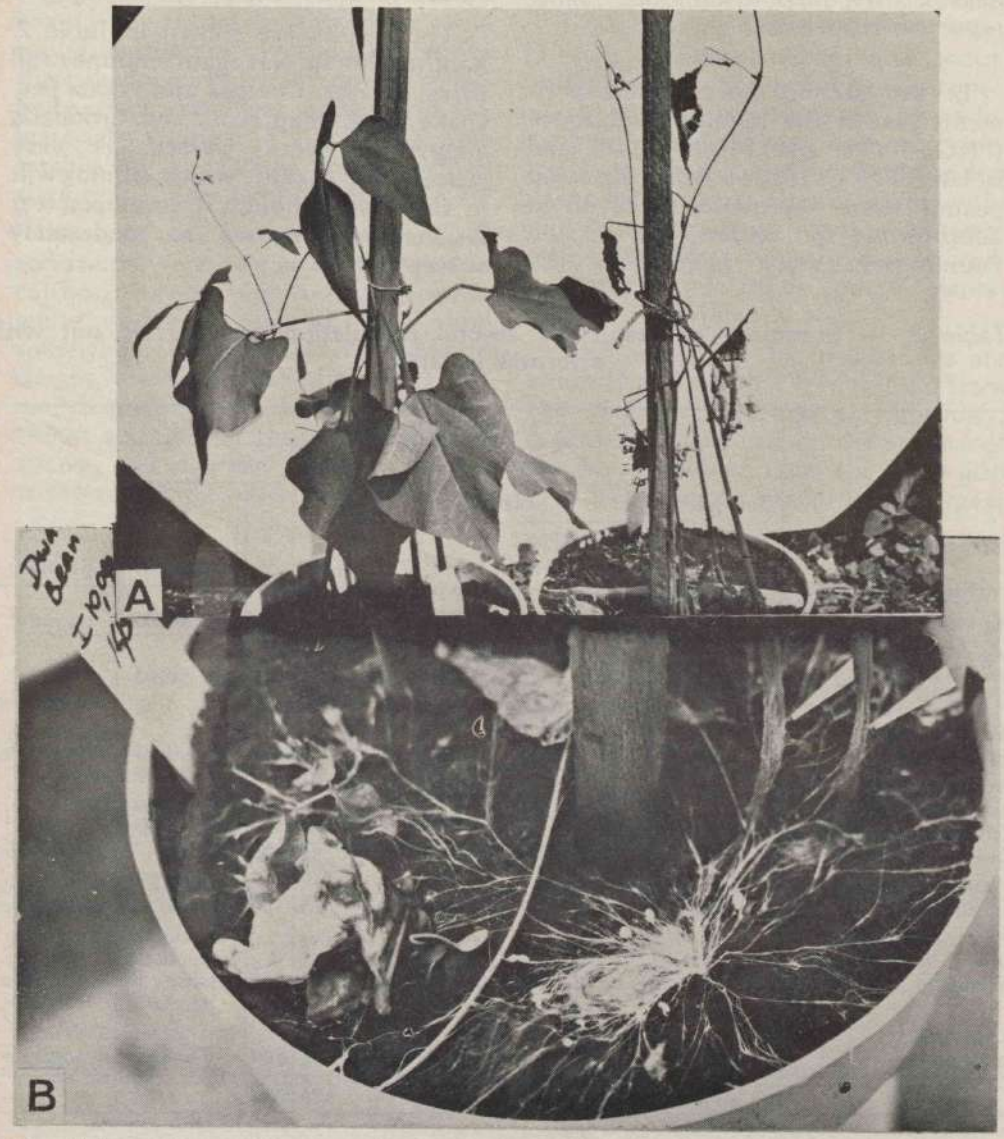

***Plate* II Dwarf beans (*Phaseolus vulgaris*) after inoculation with isolate PNG 10040 of *Sclerotium* sp.**

A. Right: severe wilting of inoculated plants; left: control plants.

B. Base of plants in right hand pot in A; note white mycelium at base of two plants (arrows) and ropy white strands and young sclerotia on the surface of the soil.

Some of the leaf tissue infected after inoculation was surface sterilized as described previously, and on PDA yielded cultures similar to those originally isolated.

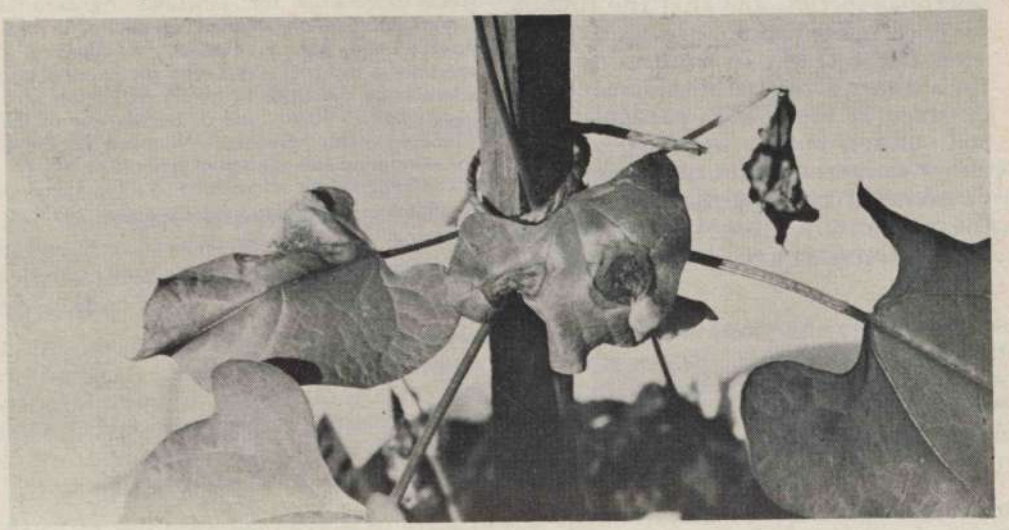

Plate III Snake bean after inoculation with isolate PNG 10040 of *Sclerotium* sp. showing leaf wilt of one plant, and two slightly zonate lesions on one leaflet.

DISCUSSION

The inoculations carried out with the three accessions derived from sclerotia originally found loosely attached to unthrifty *Xanthosoma*, and from the surface of the soil around healthy *Xanthosoma*, showed that the plants of this genus used in the tests were immune to these isolates. It is concluded, therefore, that the fungus was using the dead leaves and other moribund tissue in the field as a saprophyte, and was not invading the healthy parts of the plants. It is probable that sclerotia are able to form on dead parts of other plant species in the field.

On the other hand, the fungus obtained from the leaf and stem rot of the peanut in the field was very closely associated with the affected tissues. Also, it was well able to attack healthy peanut leaves in the inoculation test, and is therefore considered a pathogen of *Arachis hypogaea*. The three isolates from the *Xanthosoma* accessions were also able, like the isolate from peanut, to infect several healthy legumes, such as cowpea and Poona pea, snake bean, dwarf bean and *Crotalaria anagyroides* as well as peanut, which supports the view derived from macroscopic and microscopic examination of the cultures, that these isolates and those derived from the infected peanut tissue are the same fungus.

The fact that species in four genera of the Papilionaceae (Leguminosae), three at least being widely separated taxonomically, were susceptible in the inoculation tests reported in this paper, probably indicates that the fungus is able to attack a wide range of legumes, perhaps given suitably high conditions of humidity. Whether species in other plant families are susceptible to this fungus remains to be determined.

Subcultures of PNG 10140 (IMI 202759) and PNG 10164 (IMI 202758) were sent to the Commonwealth Mycological Institute (C.M.I.) for

examination, and Dr Mordue reported that the structure of the sclerotia was distinct from that of any of the common sclerotial species, and that the fungus fairly certainly had not previously been seen at the C.M.I. in culture. As with the authors, sclerotial development was obtained at the C.M.I., particularly in soil culture, but no basidia developed either on germination of the sclerotia or on other parts of the colonies. On the advice of Dr Mordue the fungus is at present referred to as *Sclerotium* sp.

ACKNOWLEDGEMENTS

Acknowledgement is made of the help received from officers at the Lowlands Agricultural Experiment Station, Keravat, especially Mr R.M. Bourke and Mr S. Rangai, in forwarding specimens; to Dr C. Prior who first noticed the sclerotia in the field; to Mr W.A. Layton who isolated PNG 10090, and to Dr Mordue of the Commonwealth Mycological Institute, England, for examining subcultures of two of the isolates.

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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.

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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.

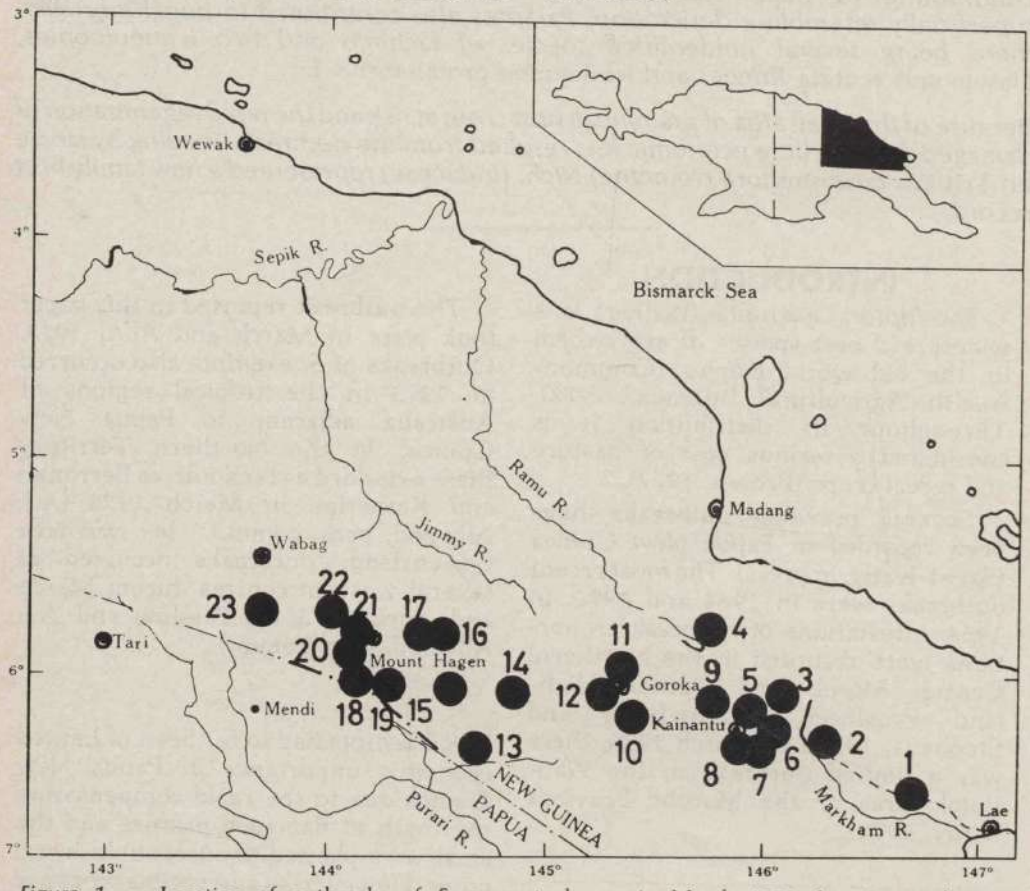

Figure 1. — Location of outbreaks of *S. exempta* larvae in March 1973. Location and time of pupation, where known, are: 1, Bubia (19.3.1973); 2, Mutsing; 3, Gusap; 4, Dumpu; 5, Yonki (30.3.73 — 6.4.73); 6, Arona; 7, Aiyura; 8, Kainantu (30.3.73 — 6.4.73); 9, Henganofi; 10, Korofeigu; 11, Goroka North; 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.

