Papua New Guinea

SURVEYS OF INSECTS ASSOCIATED WITH FOOD CROPS in THREE STUDY AREAS IN THE SOUTHERN HIGHLANDS PROVINCE

by

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A report on

SURVEYS OF INSECTS ASSOCIATED WITH FOODCROPS in THREE STUDY AREAS IN THE SOUTHERN HIGHLANDS PROVINCE

carried out for

The AFTSEMU team

of the

Southern Highlands Rural Development Project

by

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INTRODUCTION

The AFTSEMU team of the Southern Highlands Rural Development Project has been carrying out studies in three areas of the Southern Highlands Province using a modification of the International Rice Research Institute's 'Cropping Systems Research' method. This method starts with a description of the study areas in terms of physical resources, agricultural systems and socio-economic characteristics (see Appendix 1). From this base changes to the agricultural systems can be made, monitored and evaluated.

Part of this study involves the establishment of pest and disease profiles for the areas being investigated, and in 1981 the AFTSEMU team sought assistance from specialists in National D.P.I. in these two aspects. This report gives the results of surveys carried out by D.P.I. entomologists on the insects associated with food crops in these study areas.

THE STUDY AREAS

The three areas chosen for study by the AFTSEMU team were the Tari Basin, the Upper Mendi and Pangia areas. Details of these areas and reasons for their choice are given in Appendix 2. The location of the areas is shown on Maps 1 to 4.

OBJECTS OF THE SURVEYS

The initial proposal put forward by the AFTSEMU team is given in Appendix 3. It was proposed that the surveys should consist of three stages:

1. Preparation of a check list of pests occurring on cultivated and propagated crops in sample gardens.
2. Measurements of pest incidence for specified pests on specified crops.
3. Interpretation of results, recommendations and development strategies for further survey or experimental work.

The aims of the surveys carried out to date have been:

1. To collect and identify insects from crops in each of the study areas for the preparation of checklists.
2. To carry out a small amount of quantitative sampling on selected pests on some crops to provide guidelines for the development of monitoring techniques.
3. To identify particular topics on which knowledge is at present inadequate and formulate proposals for further studies.

SCOPE OF THE PRESENT REPORT

The present report aims to present the following information:

1. Details of the insects found on each of the crops, with discussion of the damage they cause and their actual or potential importance as pests. In certain cases this may not be possible until further work has been carried out (see 3.).

2. A checklist of the insects found on each crop in each area, derived from 1.

3. Details of the current knowledge on each pest derived from published literature and internal D.P.I. reports and a discussion of further work considered necessary to establish the effect of specific pests on specific crops.

4. Results of quantitative sampling and discussions on the possibility of developing long term monitoring programmes for specific pests on specific crops.

The report will be structured to give firstly details of the general methods used, itinerary for field work, etc.; secondly a section on each crop in turn, giving detailed methods and details of the insects found with, for each species, a discussion of importance as a pest (if known), presentation of quantitative data (if appropriate), and a discussion of any further work considered necessary; thirdly a general discussion of results including an appraisal of the advantages and problems associated with this type of survey; and fourthly the presentation of a checklist of insects for each area listed by crop.

GENERAL METHODS

(i) Field work

At each garden a list of the crops present was made. The crops were then examined for insects which were recorded and/or collected for determination later. In some cases sweep nets and/or pooters were used to collect small insects. In the initial parts of the survey (Pilot Survey, Upper Mendi, see itinerary) no further work was undertaken.

In the later parts of the survey (Main Survey, all areas, see itinerary) some quantitative sampling was attempted for pests on the more important crops. This varied from actual counts of insects in quadrats laid onto the foliage (sweet potato) to counts of numbers of plants infested by a particular species of insect (taro, sugar cane).

(ii) Itinerary for field work

The field work was carried out in six main phases as follows:

1. Pilot Survey, part 1. This was carried out by R.T.M. in the Upper Mendi area from 28 July to 6 August 1981. The purpose of this pilot survey was twofold. Firstly preliminary information was gathered as to what crops and associated insects were present in the area, so that plans for the main survey could be formulated. Secondly, since R.T.M. was a

relatively new recruit to the Entomology Section, he was able to use this pilot survey to familiarise himself with some of the insect pests present.

2. Pilot Survey, part 2. This was carried out by B.M.T. and R.T.M. in the Upper Mendi area from 3 to 5 November 1981. Further preliminary information was gathered and plans for the main survey finalised. Following this an outline of the proposed methods for the main survey was prepared and discussed with AFTSEMU staff. (Appendix 4).

3. Main Survey, Upper Mendi. This was carried out by R.T.M. from 9 to 19 November 1981.

4. Main Survey, Tari. This was carried out by R.T.M. from 24 November to 2 December 1981.

5. Main Survey, Pangia. This was carried out by B.M.T. from 20 to 29 April 1982.

6. Follow-up visits. B.M.T. visited the Pangia area on 1 December 1982 and the Tari area from 9 to 11 February 1983 and 20 to 21 July 1984 to carry out extra collecting for the survey. B.M.T. was also in the Upper Mendi on several occasions in late 1983 to mid 1984 for a Plutella xylostella experiment and a few extra records for this survey were collected during this period.

A detailed list of all gardens visited during all phases of the survey is given in Appendix 5. Information gathered in all six phases of the survey is presented in this report. In addition we have also included a few records which have come to our attention since the survey was carried out and a few records from other localities in the Southern Highlands Province but not within the three main study areas.

(iii) Laboratory and other work.

Following the field work there was a great deal of further work to be carried out. This included breeding through of the larvae of various species of Lepidoptera to obtain adults for identification, mounting and labelling of specimens and identification of those species already known from Papua New Guinea. There were a large number of species which could not be identified and these were sorted, prepared and documented for determination by specialists overseas. Identifications of many of these have been received. Those not yet identified are referred to in the following pages by code numbers, which will later be replaced with confirmed identifications, (see Appendix 8).

Following identification, records of insects were collated on a crop basis from the field noted. In addition literature searches were carried out to establish the current state of knowledge on each of the species. Using this information suggestions for further studies have been drawn up.

In the following pages ' * ' next to a species indicates that specimens have been sent to specialists for determination, ' ** ' indicates that the name presented is that determined by a specialist. Appendix 8 lists all the specimens sent for identification and gives provisional identifications, confirmed identifications from specialists where these have been received, and the name of the specialists who carried out the determinations.

DETAILED METHODS, RESULTS AND DISCUSSION FOR EACH CROP

The crops examined during this survey are listed in Appendix 6. This list reflects the incidence of each of the crops in each of the areas. For example sweet potato was a dominant crop in all areas and was examined in a large number of gardens. Others, such as soy bean and chinese cabbage, were encountered on only one or two occasions.

In the sections that follow the major crops are dealt with first in some detail. More minor crops follow in less detail. In some cases, where certain crops have only been examined in one or two gardens, the treatment is fairly superficial.

Within each crop section each insect is dealt with in turn giving the results, plus some discussion on its taxonomy, relative importance as a pest, references to other studies, further studies considered desirable, etc., as relevant in each case. At the end of each crop section is a further discussion which covers the pest situation on the crop as a whole.

I SWEET POTATO

IA Foliage Insects

(i) Methods

Sweet potato foliage was examined in a large number of plots in each area (25 in Mendi, 23 in Tari and 9 in Pangia, a total of 57). Collections of insects were made either by hand or by sweep net, the smaller insects being removed from the net using a pooter. This latter method was particularly useful for collecting small leafhoppers (Hemiptera: Cicadellidae and Delphacidae). Sweep netting was carried out in three gardens in Mendi (M12, 13 & 15), two in Tari (T22 & 23) and eight in Pangia (P3, 4, 8, 9, 11, 14, 15 & 16).

In some gardens half square metre quadrats (50 cm x 100 cm) were laid on the foliage and counts made of the insects present. Insects counted were: lepidopterous larvae, flea beetles, tortoise beetles and cicadellid sp. 1 (see Appendix 4). Quadrat counts were made in eleven gardens in Mendi (M21 - 29, 31 & 33), nineteen in Tari (T1 - 10 & 12 - 20) and five in Pangia (P8, 9, 11, 15 & 16).

(ii) Lepidoptera

Most plots of sweet potato had some damage caused by larvae of Lepidoptera. Specimens were collected from foliage at Pangia, but not at Tari and Mendi. Twelve species were recorded as follows:

** <u>Acrocercops homalacta</u> Meyrick (Gracillariidae).

This leaf miner was found in all three study areas and in virtually all the plots examined. It appears to be a common insect throughout the highlands of Papua New Guinea. The larva mines the leaves of sweet potato, forming a serpentine mine when young and later a blotch mine. It does not leave the mine until ready to pupate, and it does this in a leaf crease under a brown cocoon.

Damage symptoms are like those given in Swain (1971) for <u>Acrocercops prosacta</u> Meyr. Larvae dissected from mines in sweet potato leaves collected at Kuk Agricultural Research Station (Kuk A.R.S.) resemble the photograph in Swain (1971) and the description in Hinckley (1962) for the closely related <u>A. prosacta.</u>

At Kuk A.R.S. this species is attacked by a small chalcid parasite. Samples dissected in late July and early August 1983 yielded several parasitised larvae or parasite pupae. Other larvae were dead from an unknown cause and very few living healthy larvae were obtained for breeding purposes. Some specimens bred later were sent for identification.

Bedellia somnulentella Zell. (Lyonetidae).

This insect was found in all three of the survey areas (one and two adults collected by sweep netting in the Mendi and Pangia areas respectively; one adult bred from a larva collected in the Tari area). No serious damage to foliage was observed. However late in 1982 (September to November) reports were received of serious damage in many parts of the highlands (E.P., S.H.P., W.H.P., C.P., E.H.P.). A visit to Pangia on 1 xii 82 confirmed its presence in damaging population levels at one locality (P18).

Kimber (1972) noted various outbreaks of this insect in the highlands in 1972. Some of these outbreaks were severe enough that spraying was considered necessary. It may be significant that in both 1972 and 1982 there was a severe drought throughout the highlands of P.N.G.

Like the previous species the larva again makes a serpentine mine at first, and later blotch mines. It leaves the mine when almost fully grown and spins a silk web on the leaves. The larva then pupates, and the pupa hangs in this silk webbing. When populations are large the damage can be very severe, the remains of the mined leaves turning brown and brittle in the sun, and the whole plant becomes covered in silk webbing and hanging pupae (Kimber 1972).

Details of the biology of B. somnulentella can be found in Shorey and Anderson (1960).