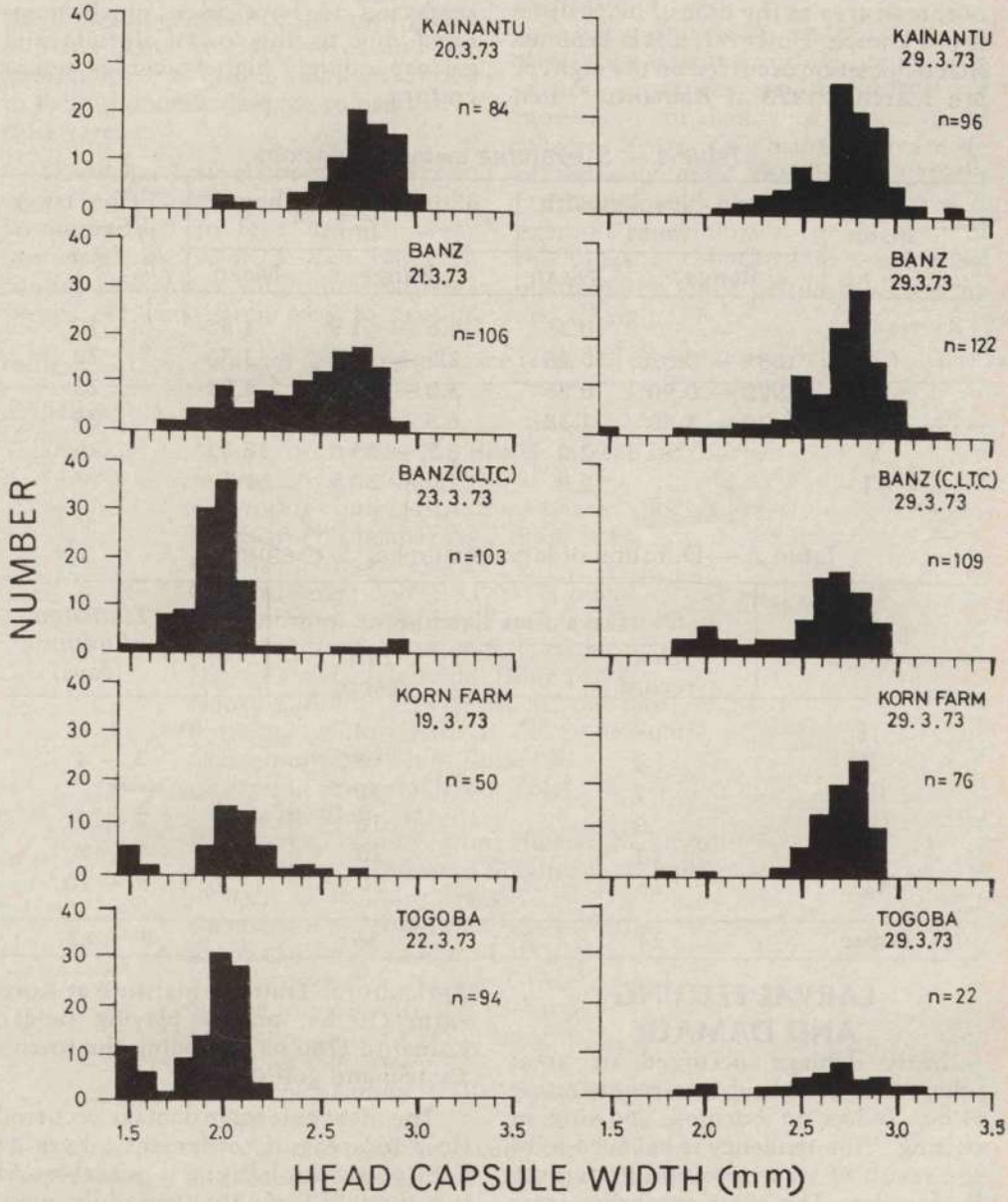

Figure 2. — Frequency distribution histograms of the head capsule width of *S. exempta* larvae sampled during the outbreak. (For location of sites refer to *Figure 1*).

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*).

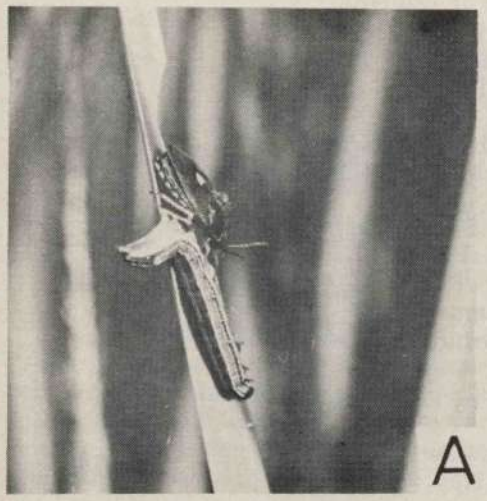

Plate 1. — A. *Platynopus* sp. attacking final instar *S. exempta* larvae.

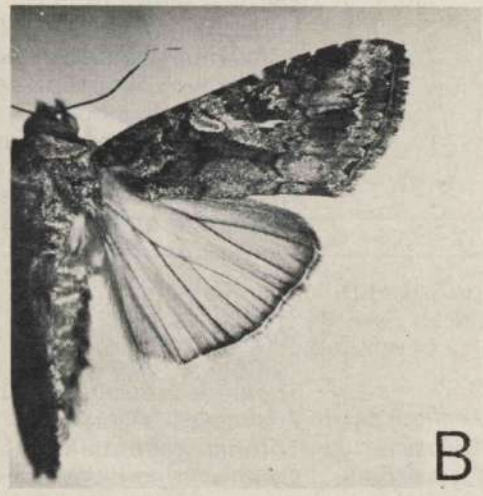

Plate 1. — B. Adult female *S. exempta*.

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 m² soil samples at two locations in the Western Highlands Province.

Location	Date	Per cent of samples					Sample size
		Viable	Adults emerged	Preyed upon	Parasitised*	Dead (cause unknown)	
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 m² 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.

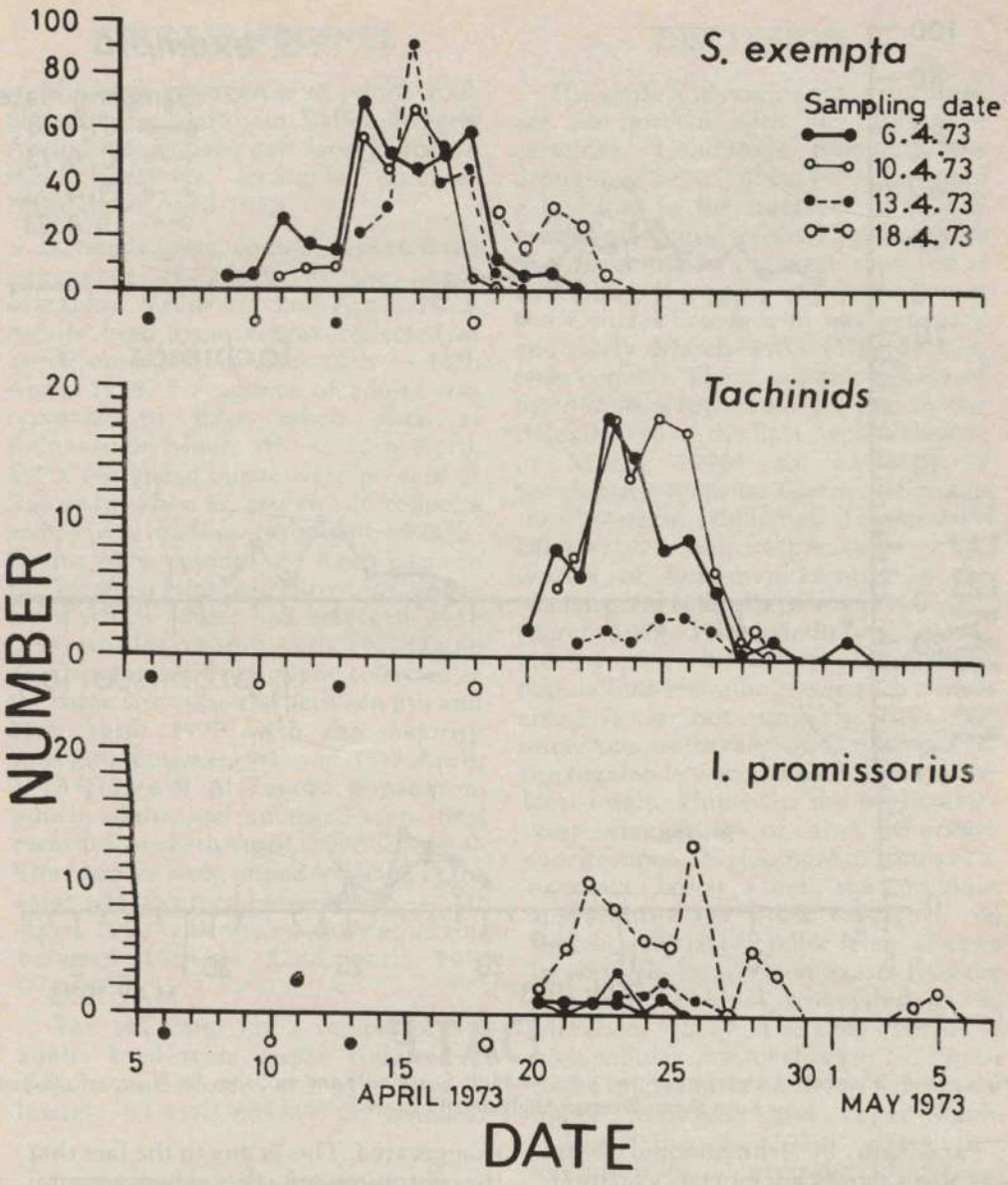

Figure 3. — Number of emergences and date, of adult *S. exempta* and parasites from pupae collected at Togoba, Western Highlands Province in April 1973.

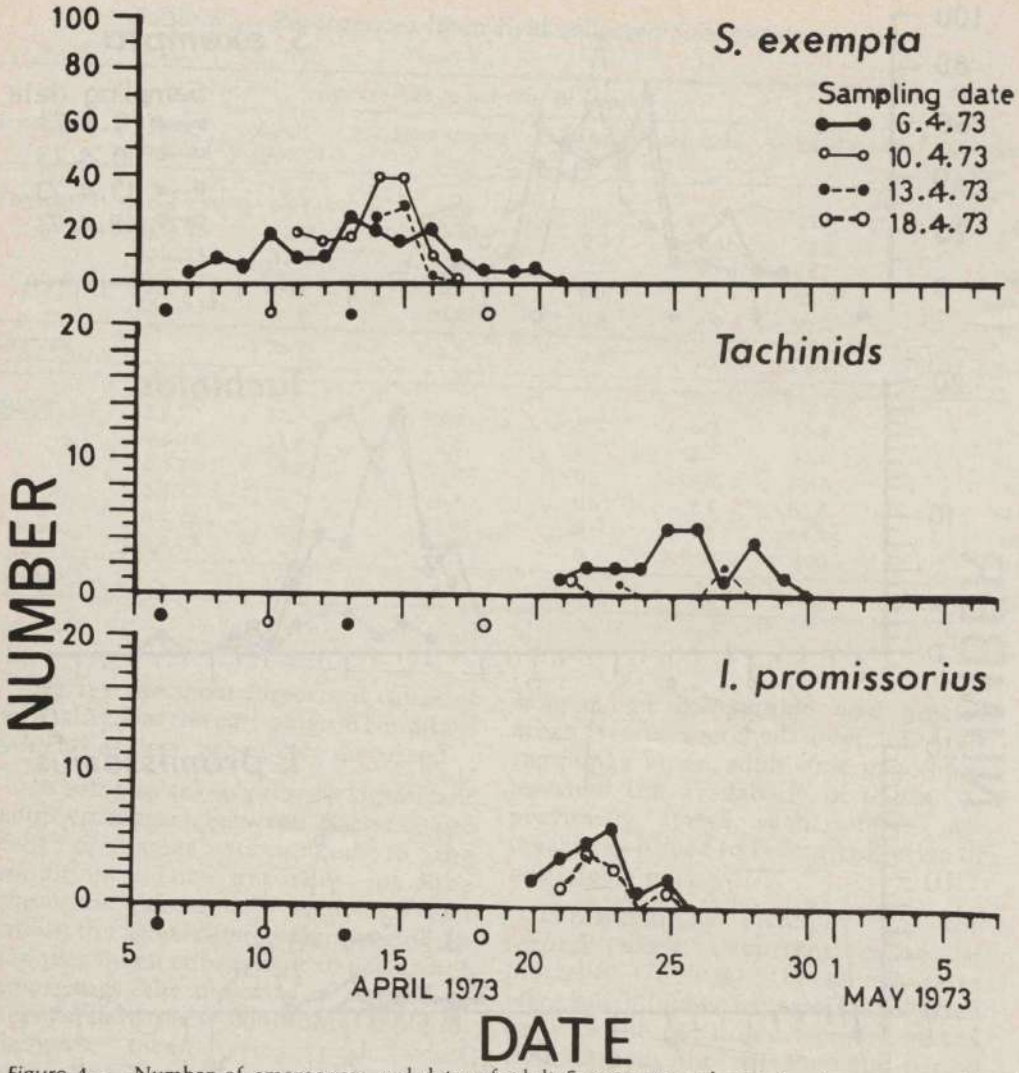

Figure 4. — Number of emergences and date, of adult *S. exempta* and parasites from pupae collected at Korn Farm, Western Highlands Province in April 1973.

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.

ACKNOWLEDGEMENTS

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INSECTICIDES AGAINST LARVAE OF THE CACAO WEBWORM *PANSEPTA TELETURGA* MEYRICK (LEPIDOPTERA : XYLORYCTIDAE)

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ABSTRACT

Thirty-five insecticides were screened for effectiveness against larvae of Pansepta teleturga, *a woodborer in cacao trees. Several of the more promising insecticides were selected for field trials, using 1 or 2 of 3 methods of application:*

(i) spraying onto the web,
(ii) application of systemic insecticides to the bark, and
(iii) swabbing a dilute solution onto the feeding area.

Swabbing was the only effective method. Endrin, azinophos-ethyl and dimethoate were the most effective insecticides when swabbed. Dimethoate is recommended because of its comparatively low mammalian toxicity.

INTRODUCTION

Pansepta teleturga is a woodborer of cacao trees in some cacao growing areas of Papua New Guinea. When many larval channels occur in a young tree they may cause death of branches. Sometimes, when there are many larval channels in the main stem or in the jorquette, the young tree may die. In trees older than about 3 — 4 years, severe larval channelling may cause death of some branches, but no tree deaths directly attributable to *P. teleturga* have been observed. Because the effects of *P. teleturga* on young cacao trees are much more severe than on older trees, the field trials reported in this paper were done on young trees.

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METHODS

Laboratory Screening

Thirty-five insecticides were used in this screening trial. They were chosen so as to include representatives of the main insecticide groups.

These insecticides were applied to field collected 4th and 5th instar larvae of *P. teleturga* in 2 series of tests.

(a) Contact toxicity: Larvae were dipped into each insecticide for 2 seconds, dried on paper towel and placed on a fresh cacao water shoot in a petri dish.

(b) Stomach/some contact toxicity: Cacao water shoots were dipped into the insecticide solution, then placed in a petri dish with untreated larvae.

Each insecticide was applied in concentrations of 0.01%, 0.05%, 0.1% and 0.3% of active ingredient respectively to 20 larval replicates. The mortality after 3 days was recorded.

Field Trials

Three methods of applying the insecticides were used:

(1) swabbing the larval feeding area with insecticide

(2) spraying, and

(3) painting systemic insecticide onto the bark of the tree.

A swab is made and the insecticide solution applied to the feeding area on the bark with a single movement, which removes the outer frass and simultaneously applies the insecticide to the feeding area.

The spray was applied as a high volume solution by a motor powered sprayer to the web, which was not removed.

The systemic insecticide was applied in a 5 cm band around the main trunk at a level just below the lowest web, or if there were no webs on the main trunk, then just below the jorquette.

Mortality was determined as follows. The webs from each tree in the trial were removed with a wire brush. On the following day the trees were inspected, and only those channels in which new web had been spun over the channel opening were recorded in the pretreatment count. This excluded channels in which there were pupae, dead larvae, or empty holes. Seven days after the treatment was applied the trees were inspected and the number of active channels was recorded.

Each treatment was applied to a block of 100 trees except the *Bacillus thuringiensis* treatment, which was applied to 20 trees. The trees were 2.5 — 4 years old.

RESULTS

In the screening trials no insecticide less concentrated than 0.3% gave greater than 90% mortality. The results of the screening trial shown in *Table 1* are for 0.3% insecticide solutions only.

Insecticides were chosen for field trials so as to include representatives of most groups of insecticides, and with high larval toxicity, low mammalian toxicity and locally available at moderate prices. B.H.C. was also included because it is commonly used by plantations against *P. teleturga*.

Six insecticides, shown in *Table 2* were chosen for the swabbing trial, and are ranked in order of their effectiveness. The best 3 were endrin, azinphos-ethyl and dimethoate which gave between 85% and 90% (in round figures) mortality.

The biological control agent, *Bacillus thuringiensis* was applied on a swab to larvae in 20 trees. It was found that in addition to dead larvae, many larval channels were empty (*Table 3*). In the control trees there were no empty channels. The fate of those larvae which vacated their channels is not known, but it is assumed that they died. Thus the total mortality in the treated trees was 50% compared with 3% in the control trees.

In the spraying trial, only 3 of the selected insecticides were used; the other 3 were considered too dangerous to human health to use as a spray. *Table 4* shows the results of spraying 3 insecticides into webs. The most effective, dimethoate, gave only 38% mortality.

Two insecticides, monocrotophos and acephate were used as systemics. Acephate was not available at the time that the screening trial was done, but it was included in this field trial because of reports that it had been successfully used as a systemic insecticide in cacao in West Africa. The results of this trial are shown in *Table 5*. A dilute solution (6%) of monocrotophos was found to be ineffective, while a concentrated solution gave about 67% mortality.

Table 1. — Laboratory Screening: Mortality caused by insecticides applied to larvae of *P. teleturga*.
Also shown are tabulated values of mammalian toxicity.