Aedia sericea Butler (Noctuidae).

Frequently found in gardens at Pangia (P1, 3, 8 & 11) but only in ones and twos. This species has also been recorded from Kuk A.R.S. and Laloki (Central Province), again in low numbers.

Swain (1971) gives the distribution of this insect (under the name Catephia sericea) as "limited in range to Fiji, Tonga, Tutuila and the Pacific Islands east of Samoa". He records the species as being "common in sweet potato fields in Fiji, but generally of minor importance".

Onchyrotica concursa Walk. (Pterophoridae).

Four larvae collected at Pangia (P8, P14), larvae noted at Tari (T25) and one adult sweep netted in Upper Mendi. This species has previously been bred from larvae collected at Kuk A.R.S., the Tsak Valley (Enga Province) and Wabag (Enga Province). The larvae fold and web leaves. This is a small moth and at low population levels damage is not significant. The species has also been recorded in Malaysia (Hua 1970).

Undetermined sp. A (Pyralidae).

Frequently found in gardens at Pangia but only in low numbers: four larvae collected from P9, five from P14, one seen P15, four seen P16 and damage noted in other plots. A small larva was observed feeding on the lower epidermis of a leaf. Larger larvae were collected from folded leaves feeding on the upper epidermis, or chewing right through the leaves to eventually leave folded, skeletonised leaves.

<u>Herse convolvuli</u> (L.) (Sphingidae).

A few larvae observed in the Tari area (T2, 3, 6, 12, 14 & 18). Also present in low numbers in the Mendi area.

<u>Agrotis ipsilon</u> (Hufnagel) (Noctuidae).

Larvae were causing minor damage to sweet potato cuttings in Mendi (M1, 2 & M15).

Other species.

Five other species of Lepidoptera were represented by single larvae only from the Pangia area (noted as species B, D, F, G and H respectively in the survey notes at Kuk A.R.S.).

Counts.

In the half square metre quadrats at Pangia lepidopterous larvae were counted by species. In the case of the <u>Acrocercops homalacta,</u> mined leaves were counted. For all the others the number of larvae present were counted. The figures given below are for ten quadrats in each garden, a total area of five square metres.

TABLE 1. Counts of Lepidoptera larvae on sweet potato foliage in the Pangia area, ten half square metre quadrats per garden.

	P8	P9	P11	P15	P16	Total	Per m^2
<u>A. homalacta:</u>	3	6	4	11	6	30	1.2
<u>B.somnulentella:</u>	0	0	0	0	0	0	0
<u>A. sericea:</u>	1	0	0	0	0	1	0.04
<u>O. concursa:</u>	1	0	0	0	0	1	0.04
Sp. A:	0	2	0	1	4	7	0.3
Sp. B:	1	0	0	0	0	1	0.04
Sp. G:	0	0	0	1	0	1	0.04
Sp. H:	0	0	0	1	0	1	0.04
Others	1	0	0	0	0	1	0.04
Total	7	8	4	13	11	43	1.7
Per m^2	1.4	1.6	0.8	2.6	2.2	1.7	

These counts indicate the scarcity of lepidopterous larvae, with the exception of <u>A. homalacta,</u> on sweet potato foliage in the Pangia area. This scarcity was confirmed by observations on other plots of sweet potato in the area.

In Mendi and Tari counts were made of total Lepidoptera present in each quadrat, but these were not separated into species. A. homalacta, was again counted on the basis of mined leaves. Some of the other species, particularly those which fold the leaves, were also counted on the basis of damaged leaves rather than actual numbers of larvae present. In Pangia many of the folded leaves did not have larvae in them and were therefore not counted. It is therefore not possible to compare the numbers of Lepidoptera from Mendi and Tari with those from Pangia. The results for the Mendi and Tari counts were:

TABLE 2. Counts of Lepidoptera larvae on sweet potato foliage in the Mendi and Tari areas, ten half square metre quadrats per garden.

2a. Mendi	M21	M22	M23	M24	M25	M26	M27	M28	M29	M31	M33
Total	49	28	65	28	19	39	43	65	24	17	49
Per m^2	9.8	5.6	13.0	5.6	3.8	7.8	8.6	13.0	4.8	3.4	9.8

2b. Tari	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T12
Total	20	5	26	25	30	42	23	22	29	108	24
Per m^2	4.0	1.0	5.2	5.0	6.0	8.4	4.6	4.4	5.8	21.6	4.8
	T13	T14	T15	T16	T17	T18	T19	T20			
Total	31	41	49	35	21	66	22	18			
Per m^2	6.2	8.2	9.8	7.0	4.2	13.2	4.4	3.6			

Although only total Lepidoptera were recorded, the majority of these were A. homalacta. The figures are, for the most part, rather higher than those obtained in Pangia. This is probably due in part to the counting of damaged leaves (in many cases) rather than actual larvae, but could also reflect a real difference between counts in the different areas, due either to differences between the areas or differences due to the time of year when the counts were made.

In some plots damage was quite obvious, and this is reflected by the figures in Tables 1 and 2. However when visual assessments were made of the of the actual percentage of leaf area damaged or destroyed these were usually quite low. This amount of damage probably has little effect on tuber yield. Other root crops have been shown to be able to withstand substantial defoliation without significant reduction in yield (e.g. Perry 1976, 1977, for taro; Cranshaw and Radcliffe 1980, for potatoes).

If further work (see IC) on lepidopterous damage to sweet potato foliage is envisaged a much more detailed sampling programme would obviously be required, as well as assessments of amount of leaf material damaged or destroyed and experiments to relate leaf damage with reduction in yield of tubers.

(iii) Coleoptera

* Arsipoda tenimberensis Jacoby (Chrysomelidae).

Found in all gardens sampled. Adults feed on the upper epidermis of sweet potato leaves leaving small brown marks. Counts were as follows:

TABLE 3. Counts of Arsipoda tenimberensis adults on sweet potato foliage in the Mendi, Tari and Pangia areas, ten half square metre quadrats per garden.

3a. Mendi	M21	M22	M23	M24	M25	M26	M27	M28	M29	M31	M33
Total	14	3	10	13	29	7	51	41	41	36	49
Per m^2	2.8	0.6	2.0	2.6	5.8	1.4	10.2	8.2	8.2	7.2	9.2

3b. Tari	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T12
Total	31	18	54	49	54	42	42	28	43	27	13
Per m^2	6.2	3.6	10.8	9.8	10.8	8.4	8.4	5.6	8.6	5.4	2.6
	T13	T14	T15	T16	T17	T18	T19	T20			
Total	45	20	86	21	32	38	50	44			
Per m^2	9.0	4.0	17.2	4.2	6.4	7.6	10.0	8.8			

3c. Pangia	P8	P9	P11*	P11*	P15	P16
Total	70	54	45	47	43	37
Per m^2	14.0	10.8	9.0	9.4	8.6	7.4

*Two separate counts made on same sweet potato patch, 26 iv 82 and 27 iv 82 respectively.

There is a great variation in the counts (range 0.6 to 17.2 per m^2). Many counts were higher than previously recorded by Sutherland (1981) at Laloki where counts ranged from 0.6 to 7.1 per m^2 (three counts at different dates on one variety) and at Wau (Sutherland 1982a) where the range was 2.8 to 6.1 per m^2 (counts made on nine different varieties on twelve separate dates).

A nested analysis of variance (data in log(x+1) transformation) showed that there was a significant difference in counts between areas ($F = 5.07$ with 2 and 33 d.f., $P < 0.05$) but an even greater amount of variation was accounted for by gardens within areas ($F = 5.16$ with 33 and 324 d.f., $P < 0.001$) (see Appendix 7).

Variations in numbers could have been caused by many different variables. Sutherland's (1981) counts at Laloki showed different numbers on different ages of sweet potato foliage (although the data was not analysed for significance) and Sutherland (1982a) demonstrated significant differences (at $P = 0.05$) between numbers of A. tenimberensis on different varieties at Wau. Both of these variables would have been present for the counts presented here. Certainly there were a large number of varieties encountered, with usually several varieties in each garden. Variation in the varietal composition of each garden could have lead to variation in the numbers of A. tenimberensis.

Another variable which possibly has an affect on the numbers of A. tenimberensis is altitude. This could explain some of the variation in numbers between areas. This possibility is analysed in more detail in Appendix 7.

This species also occurs in Indonesia (Kimoto et al 1984).

Cassidinae (Chrysomelidae).

Many species of Cassidinae (tortoise beetles) are foliage feeders on sweet potato. Four species were collected during the course of the survey:

** _Cassida_ sp. _?diomma_ Boisduval.

This was the commonest cassidine collected. It is almost certainly _C. diomma_, but one or two of the specimens were not entirely typical and were sent for determination. The name above was given by a specialist for one of the specimens; notification is still awaited for the other, see Appendix 8.

** _Laccoptera impressa_ Blanchard.

Three specimens collected from sweet potato at Tari (T3). Also known from N. Australia (Kimoto et al 1984).

** _Aspidomorpha ?punctum_ (Fabricius).

Collected at Tari (T3, one only) and Pangia (P10, seventeen; P15, one only).

** _Aspidomorpha australasiae_ Boisduval.

Only collected from Pangia (P10, five).

Counts.

Cassidines were generally uncommon. The following are the counts made (virtually all C. diomma):

TABLE 4. Counts of Cassidine adults on sweet potato foliage in the Mendi, Tari and Pangia areas, ten half square metre quadrats per garden.

4a. Mendi	M21	M22	M23	M24	M25	M26	M27	M28	M29	M31	M33
Total	0	0	0	0	0	2	0	0	0	3	3
Per m^2	0	0	0	0	0	0.4	0	0	0	0.6	0.6

4b. Tari	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T12
Total	0	0	1	0	2	3	0	2	2	4	0
Per m^2	0	0	0.2	0	0.4	0.6	0	0.4	0.4	0.8	0

	T13	T14	T15	T16	T17	T18	T19	T20
Total	0	2	0	0	0	2	2	0
Per m^2	0	0.4	0	0	0	0.4	0.4	

4c. Pangia	P8	P9	P11*	P11*	P15	P16
Total	0	0	0	0	1	0
Per m^2	0	0	0	0	0.2	0

*Two separate counts made on same sweet potato patch, 26 iv 82 and 27 iv 82 respectively.