GROUP	INSECTICIDE	Larval Mortality From		Mammalian Toxicity ""	
		Toxicity Contact*	Stomach/ Some Contact Toxicity*	Oral LD 50 mg/kg	Dermal LD 50 mg/kg
1. Biological	*Bacillus thuringiensis*	L	M	0	0
2. Botanical	nicotine sulphate	M	M	70	140
	pyrethrin/ piperonyl butoxide	M	H	570	1,350 — 5,400
3. Arsenical	lead arsenate	L	M	10 — 100	2,400
4. Chlorinated hydrocarbon	B.H.C.	M	H	300 — 500	2,500
	chlordane	L	L	283	1,600
	D.D.T.	L	L	300 — 500	2,500
	dieldrin	L	L	40	100
	endosulphan	H	H	35	74 — 680
	endrin	H	H	3 — 6	60 — 120
	heptachlor	M	L	40	195 — 250
5. Carbamate	aprocarb	L	H	80	2,400
	carbaryl	L	M	400	500
6. Organo-Phosphate	azinphos-ethyl	H	H	9	280
	bromophos	L	L	1,600 — 8,000	5,000
	carbophenothion	L	H	7 — 30	800
	chlorfenvinphos	M	H	10 — 155	30 — 108
	coumaphos	M	L	13 — 180	860
	diazinon	L	L	300 — 600	500 — 1,200
	dichlorvos	M	M	25 — 30	75 — 900
	dicrotophos	H	M	15 — 45	42
	dimethoate	L	H	200 — 300	700 — 1,150
	"Dyfonate"	M	M	23	130
	fenitrothion	L	L	130 — 200	700
	fenthion	M	H	200	1,300
	formothion	L	L	400	400 — 1,680
	"Imidan"	H	H	113 — 245	1,550
	maldison	L	L	1,400 — 1,900	4,000
	mevinphos	H	H	3 — 5	90
	monocrotophos	H	H	17 — 21	112
	parathion	L	L	3 — 6	4 — 35
	phosalone	M	H	120 — 170	390
	"Schradan"	L	L	5	50 — 100
	T.E.P.P.	L	L	0.5	20
	trichlorphon	L	L	650	2,800

*L = low (0 — 50%) mortality M = medium (51 — 90%) mortality
H = high (91 — 100%) mortality "" From Ben-Dyke *et al* (1970)

Table 2. — Field Trial
Insecticides swabbed onto larval feeding area

Treatment	Pre-treatment Count (Larvae/100 Trees)	% Mortality (Corrected for Controls*)
0.3% endrin	1363	89.7
0.3% azinphos-ethyl	1124	85.9
0.3% dimethoate	1044	84.6
0.3% monocrotophos	2046	79.8
0.3% aprocarb	672	76.0
0.3% B.H.C.	1,146	16.7
control	917	(68.8)

* Using Abott's Correction (Busvine, 1957)

Table 3. — Field Trial
Bacterial solution swabbed onto larval feeding area

Treatment	Pre-treatment Count (Larvae/20 Trees)	%Dead	%Empty Channels
0.3% *Bacillus thuringiensis* ("Dipel" : Abbott)	120	31.7	18.3
Control	94	3.2	0

Table 4. — Field Trial
Insecticides sprayed onto web

Treatment	Pre-Treatment Count (Larvae/100 Trees)	% Mortality (Corrected for Controls*)
0.3% dimethoate	394	38.1
0.3% B.H.C.	411	24.3
0.3% aprocarb	341	17.3
control	917	(68.8)

* Using Abott's Correction (Busvine, 1957)

Table 5. — Field Trial
Insecticides painted onto bark

Treatment	Pre-Treatment Count (Larvae/100 Trees)	% Mortality (Corrected for Controls*)
6% monocrotophos	228	0
60% monocrotophos	117	66.9
Control	156	(27.6)
60% acephate	79	36.0
Control	104	(6.2)

* Using Abott's Correction (Busvine, 1957)

DISCUSSION

A number of insecticides gave good results when applied to larvae of *P. teleturga* in the laboratory. However, their effectiveness in the field depended upon the method by which they were applied.

Systemic insecticides would appear to be an ideal way of controlling wood-chanelling insects such as *P. teleturga*. However, the better systemic insecticide, monocrotophos, only killed 67% of larvae when applied as a 60% solution. It was noted that larvae which were distant from the point of application and those with channels close to the surface of the stem, survived the treatment. Some phytotoxic symptoms were also noted. It was thought that a more dilute solution (6%) might avoid the problem of phytotoxicity and also obviate the problem of unskilled workers handling concentrated insecticide. However, at 6% concentration, monocrotophos was ineffective.

There have been a number of attempts to use systemic insecticides in cacao trees, but the results have been variable. Bowman and Casida (1958) studied the passage of a number of insecticides through cacao trees in Costa Rica and found that they were distributed throughout the plant. However, these authors did not test the actual effectiveness of their insecticides against insects in the field. Dunn and Ward (1965) using radio-phosphorus in dimethoate, found that only 11% of the insecticide effectively entered the tree and, of this, 83% remained within 0.3 metres of the point of injection.

Spray application of insecticides was not effective because the insecticide did not penetrate the protective web to reach the feeding area. The most effective insecticide tested in this way, dimethoate, may have owed its superiority over others to a possible local systemic action.

The only method tested and found to be effective was by swabbing. This method has the advantage that the insecticide is applied directly to the feeding area. On the other hand, it is a labour-intensive method and it is probably not economically worthwhile to treat trees older than 4 — 5 years in this way.

Of the insecticides which were tested by swabbing, dimethoate (Rogor) is recommended because it is comparatively effective and somewhat less toxic than the others. Dimethoate is more expensive than some of the other effective insecticides. However, in plantation-scale swabbing operations it is estimated that the cost of insecticide is only a small part of the total cost of the operation.

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YIELD OF PARA GRASS *(BRACHIARIA MUTICA)* AS INFLUENCED BY SOURCE, RATE AND FREQUENCY OF APPLICATION OF FERTILIZER NITROGEN

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ABSTRACT

Ammonium sulphate, ammonium nitrate and urea at rates of 100 and 200 kg per ha per year were applied to a Para grass pasture in the wet tropics over three periods of about a year each. In the first period, a single initial application was compared with three splits at about 15 week intervals. In the second and third periods, comparison was between 4 splits at 12 week intervals and 8 splits at 6 week intervals.

Drymatter yeilds averaged 36 kg per kg N applied for ammonium nitrate, 29 kg for ammonium sulphate and 25 kg for urea. Response to frequency of application was small. There was little residual effect beyond six weeks after application. Response appeared almost linear to increasing rates up to 50 and perhaps even 200 kg per ha per application.

Nitrogen content of herbage cut at 6 to 8 week intervals averaged about 1%, with very little effect of treatments. Recovery of applied nitrogen averaged 42, 28 and 27 per cent in the three successive periods.

INTRODUCTION

Para grass (*Brachiaria mutica*) is an important pasture species in high rainfall areas of the Markham Valley and in other well-watered locations in Papua New Guinea, both lowlands and highlands. Most of these Para grass pastures are pure grass swards as it has been difficult to find legumes which will persist in combination with this highly competitive species. No nitrogen fertilization has been practised commercially, although there is evidence from overseas that Para grass responds well to nitrogen. This paper presents results of an experiment running over three years studying the response of Para grass to different types, rates and frequencies of application of nitrogen fertilizers.

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PROCEDURE

The experiment began in August 1971, on a three year old Para grass pasture and covered three periods of about one year each, concluding in February, 1975. The site was Narakapor, 15 km from Lae in the lower Markham Valley (latitude 6 deg. 40 min. S, altitude about 50 m, mean temperature about 26°C, annual rainfall about 2,000 mm). The site had previously been planted with coconuts but these had been cut down to promote pasture growth. Soil was an alluvial clay loam of pH 7.5 to 7.7. Soil samples were taken at the end of the first and third years and were analysed by the Agricultural Chemistry Section of the Department of Agriculture, Stock and Fisheries. Results are shown in *Tables 1* and *2*.

The trial compared three fertilizers; ammonium sulphate, ammonium nitrate and urea. All were applied at rates of 100 and 200 kg N per ha per year.

Table 1

Soil Analysis Data from Nil Nitrogen Plots, Sampled in 1972 and 1975

	1972	1975
pH	7.6	8.1
Specific Conductivity (Mhos x 10^3)	0.018	0.130
Total Soluble Salts	0.006	0.039
Olsen P (p.p.m.)	32.3	12.3
Exchangeable Cations (m.e.%)		
Ca	63.0	67.5
Mg	9.6	8.7
K	1.54	1.75
Na	2.57	2.46
Cation exchange capacity (m.e.%)	54.0	67.8
Base saturation %	100	100
Carbon (W and B)%	1.7	1.9
Nitrogen %	0.17	0.23
C/N Ratio	10.5	8.2

Fertilizer was hand broadcast onto the grass after slashing it to a height of about 15 cm. Two application frequencies were compared in each period. In the first period, the comparison was between a single initial application and three equal splits applied after every second grass harvest. Because the fertilizer response was found to be very short-lived, frequencies were changed and the comparison in the second and third periods was between application at every harvest and at alternate harvests. Details are shown in *Table 3*. Design was randomized blocks with four replications, each block including two nil-nitrogen plots in addition to the twelve factorail combinations.

At the start of the first and second but not the third period, potassium sulphate was applied to all plots not receiving ammonium sulphate, so as to equalize sulphate levels. Basal dressings of phosphorus, potash and trace element mixture, each at 50 kg per ha, were applied at the start of the first period only.

To estimate drymatter yield, six harvests were taken in the first year, at about seven-week intervals, and eight harvests each in the second and third periods, at about six-week intervals. From each plot, four quadrats 50 cm x 50 cm were cut at a height of 15 cm for recording purposes, and the remainder of the plot (size $10m^2$) was then cut back to the same height. All cut grass was carried off the plots. Samples were dried for 48 hours at 80°C and then weighed. Samples from each treatment, pooled over the four replications, were subsampled for nitrogen analysis by the Agricultural Chemistry Section.

Rainfall data for the first two periods are presented in *Table 3*. The second period was slightly wetter than the first. The third period was similar to the second but records are not available. All plots were flooded for three to seven days at least once each year when the nearby Markham River overflowed. At the end of the first period, small ditches were dug around each plot to prevent fertilizer washing from one plot onto another.

RESULTS AND DISCUSSION

DRYMATTER YIELDS

Yields, according to treatment, are presented in *Table 4* in the form of yearly totals. Effects of rates and frequencies of fertilizer application on yields at individual harvests are shown in *Figure 1*.