Sutherland (1982a) reported Cassida spp. "present in very low numbers" at Wau, but did not observe Aspidomorpha spp. At Laloki (Sutherland 1981), mean values per m^2 for Cassida sp. and Aspidomorpha sp. were 3.0 and 0.2 respectively. Cassida sp. was therefore more common there than in the present survey areas, but was till in relatively low numbers. Occasionally cassidines can increase to high numbers in some areas (unreported results at Bubia Agriculture Research Centre) and can severely damage crops already stressed by drought (Sutherland 1982b). Under normal circumstances, however, it appears that the plants are able to compensate for the relatively small amount of foliage removed.

Several other species of Cassidinae have been recorded from Papua New Guinea and other countries (e.g. D.P.I. Crop Insect Survey Records; Anon. 1978, Kimoto et al 1984). The taxonomy of the members of this subfamily from P.N.G. is still very confused and it appears that some species are known by various synonyms.

Other Coleoptera.

Several other species of Coleoptera were observed on or collected from sweet potato foliage. Some of these were predatory cantharids or coccinellids and are not included here. Others were known herbivores. Most of these were found in very low numbers, often in only one or two gardens. They included:

<u>Monolepta semiviolacea</u> Fauvel (Chrysomelidae).

Six collected from foliage at Tari (T23).

This species is a pest of sweet potato in New Caledonia (Brun and Chazeau 1980).

<u>Oribius inimicus</u> Marshall (Curculionidae).

Adults feeding on foliage at Mendi (M3, one only) and Pangia (P4, two; P16, one only).

(iv) Orthoptera

Several species of Orthoptera were collected from sweet potato foliage; with one exception, collections were only made in the Pangia area. Some of these species were found frequently and it is probable that some of the chewing damage on the leaves could be attributed to them. The more common species were:

Gryllid sp. 1 (Gryllidae).

A small gryllid species which was quite frequently found on the foliage in the Pangia area (P8, two collected, one or two observed in each of the ten half metre square quadrats; P9, eight collected, frequently observed; P11,present, but only three observed in the quadrats; P14, common; P15, present, only one observed in quadrats). Also noted at Tari (T25) and at Mendi (M39).

Gryllid sp.2 (Gryllidae).

Another small gryllid species found in Mendi (M12, two; M13, one) and Pangia (P8, one).

<u>Phaneroptera brevis</u> Serv. (Tettigoniidae).

Present on foliage in gardens in the Pangia area (P9, P16).

<u>Phaneroptera</u> sp. has been recorded as a pest of sweet potato in Malaysia (Hua 1970).

Tettigoniid sp.1 (Tettigoniidae).

Present on foliage in the Pangia area (P4, one collected; P9, one collected; P14, present but not common). A record made early in the survey in Mendi (M3) of tettigoniid nymphs and adults feeding on and causing minor damage to foliage could have been this species, but specimens are not available for confirmation.

** Atractomorpha crenaticeps (Blanch) (Pyrgomorphidae).

Collected from foliage in Pangia (P14, present but not common; P15, present; P16, present; present also in general collections from P1, P2, P8, but not from sweet potato) and noted on foliage at Tari (T25). This species was also collected from Mendi (M2, one; M15, one) and Tari (T21, two; T24, eight) but not specifically from sweet potato.

(N.B. Orthoptera were not collected and/or studied in all gardens. The species listed above were probably present in more gardens than actually noted. General collections also included species of Orthoptera from sweet potato, but they were not specifically noted as such).

(v) Hemiptera

Cicadellids (Cicadellidae).

Many species of cicadellid (leaf hoppers) were collected from the foliage of sweet potato. Virtually all of these were collected with the sweep net and were therefore, with the exception of Cicadellid sp.1, only recorded from those gardens listed on page 5. The species recorded were:

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* Cicadellid sp. 1: **Zygina medioborealis Ghauri / **Zygina sp. sensu lato / **Balclutha sp.

These are small yellow green cicadellids and are the commonest type found on the foliage in all three areas. They were originally thought to be one species but a series (all from the same garden) sent for identification, included specimens assigned to each of the above three names (see Appendix 8). This type was the only one counted in the quadrats (see below).

Zygina medioborealis was originally described by Ghauri (1980) from specimens collected in the Enga Province by B.M.T.

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* Cicadellid sp. 3: **Cicadella wallacei Distant.

Present in several gardens at Pangia (P3, two collected; P4, two coll.; P8, to coll.; P9, one coll.; P15, three coll.; P16, two coll.).

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*   Cicadellid sp. 4: **Genus near <u>Orosius</u> / Gen. et sp. indet.

Present in several gardens at Pangia (P4, two collected; P8, seven coll., one or two recorded in most quadrats; P9, one coll., present but not common; P11, six coll., four in quadrats; P15, four coll., three in quadrats; P16, four coll., six in quadrats) and Tari (T22, one coll; T23, one coll.).

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*   Cicadellid sp. 5: <u>**Cicadella</u> sp. <u>sensu lato.</u>

Present at Mendi (M12, one coll.; M13, one coll.) and Pangia (P4, one coll., not from sweet potato).

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*   Cicadellid sp. 6:

Present at Pangia (P3, one coll.; P15, one coll.).

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*   Cicadellid sp. 7: <u>**Zygina</u> sp. <u>sensu lato.</u>

Present at Mendi (M14, one coll., not from sweet potato) and Pangia (P3, one coll.; P8, one coll.; P11, one coll.; P14, one coll; P15, four coll.). This species also previously collected at Wabag (E.P.) and Kagoba (S.H.P.).