Table 2

Details of Soil pH, P, N and C/N Ratio, according to Treatment

		Am. Sulph.			Am. Nit.			Urea			MEAN
		F1		F2	F1		F2	F1		F2	
pH											
1972	No	—		—	—		—	—		—	7.6
	N100	7.7		7.6	7.5		7.6	7.5		7.6	7.6
	N200	7.7		7.6	7.4		7.5	7.6		7.6	7.6
	MEAN		7.7			7.5			7.6		
				F1—7.6		F2—7.6					
pH											
1975	No	—		—	—		—	—		—	8.0
	N100	8.1		7.6	7.9		8.0	7.7		7.6	7.8
	N200	7.8		7.8	7.6		7.8	8.0		7.6	7.8
	MEAN		7.8			7.8			7.7		
				F1—7.9		F2—7.7					
Olsen P	No	—		—	—		—	—		—	32.3
ppm	N100	47.0		32.5	32.5		27.5	29.0		29.0	32.9
1972	N200	31.0		23.5	35.5		33.5	33.0		38.5	32.5
	MEAN		33.5			32.3			32.4		
				F1—32.7		F2—30.8					
Olsen P	No	—		—	—		—	—		—	12.3
ppm	N100	5.0		6.5	6.5		5.0	6.0		6.0	5.8
1975	N200	5.0		5.0	4.5		4.5	4.5		5.0	4.8
	MEAN		5.3			5.1			5.4		
				F1—5.3		F2—5.3					
N%	No	—		—	—		—	—		—	0.17
1972	N100	0.19		0.18	0.19		0.17	0.17		0.17	0.18
	N200	0.17		0.17	0.20		0.20	0.13		0.17	0.17
	MEAN		0.18			0.19			0.16		
				F1—0.18		F2—0.18					
N%	No	—		—	—		—	—		—	0.23
1975	N100	0.26		0.25	0.27		0.24	0.21		0.23	0.24
	N200	0.24		0.23	0.25		0.28	0.22		0.25	0.21
	MEAN		0.25			0.26			0.23		
				F1—0.24		F2—0.21					
C:N	No	—		—	—		—	—		—	11.0
Ratio	N100	10		10	10		9	10		10	9.9
1972	N200	11		11	10		10	15		10	11.2
	MEAN		10.5			9.8			11.3		
				F1—11.0		F2—10.0					
C:N	No	—		—	—		—	—		—	8.2
Ratio	N100	7.7		12.4	8.7		6.8	6.7		7.0	8.2
1975	N200	12.4		7.1	6.7		6.1	7.7		8.0	8.2
	MEAN		9.9			7.1			7.4		
				F1—8.3		F2—7.9					

Table 3

Details of Fertilizer Treatments, and Intervals and Rainfall Recorded Between Fertilizer Application and Harvest

Fertilizer Application (kg N per ha)

Period 1: F_1N_1 = 100, F_1N_2 = 200 at harvest 0
F_2N_1 = 33, F_2N_2 = 66 at harvests 0, 2, 4*

Periods 2, 3: F_1N_1 = 25, F_1N_2 = 50 at harvests 0, 2, 4, 6
F_2N_1 = 12.5, F_2N_2 = 25 at harvests 0, 1, 2, 3, 4, 5, 6, 7

Intervals and Rainfall

Period		Harvest No. 1	2	3	4	5	6	7	8
1	F_1 (days)	53	108	149	197	303*	359	—	—
	F_2 (days)	53	108	41	89	47*	103	—	—
	Rain (mm)	86	318	67	99	81	246	—	—
2	F_1 (days)	43	83	46	84	43	82	42	85
	F_2 (days)	43	40	46	38	43	39	42	43
	Rain (mm)	58	116	221	332	262	157	225	406
3	F_1 (days)	42	80	47	89	42	84	41	83
	F_2 (days)	42	38	47	42	42	42	41	42

* The long interval between harvests 4 and 5 arose through cattle breaking in and gazing the plots; they were therefore cut back and fertilizer was reapplied to F_2 plots.

Table 4

Yields of Para Grass According to Type, Rate and Frequency of Fertilizer Application
Total drymatter yields (t per ha)

	Ammonium Sulphate		Ammonium Nitrate		Urea		
	F_1	F_2	F_1	F_2	F_1	F_2	Mean
Period 1							
No	—	—	—	—	—	—	7.2
N1	11.1	12.5	12.8	12.0	11.9	11.3	11.9
N2	13.9	16.3	14.6	15.5	12.8	14.3	14.6
MEAN	13.4		13.7		12.6		
		F_1—12.8		F_2—14.2			
	N_1F_1—11.9		N_1F_2—11.9	N_2F_1—13.8		N_2F_2—15.3	
Period 2							
No	—	—	—	—	—	—	13.5
N1	15.8	14.8	17.3	16.4	14.1	15.2	15.6
N2	17.6	19.5	18.5	20.1	18.0	18.5	18.7
MEAN	16.9		18.1		16.4		
		F_1—16.9		F_2—17.4			
	N_1F_1—15.8		N_1F_2—15.4	N_2F_1—18.1		N_2F_2—19.4	
Period 3							
No	—	—	—	—	—	—	7.8
N1	10.2	9.5	11.5	10.7	8.6	10.6	10.2
N2	12.3	11.9	14.7	14.2	12.0	12.2	12.9
MEAN	11.0		12.8		10.8		
		F_1—11.5		F_2—11.5			
	N_1F_1—10.1		N_1F_2—10.3	N_2F_1—13.0		N_2F_2—12.8	

Drymatter yield in the second period was higher than in the first and third possibly because of seasonal differences. Nitrogen application produced very highly significant yield increases in all years, averaging about 3,000 kg per ha from the first 100 kg N and a further 2,800 kg per ha from the second. This response of about 30 kg drymatter per kg N applied may be compared with such overseas results as 32.3 and 49.1 lb per lb N from 200 lb per acre at cutting intervals of 40 and 60 days respectively in Puerto Rico (Vicente-Chandler *et al*, 1959) and 37 kg per kg N from a single harvest six months after application of 200 kg N per ha in Northern Territory, Australia (Miller and Nobbs, 1976). Although the Northern Territory response and 60 day response in Puerto Rico were higher than the returns recorded at Narakapor, the longer growth intervals would have led to decline in quality of the herbage. It is also probable that N response at Narakapor was restricted by the declining P levels indicated by the 1975 soil analyses (*Table 2*).

Differences between sources of nitrogen were significant in the first year, non-significant in the second, and very highly significant in the third. Overall, ammonium nitrate produced the greatest response and urea the lowest, while ammonium sulphate was similar to ammonium nitrate in the first year but similar to urea in the second and third. On average, ammonium nitrate yielded about 1,000 kg drymatter per ha more than yield from ammonium sulphate and 1,500 kg more than from urea. At the current cost of K100/per tonne for sulphate of ammonia, K150 for urea and K180 for ammonium nitrate, the drymatter return per unit expenditure would be slightly greater for urea than for ammonium nitrate, which would be slightly greater again than that for sulphate of ammonia. In terms of efficiency of N utilization (kg drymatter per kg applied N) the figures were 36 for ammonium nitrate, 29 for sulphate of ammonia and 25 for urea. Gartner and Everett (1970) reported similar superiority of ammonium nitrate over urea on kikuyu grass but only at fairly high application rates (200 and 400 lb N per acre). Figarella *et al* (1972) reported a trial including comparison of ammonium sulphate, ammonium nitrate and urea on Pangola grass in Puerto Rico. Differences were non-significant but ammonium sulphate was generally the most efficient and urea least efficient source of N.

In the first year, the total yield from the split applications was 10 per cent greater than that from the single initial application. In the two later years, there was virtually no difference in overall yield between application at every harvest and application at alternate harvests. This, however, masks the fact that there were very big differences in response to application frequencies at individual harvests, as can be seen from *Figure 1*. The pattern of response is seen best when it is recognized that almost the whole of the nitrogen response was recorded in the growth between fertilizer application and the subsequent harvest (see *Table 5*).

Table 5

Yields at First and Second Harvests After Fertilizer Application

	First Harvest*		Second Harvest*	
	N_1	N_2	N_1	N_2
Period 1	194	268	125	133
Period 2	134	163	101	106
Period 3	158	222	99	110

* Based on mean drymatter yields from treatments where fertilizer was applied at alternate harvests, yield of fertilized plots being expressed as percentage of yield of unfertilized plots at the same harvests. Means of three harvests in Period 1, and four harvests each in Periods 2 and 3.

The residual response at the second harvest after each application was small in the first period, and in the second and

third periods there was a small residual effect only at the higher application rate.

The short duration of the nitrogen response is also evident in *Figure 1*, where it may be seen that yield in the plots which received all fertilizer in one application reverted almost to the level of the unfertilized plots in the second and subsequent harvests. At the lower N rate, yield at the first harvest was 327% of the control yield but it was only 142% at the second and 124% for the total of harvests 2 to 6. At the higher N rate, figures were 460, 152 and 120% respectively.

As most of the fertilizer response was recorded in the first harvest after fertilizer application and there was little residual effect at subsequent harvests, the trial may also be viewed as covering a range of fertilizer rates from 12.5 to 200 kg per ha in a single application if a study is made of immediate post-fertilizer yields only. These are isolated in *Table 6*, which presents both dry matter yields and response expressed in terms of kg drymatter per kg N applied.

Table 6

Yields and Nitrogen Response in Harvests First after Fertilizer Application*

		Nitrogen Rate (kg per ha)								
Period 1		0	33		66		100		200	
Harvest	1	1486	2493	(31)	3197	(26)	4866	(34)	6840	(27)
Harvest	3	1092	2469	(42)	3866	(42)	—		—	
Harvest	5	1646	3251	(49)	4260	(40)	—		—	
Mean		1408	2738	(40)	3774	(36)	4866	(34)	6840	(27)
Period 2		0	125		25		25		50	
Harvest	1	975	1249	(22)	1480	(20)	1460	(19)	1687	(14)
	2	1339	1958	(50)	2734	(56)	—		—	
	3	2006	1864	(-11)	2317	(12)	2279	(11)	2907	(18)
	4	2285	2278	(-1)	2783	(20)	—		—	
	5	2233	2617	(31)	3235	(40)	3175	(38)	3700	(29)
	6	1267	1491	(18)	1899	(25)	—		—	
	7	1486	1806	(26)	2156	(27)	2056	(23)	2628	(23)
	8	1854	2151	(24)	2763	(36)	—		—	
Mean		1681	1927	(20)	2421	(30)	2243	(23)	2731	(21)
Period 3		0	12.5		25		25		50	
Harvest	1	919	1183	(21)	1541	(25)	1656	(29)	2119	(24)
	2	1026	1134	(9)	1217	(8)	—		—	
	3	1175	1814	(51)	2460	(51)	2080	(36)	3015	(37)
	4	799	949	(12)	1145	(14)	—		—	
	5	1326	1409	(7)	1368	(2)	1265	(-2)	1827	(10)
	6	1139	1569	(34)	2060	(37)	—		—	
	7	580	955	(30)	1228	(26)	1318	(30)	1903	(28)
	8	835	1189	(28)	1740	(36)	—		—	
Mean		975	1275	(24)	1595	(25)	1580	(23)	2216	(24)

* Figures in the body of the table are drymatter yields (kg per ha). For nitrogen rates above zero, figures in brackets show the nitrogen response in terms of the increase in drymatter yield expressed as kg drymatter per kg applied nitrogen.

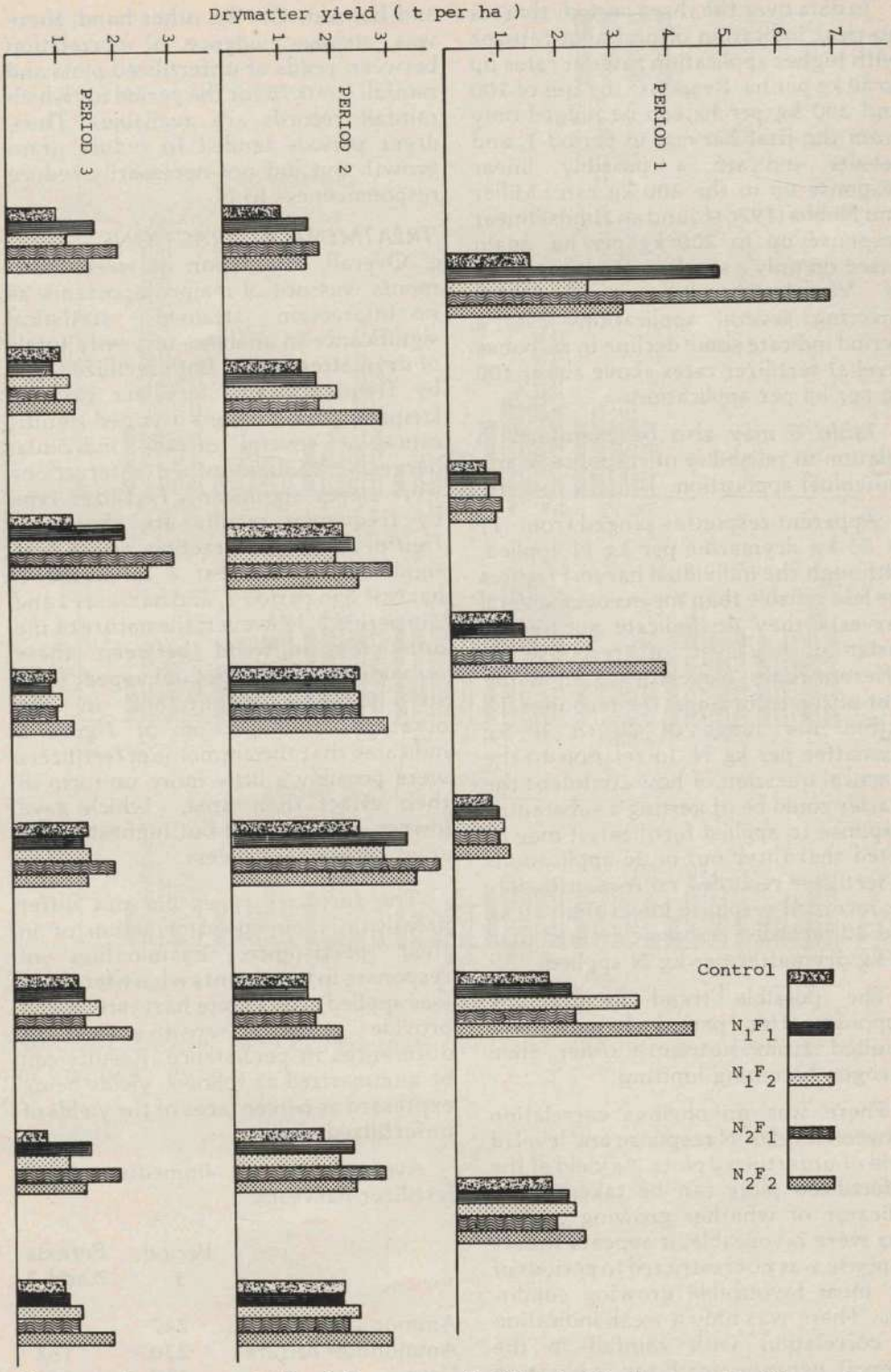

Figure 1 – Drymatter yield of Para grass fertilized with nitrogen. Fertilizer rate and frequency effects.

In data over the three periods there is no clear indication of declining returns with higher application rates at rates up to 50 kg per ha. Response to rates of 100 and 200 kg per ha can be judged only from the first harvest in period 1, and results indicate a possibly linear response up to the 200 kg rate. Miller and Nobbs (1976) found an almost linear response up to 200 kg per ha, again based on only a single application. Data of Vicente-Chandler *et al* (1959) covering several applications over a period indicate some decline in response level at fertilizer rates above about 100 kg per ha per application.

Table 6 may also be examined in relation to reliability of response to any individual application.

Apparent responses ranged from -11 to 56 kg drymatter per kg N applied. Although the individual harvest figures are less reliable than means over several harvests they do indicate substantial variation in level of response at different times. Nevertheless, in 60 per cent of the recordings, the response fell within the range of 20 to 40 kg drymatter per kg N. In relation to the practical question of how confident the grazier could be of getting a substantial response to applied fertilizer, it may be noted that three out of 56 applications of fertilizer recorded no response, only six recorded response lower than 10 kg and 40 recorded response greater than 20 kg drymatter per kg N applied.

The possible trend to declining response after period 1 may have resulted from nutrients other than nitrogen becoming limiting.

There was no obvious correlation between level of N response and level of yield of unfertilized plots. As yield of the unfertilized plots can be taken as an indicator of whether growing conditions were favourable, it appears that N response was not restricted to periods of the most favourable growing conditions. There was only a weak indication of correlation with rainfall in the interval between fertilizer application and harvest. On the other hand, there was strong evidence of correlation between yeilds of unfertilized plots and rainfall ($r = 0.75$ for the period for which rainfall records are available). Thus, dryer periods tended to reduce grass growth but did not necessarily reduce responsiveness to N.

TREATMENT INTERACTIONS

Overall, interaction between treatments was not of major importance as no interaction attained statistical significance in analyses of yearly totals of drymatter yields. Both fertilizer type by frequency and fertilizer rate by frequency interactions attained significance at several of the individual harvests, though other interactions were never significant. Fertilizer type by frequency results are shown in *Figure 2*. The interaction effect was significant at harvest 3 in period 1, harvest 5 in period 2, and harvests 1 and 3 in period 3. However, the nature of the interaction differed between these occasions so there does not appear to be any practical significance in the observation. Inspection of *Figure 2* indicates that the ammonium fertilizers were possibly a little more uniform in their effect than urea, which gave lowest yields overall but highest yields at an occasional harvest.

The fertilizer types did not differ greatly in their speed of action or in their persistence. Examination of responses in treatments where fertilizer was applied at alternate harvests should provide a fairly sensitive test of differences in persistence. Results can be summarized as follows, yields being expressed as percentages of the yields of unfertilized plots.

Averages of all immediate post-fertilizer harvests:

	Period 1	Periods 2 and 3
Ammonium sulphate	247	161
Ammonium nitrate	230	182
Urea	217	149

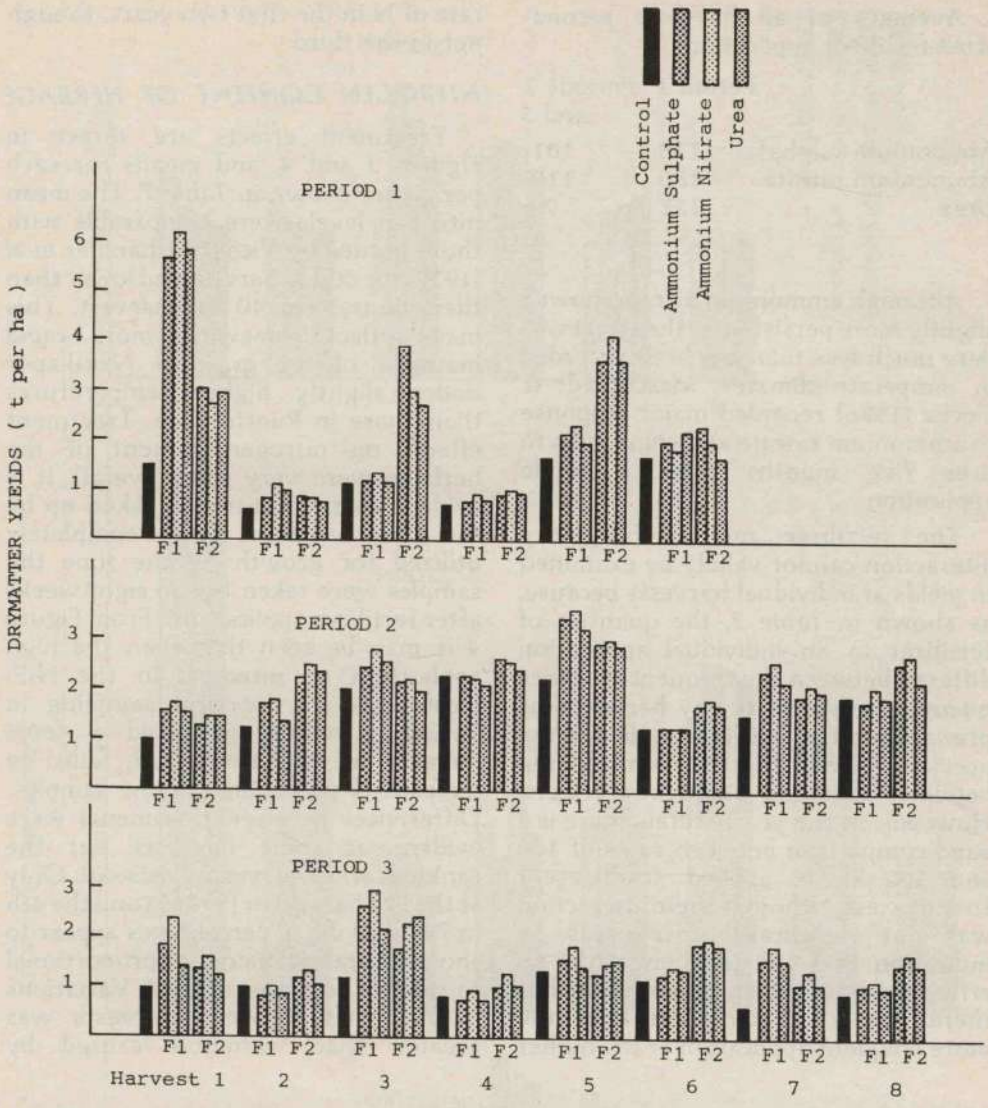

Figure 2.–Drymatter yield of Para grass fertilized with nitrogen. Fertilizer type and frequency effects.