Cicadellid sp. 9.

Present at Pangia (P8, one coll.).

Cicadellid sp. 10.

Present at Mendi (M12, one coll.; M13, one coll.).

Cicadellid sp. 11.

Present at Mendi (M5, one coll.).

Cicadellid sp. 12.

Present at Pangia (P3, one coll.).

Cicadellid sp. 13.

Present at Pangia (P9, one coll.).

Cicadellid sp. 14.

Present at Mendi (M12, one coll.).

Cicadellid sp. 15.

Present at Tari (T23, one coll.).

Cicadellid sp. 16.

Present at Tari (T23, one coll.).

Cicadellid sp. 17.

Present at Tari (T23, one coll.).

Cicadellid sp. 18.

Present at Tari (T22, six coll.; T23, two coll.).

Cicadellid sp. 19.

Present at Tari (T23, two coll.).

Cicadellid sp. 20.

Present at Tari (T23, three coll.).

Cicadellid sp. 21.

Present at Tari (T22, one coll.).

Many of these were represented only by single specimens from the sweep net samples. However they are all listed to show the range of species of cicadellids which do occur on sweet potato (see below for a discussion on the possible importance of cicadellids on this crop). Some of the species may not in fact feed on the foliage of sweet potato but may be feeding on other plants, particularly weed species, within the gardens. However care was taken when sweeping to avoid weed patches as much as possible.

Of those species which were sent for identification (those for which a reasonable series was obtained) only two (sp. 1a & 3) have been given confirmed specific names. Ghauri at the Commonwealth Institute of Entomology is apparently revising this group at present, and definite names should be available for some of these species in the not too distant future.

Counts.

Only the type originally called Cicadellid sp. 1 was counted in the quadrats. This was far more common than any of the other species. The counts were:

TABLE 5. Counts of Cicadellid sp.1 (in fact three species, see text) on sweet potato foliage in the Mendi, Tari and Pangia areas, ten half square metre quadrats per garden.

5a. Mendi	M21	M22	M23	M24	M25	M26	M27	M28	M29	M31	M33
Total	12	14	32	45	26	31	38	36	40	47	66
Per m^2	2.4	2.8	6.4	9.0	5.2	6.2	7.6	7.2	8.0	9.4	13.2

5b. Tari	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T12
Total	74	35	72	91	81	75	50	46	68	89	25
Per m^2	14.8	7.0	14.4	18.2	16.2	15.0	10.0	9.2	13.6	17.8	5.0
	T13	T14	T15	T16	T17	T18	T19	T20			
Total	81	45	57	60	58	86	63	82			
Per m^2	16.2	9.0	11.4	12.0	11.6	17.2	12.6	16.4			

5c. Pangia	P8	P9	P11*	P11*	P15	P16
Total	18	0	0	4	1	5
Per m^2	3.6	0	0	0.8	0.2	1.0

*Two separate counts made on same sweet potato patch, 26 iv 82 and 27 iv 82 respectively. 2

Counts ranged from zero to 18.2 per square metre. Even the higher population levels were not enough to give significant feeding damage, but cicadellids could become important as disease vectors (see next section).

Disease transmission.

Cicadellids have been shown to be vectors of some diseases caused by viruses and mycoplasma-like-organisms. One of the latter diseases found in P.N.G. is the "Little Leaf" or "Witches Broom" disease (Anon. 1978; Pearson 1981, 1982; Van Velsen 1967). The disease has been reported from Keravat (E.N.B.P.) and Lae (M.P.) but only appears to cause serious losses in the Central Province (Pearson 1981, 1982). It had not been recorded in the highlands (Pearson 1981) until 1982 when a suspected case was discovered in the S.H.P. (Anders, personal communication; Pearson, personal communication).

Sweet potato "Little Leaf" disease has been shown to be transmitted by a cicadellid, Orosius lotophagorum ryukiensis (Ishihara), in the Solomon Islands (Anon. 1978; Jackson and Zettler 1983). This species has been recorded from Laloki, C.P. (Ismay, pers. comm.) but was not recorded in the present survey.

Tests overseas failed to obtain transmission by Cicadella viridis (L.) or Myzus persicae (Sulz.) (Aphididae). Van Velsen (1967) working in P.N.G., was able to get transmission by Halticus tibialis Reuter (Miridae), but not by Planococcus citri (Risso) (Pseudococcidae), Bemisia tabaci (Genn.) (Aleyrodidae) or M. persicae. The discovery of a mirid vector is surprising; in a list of fifteen diseases caused by mycoplasma or mycoplasma-like organisms in which the vector has been identified (Kranz et al. 1977), in all cases the vector was a leafhopper (it was not specified whether these were delphacids or cicadellids).

At present no further work is probably justified on cicadellids on sweet potato in the highlands. However if virus or mycoplasma diseases do become a problem further work on the identity and role vectors of the above species would be warranted.

Delphacids (Delphacidae).

A few species of delphacid were found on sweet potato foliage, but they were generally far less common than cicadellids. The species were:

Delphacid sp. 5.

Present at Mendi (M13, one) and Tari (T22, one).

Delphacid sp. 7.

Present at Pangia (P3, one).

Delphacid sp. 9.

Present at Pangia (P3, one).

Delphacid sp. 10.

Present at Tari (T22, four; T23, two).

Delphacid sp. 11.

Present at Tari (T23, one).

Delphacid sp. 12.

Present at Tari (T23, one).

Populations were so low that no significant damage was evident. However, as with cicadellids, delphacids can act as vectors of diseases.

Mirids (Miridae).

Two phytophagous species were found which are potential pests:

Halticus tibialis Reuter.

Commonly found on sweet potato foliage in P.N.G. Present at Tari (T22, four coll.; T25, two) and Pangia (P3, four coll.; P8, five in quadrats; P11, one in quadrats; P14, one coll.). The mean number per square metre for the Pangia area was 0.2 (n = 60 half square metre quadrats). This is considerably lower than recorded in other localities (Laloki, Wau, Lae) by Sutherland (1981, 1982a, b) where mean values of up to 10 per square metre were recorded. This species has been implicated as a vector of "Little Leaf" disease (Van Velsen 1967) (see also discussion under cicadellids).

Helopeltis clavifer (Walker.

Found in Tari (present in T2, T3, T4, T5, T6, T7, T8, T10, T18, T20) and Pangia (P3, one coll.; P11,4; P14, 4; P15, 1; P16, 1). Counted in the quadrats at Pangia where the mean number per square metre was 0.1 (n = 60 half square metre quadrats). It was not counted at Tari but was recorded by one of us (R.T.M.) as fairly common and common in two gardens.

Damage by Helopeltis sp. typically takes the form of necrotic areas of plant tissue caused by the toxic saliva of the insect. Fresh marks have a water soaked appearance and soon become dark brown to black due to the death of the plant cells (Smith 1978). On sweet potato leaves the brown spots have an angular shape due to the area of effect of the toxic saliva being bounded by veins. This type of damage was present at low levels in some gardens. Recently (early 1984) damage to the growing tips of sweet potato has been observed at Mendi (M39). The damage was consistent with that caused by Helopeltis clavifer and this species was present in the garden. Similar damage has also been observed in the Tari area where it was thought to be associated with die-back retarding the establishment of young plants (Quin, pers. comm.). However Miles and Thistleton (1984) concluded that a causal relationship between the mirid and the die-back was unlikely and that any mirid damage observed was probably coincidental.

These insects are relatively long lived and can make as many as fifty feeding punctures in one day (Kranz et al. 1977). Even quite low populations are therefore capable of causing serious damage. This is a species which could warrant further studies on sweet potato.

Lygaeids (Lygaeidae).

The ?foliage feeding lygaeid Nysius villicus Van Duzee, was observed in very low numbers in each of the three areas (M12, one coll.; P3, 2; P8, 2; T22, 2). Its significance on sweet potato is not known.

Pentatomids (Pentatomidae).

The pentatomid **Antestiopsis chambereti Le Guillon was common on foliage in one garden at Pangia (P9, five coll.; one or two in each half square metre quadrat) and was also found in two other gardens (P8, one coll.; P14, 1). Its significance is not known. Antestiopsis spp. are recorded as pests of coffee by Kranz et al (1977), but on this survey one A. chambereti was recorded on sugar cane at Pangia (P17) sucking the body contents of an earwig.

Other Hemiptera included the predatory nabid Tropiconabis capsiformis (Germer) (Nabidae) and several mirids including ?Deraeocoris sp. and Creontiades sp. which were assumed to be predators. All of these appear to be frequent on sweet potato in the highlands, but at very low population levels.

(vi) Other insects

Many other insects of no pest status were observed on foliage of sweet potato, or collected in the sweep net. These included adult Diptera (not damaging as adults, any species which are pests would have been collected as larvae on their host plants), parasitic Hymenoptera (identifications of these are of little value unless the host species is also known) and the odd specimen of Dermaptera and Formicidae.

(vii) Mites (Acarina)

Eriophyids (Acarina: Prostigmata: Eriophyoidea).

Early in 1984 some samples of leaves with "rust" symptoms were sent to Kuk by Dr F. M. Quin for identification. These were infested with an eriophyid mite. Apparently these symptoms are relatively common in the Upper Mendi area (Dr Quin pers. comm.) but had been overlooked in the survey. One of us (B.M.T.) has since observed this damage in Upper Mendi (M34, 35, 36, 37, 38). Some leaves had large populations of mites but no obvious symptoms, while others showed the rust symptoms of the initial samples.

Specimens have been sent to the Commonwealth Institute of Entomology and to Dr J. Gutierrez (Ecole Nationale Superieure Agronomique) for determination. Dr Gutierrez has replied that these mites belong to a new taxa.

IB Tuber Insects

(i) Methods

In a few plots samples of tubers were examined for insect damage. Whether this was done depended on the age of the crop and the willingness of the garden owner for the tubers to be dug up.

Tubers were examined in eleven gardens at Mendi (M1, M2, M17, M18, M21, M22, M24, M26, M27, M28, M33), three at Tari (T3, T6, T11) and two at Pangia (P19, P20).

(ii) Coleoptera

Cylas formicarius Fab. (Apionidae).

This species was not located at Mendi or Tari during the pilot survey or main survey, although it was undoubtedly there as populations in the vines. Present at Pangia (recorded in P9). Toward the end of 1982 several reports were received at Kuk A.R.S. of outbreaks of *C. formicarius* in the highlands. At this time the problem was present at Pangia (P19, P20) and at Mendi and Tari (Anders, pers. comm.).