Averages of all harvests second-after-fertilizer application:

	Period 1	Periods 2 and 3
Ammonium sulphate	128	101
Ammonium nitrate	136	110
Urea	122	99

Although ammonium nitrate showed slightly more persistence, the effect was very much less than has been recorded in temperate climates. Maschmedt & Cocks (1976) recorded major response to ammonium nitrate and some even to urea five months after a single application.

The fertilizer rate x frequency interaction cannot validly be examined in yields at individual harvests because, as shown in *Table 2*, the quantity of fertilizer in an individual application differed between the frequencies. Since nitrogen response at any harvest was primarily to the fertilizer applied at the previous harvest, there is a confounding between rate and frequency effects. However, in the yearly totals there is a valid comparison between rates of 100 and 200 kg N applied at different frequencies. Although their interaction was not significant, there was an indication that the frequency had no effect on total yield at the lower rate but there was some advantage from the more frequent application at the higher rate of N in the first two years, though not in the third.

NITROGEN CONTENT OF HERBAGE

Treatment effects are shown in *Figures 3* and *4*, and means for each period are shown in *Table 7*. The mean nitrogen levels were comparable with those quoted by Vicente-Chandler *et al* (1959) for 60 day harvest and lower than their figures for 40 day harvest. This may reflect somewhat more rapid maturity of the grass at Narakapor under slightly higher temperatures than those in Puerto Rico. Treatment effects on nitrogen content of the herbage were very small overall. It is evident that the nitrogen taken up by the grass had been almost completely utilized for growth by the time the samples were taken (six to eight weeks after fertilizer application). From Figure *4* it may be seen that even the high application of nitrogen in the N_2F_1 treatments in the first sampling in Period 1, which produced a 460% increase in drymatter yield, failed to increase N percentage in the samples. Differences between treatments were evident at some harvests but the rankings were not very consistent. Only at the 3rd harvest in Period 1 and the 4th in Period 3 did N percentages appear to show substantial increases proportional to rates of fertilizer applied. Variations in N levels between harvests was greater than variation caused by

Table 7
Mean Nitrogen Contents, According to Treatment
Annual Averages over Samples Taken at Each Harvest

	PERCENT NITROGEN IN DRYMATTER		
	Period 1	Period 2	Period 3
Control	0.92	1.09	1.04
N_1F_1	0.92	1.08	1.07
N_1F_2	0.96	1.07	1.06
N_2F_1	0.92	1.10	1.08
N_2F_2	1.00	1.11	1.10
Sulphate of Ammonia	0.96	1.10	1.08
Ammonium Nitrate	0.95	1.10	1.09
Urea	0.94	1.06	1.07

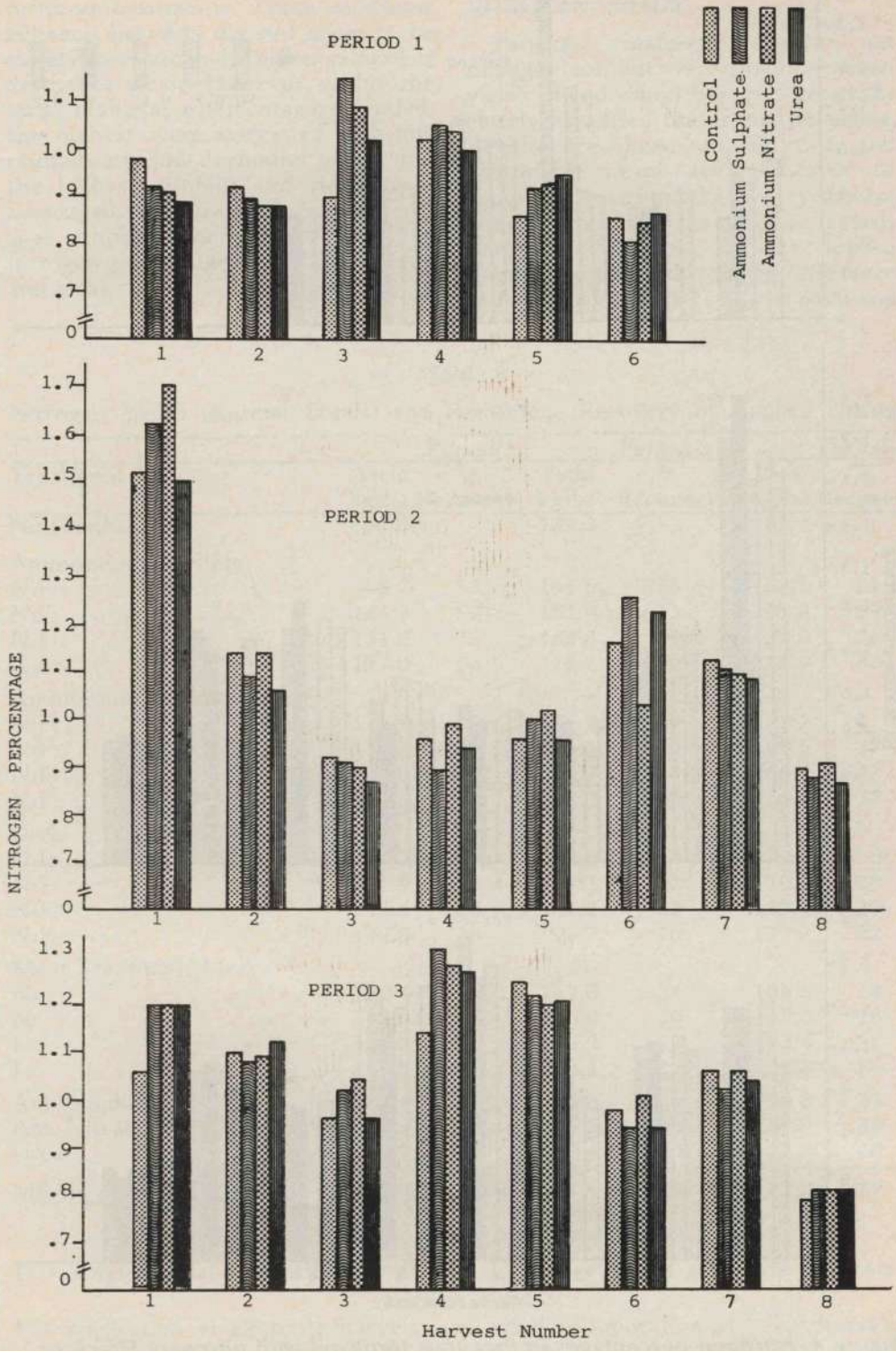

Figure 3.–Nitrogen percentages in Para grass fertilized with nitrogen. Effects of three different sources of nitrogen.

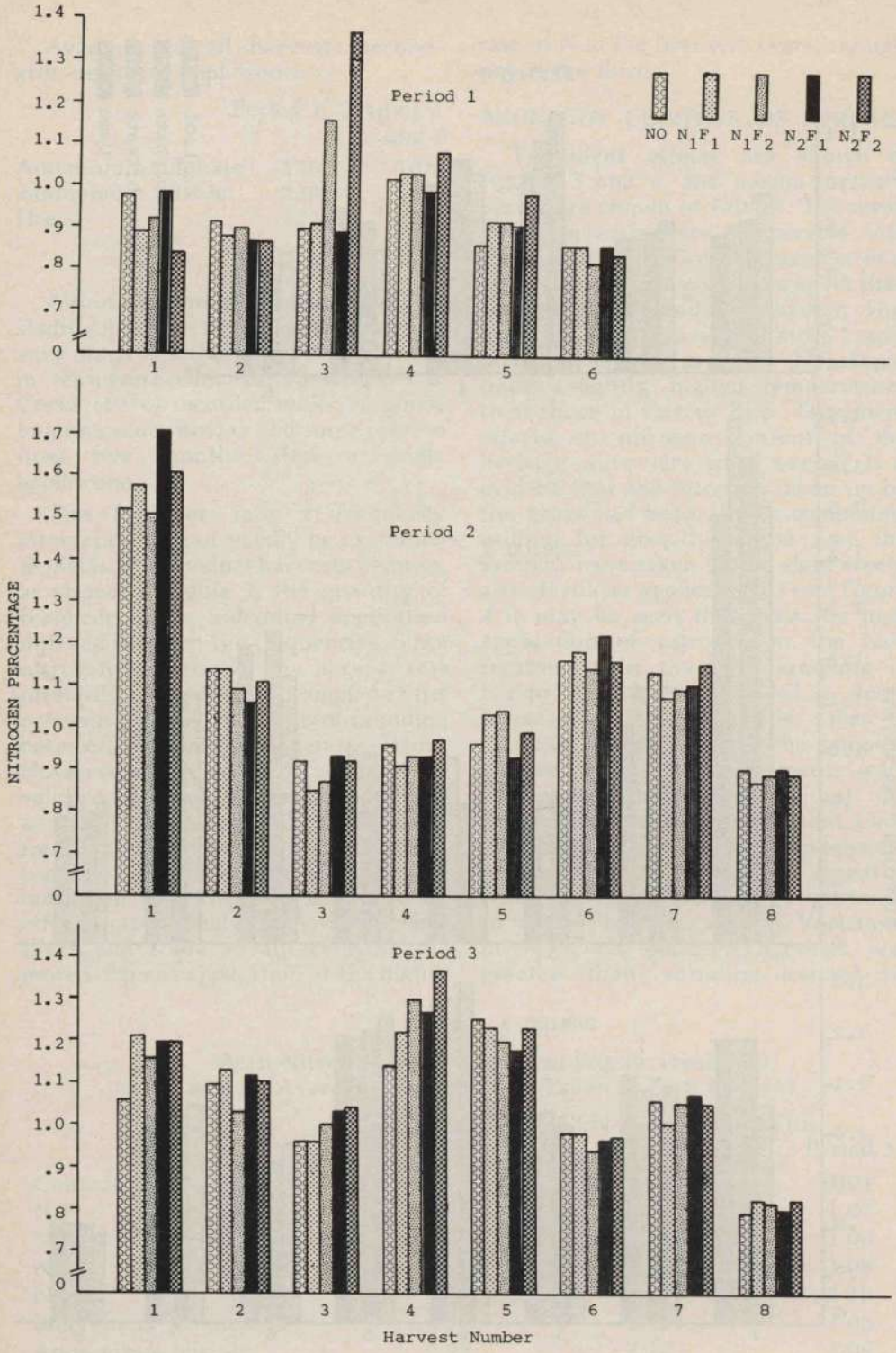

Figure 4.–Nitrogen percentages in Paragrass fertilized with nitrogen. Effects of rate and frequency of application.

fertilizer treatments. These variations between harvests did not seem to be closely correlated with either rainfall or drymatter yields. However, within the range of nitrogen percentages recorded, the highest were associated with low rainfalls and low drymatter yields, and the highest rainfalls and yields were associated with low nitrogen percentages, though there were also low nitrogen percentages with low rainfall and yield.

NITROGEN YIELDS

Because treatment effects on nitrogen content were small, nitrogen yields at individual harvests generally closely paralleled the drymatter yields. Results are shown in *Figure 5*, and treatment means averaged over all samples for each of the three years are shown in *Table 8*. This table also records percentage recovery of the applied nitrogen, calculated from the difference in N yields between fertilized plots and

Table 8

Nitrogen Yields (Annual Totals) and Percentage Recovery of Applied Nitrogen

	Period 1		Period 2		Period 3	
Treatment	Yield kg/ha	% Recovery	Yield kg/ha	% Recovery	Yield kg/ha	% Recovery
No Fertilizer	65.3		139.2		82.4	
Ammonium Sulphate						
N_1F_1	98.7	33	164.6	25	103.2	21
N_1F_2	124.3	59	151.9	13	101.0	19
N_2F_1	131.8	33	186.8	24	134.0	26
N_2F_2	177.0	56	212.1	36	126.9	22
Ammonium Nitrate						
N_1F_1	113.9	49	186.7	47	123.7	41
N_1F_2	117.7	46	168.1	29	109.5	27
N_2F_1	144.0	39	205.2	33	166.2	42
N_2F_2	159.6	47	214.7	38	156.6	37
Urea						
N_1F_1	106.2	41	144.6	6	90.5	8
N_1F_2	107.9	43	161.1	22	110.9	28
N_2F_1	115.6	25	181.3	21	123.1	20
N_2F_2	142.0	38	190.7	26	127.2	22
Main Treatment Means						
N_1	110.4	45	162.8	24	106.5	24
N_2	145.0	40	198.4	30	139.0	28
F_1	118.4	35	178.2	22	123.4	27
F_2	137.1	48	183.1	29	122.0	26
Am. Sulphate	132.9	45	178.8	26	116.3	23
Am. Nitrate	132.3	45	193.7	36	139.0	38
Urea	117.9	35	169.4	20	112.9	20
MEAN ALL FERTILIZED	127.7	42	180.6	28	122.8	27

N_1 = 100 kg N/ha N_2 = 200 kg N/ha

F_1 = single initial application in Period 1, application at alternate harvests in Periods 2 and 3.

F_2 = application at alternate harvests in Period 1, application at every harvest in Periods 2 and 3.

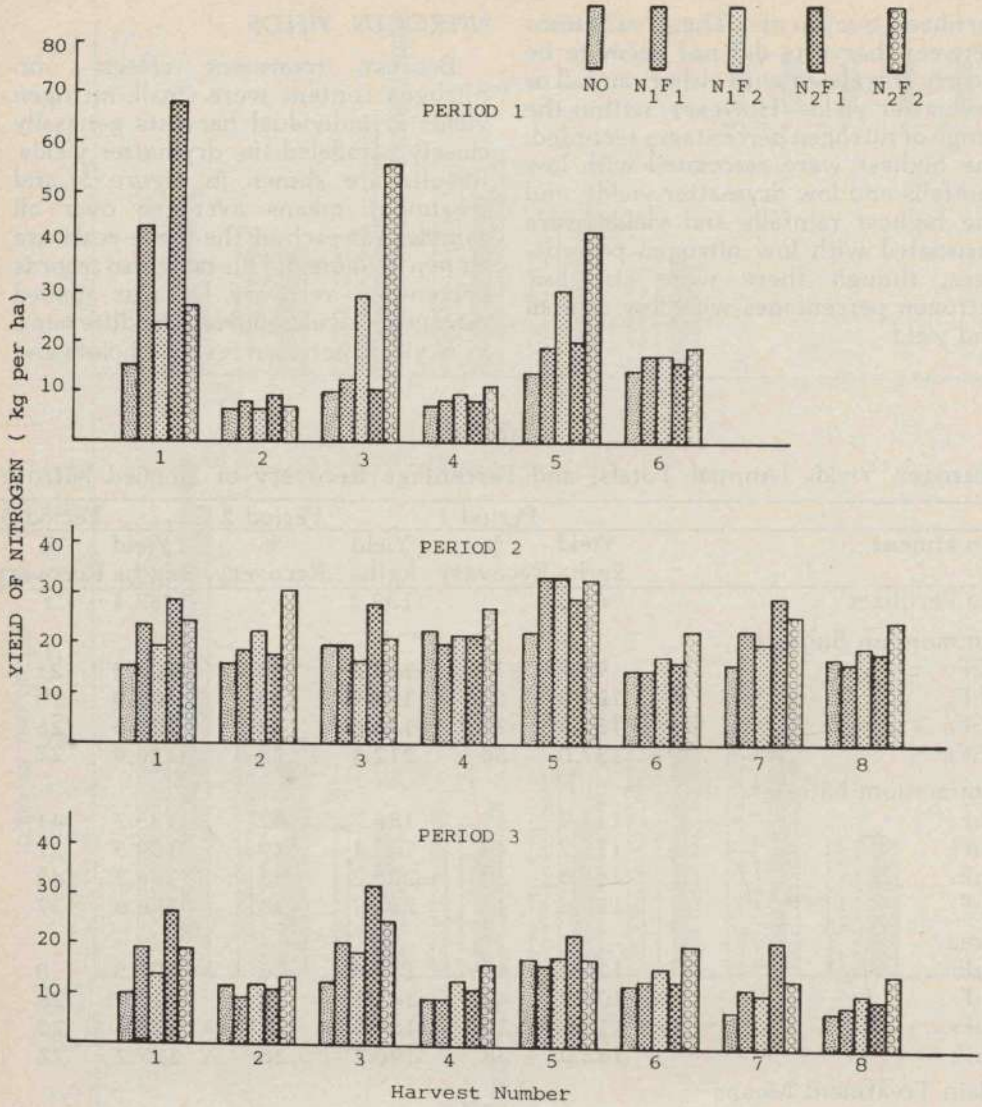

Figure 5. Nitrogen yields from Para grass fertilized with nitrogen. Effects of rate and frequency of application.

control plots receiving no nitrogen fertilizer.

Nitrogen yields were obviously increased by applied nitrogen, the increase being greater at the higher than at the lower level of nitrogen. Apart from those effects, results tended to be inconsistent. Recovery of N from urea was almost certainly lower than from ammonium nitrate, with ammonium sulphate intermediate.

Nitrogen recovered from the single initial application in Period 1 was less than that recovered from the same quantities of fertilizer in three split applications. In the following two periods, the comparison between application at every harvest and at alternate harvests did not give a clearcut result, though the overall trend was to higher recovery from the more frequent application. Recovery varied greatly from harvest to harvest, ranging from 0 to 56% where N was applied after every harvest and from 8 to 36% with application at alternate harvests. Although some of this variation was no doubt due to sampling error, there can be little doubt that there was much real variation also. This was not obviously correlated with rainfall.

There was no consistency as to whether percentage recovery of applied N was greater or less for higher application rates than for lower. The overall percentage recoveries of fertilizer N from nitrogen-treated plots, averaging 42, 28 and 27 percent respectively in the three successive periods, were relatively low, no doubt reflecting high leaching loss under tropical high rainfall conditions, and perhaps some volatilization loss also. Maschmedt and Cocks (1976) in a temperate climate recorded recovery of 44 per cent of N applied as a single dressing of urea at the start of the season and 87 to 92 per cent from ammonium nitrate or multiple dressings of ammonium nitrate or urea. Vicente-Chandler *et al* (1959) recorded recovery as high as 50% from 200 lb N per acre applied in six splits over a year in Puerto Rico. Miller and Nobbs (1976) recovered only 12% of N from fertilizer broadcast at 200 kg per ha in a single application.

ECONOMIC APPRAISAL

The trial demonstrated a substantial and fairly consistent response of Para grass to applied nitrogen. Evidence of similar results under comparable conditons overseas confirms the general indication that under wet lowlands conditions in Papua New Guinea a grazier could have a high level of confidence that he would get a return of about 30 kg drymatter from application of 1 kg N to Para grass pastures. This gives a cost of about 1.3 toea per kg of drymatter produced, at which rates the economic return would probably be marginal in terms of routine fertilizing. There is also some indication that persistent use of high levels of N would create a need for other fertilizers as well. It should be noted that in this trial the grass cuttings were removed from the plots whereas under grazing there would be some return to the plots in excreta. On the other hand, some of the additional growth might be lost through trampling and fouling of the pasture.

Although the economics of regular fertilizing may be doubtful, the rapidity of the response is such that nitrogenous fertilizer could be valuable as a management tool. At any time when there is a need for increased feed a grazier could apply fertilizer and increased herbage would be available within a few weeks. The response should be similar whether a heavy application rate were used on a small area of pasture or the same quantity of fertilizer were spread at a lower rate over a greater area.

CONCLUSIONS

1. Under equatorial lowland climatic conditions, Para grass responded

rapidly to applied nitrogenous fertilizer. Drymatter production increased linearly with increasing N rates up to 50 kg and possibly even to 200 kg N per ha per application.

2. N fertilizing had very little residual effect. By six weeks after application there was little effect on the N content of the herbage. There was little further response in drymatter production of regrowth after cutting the pasture at six weeks from fertilizer application.

3. The results obtained indicated that, at current fertilizer costs, profitability of fertilizing on a regular basis would be marginal. However, the ability to produce a large bulk of feed within a few weeks of N application could make it a useful management tool.

4. Ammonium nitrate proved more efficient than sulphate of ammonia or urea in terms of drymatter response per unit of N applied, but the lower price of urea in relation to its N content made it slightly more efficient than ammonium nitrate in terms of drymatter response per kina expended.

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