C. formicarius is probably the most serious pest of sweet potato in certain areas of P. N.G. at the present time. It appears to be more serious in the lowlands than in the highlands but this has not been studied in detail. Damage levels also appear to increase in successive crops grown on the same piece of land and there is now some experimental evidence to support this (Sutherland, pers. comm.).

It has frequently been said that *C. formicarius* damage is often more serious in periods of dry weather (e.g. Szent-Ivany 1972; Szent-Ivany and Stevens 1966) and Kimber (1972) stated that outbreaks occur regularly every year in the drier areas in the highlands. Smee (1965) attributed this increase to cracking of the soil which allow weevils to reach the tubers more easily.

Sutherland (e.g. 1981, 1983) has contested these statements and has gathered more information on *C. formicarius* outbreaks. Until data is available which can be used to *C. formicarius* populations to rainfall, soil type and moisture holding characteristics, previous history of the land regarding sweet potato plantings, etc., no firm statement can be made regarding this widely held belief.

Control measures for the weevil are at present based on cultural methods (Sutherland 1982c), with the possibility of good insecticidal methods being available for market garden situations in the near future (Sutherland, pers. comm.). Investigations being carried out into resistant varieties overseas (e.g. at I.I.T.A., A.V.R.D.C. and by U.S.D.A.) are long term projects and, even if ultimately successful, there is little prospect of resistant varieties becoming available within the next few years.

A more detailed investigation of Cylas formicarius incidence in the study areas at different times of the year may be worthwhile and may yield extra information into the factors which lead to the development of damaging population levels.

A detailed review of C. formicarius research has been prepared by Sutherland (1984).

Scarabaeids (Scarabaeidae).

Scarabaeid beetle adults are known to feed on sweet potato tubers leaving holes similar to that produced by Papuana spp. on taro. Papuana spp. are the usual species implicated but one of us (B.M.T.) has recorded Clysterius angustus Arrow causing damage at Tambul.

The following are the records of damage from this survey:

TABLE 6. Number of tubers damaged by scarabaeid beetles in the Mendi and Tari areas, ten to twenty tubers examined per garden.

	M21	M22	M24	M26	M27	M28	M33	T3	T6	T11
No. examined	20	20	20	20	10	12	10	10	20	10
No. damaged	0	0	2	2	2	0	0	0	0	3

Damaged tubers had 5% or less of the tuber removed.

Elaterids (Elateridae).

A larva of an elaterid beetle (wireworm) was found boring into a tuber in Mendi (M16) and another was found inside the subterranean part of a stem (M24). These were not recorded in other areas where stems and/or tubers were examined (M17, M22, M24, M25, M26, M27, M28, M29) although one or two wireworms were found in the soil in some of these gardens.

Data on numbers of tubers damaged by wireworms is not presented here as there was some confusion on the identification of the damage.

(iii) Orthoptera

Gryllotalpa africana Beauv. (Gryllotalpidae).

Two tubers (out of twenty sampled) were damaged by this insect in one garden in Mendi (M22). All the tubers assessed fo Papuana spp. damage were also assessed for damage by this insect but, apart from M22, no damage was recorded.

Teleogryllus commodus Wlk. (Gryllidae).

Adults and nymphs feeding near tubers at Mendi (M1).

(iv) Tuber damage.

In the instances of elaterid damage noted above the wireworm had bored into the tuber producing a narrow hole only slightly larger than its own diameter. Its posterior end was protruding from the hole. Other damage noted in the gardens where samples of tubers were assessed (same gardens as in Table 6.) consisted of superficial, shallow pits, not typical of wireworm damage. These pits were too large in diameter to have been caused by C. formicarius adults.

Samples of tubers collected from Mendi (Kiburu) in April 1984 had similar small pits plus various other damage including shallow depressions consistent with early damage by scarabaeids.

Most of the damage observed was of a fairly superficial nature and not, in itself, too serious. However the damage could allow the entry of pathogens into the tubers. One such pathogen is Ceratocystis fimbriata (black rot) which has been recorded from the Mendi area by Tomlinson (D.P.I., Plant Pathology). The significance of this disease in the area is not known at present. It is possibly also associated with various nematode problems of sweet potato.

Further work on the insects attacking sweet potato tubers (in conjunction with studies on black rot and nematode problems) is probably justified.

In the U.S.A. damage of the types under consideration is caused by various beetles (Coleoptera) of the families Elateridae (wireworms), Chrysomelidae and Scarabaeidae (e.g. Cuthbert and Reid 1965; Jones et al. 1982).

IC Discussion

(This is in addition to the discussion of each pest in the sections above).

(i) Foliage insects

Although many species of insects, both chewing and sucking, were recorded from sweet potato foliage, few appeared to be causing significant damage. Sweet potato can probably compensate reasonably readily for loss of foliage similar to other root crops (see discussion on Lepidoptera on page 8). However this has not been tested experimentally and, if more severe levels of damage are recorded, crop loss assessment trials may be worthwhile. These would be designed to allow the relationship between the amount of foliage damage and reduction in yield to be examined. However such trial work would be very time consuming and difficult to carry out and may not be warranted at this stage.

Sucking insects (Hemiptera: various families) appear not to be abundant enough to cause significant direct damage but, as already discussed, they could become important if diseases caused by viruses or mycoplasma (or mycoplasma-like organisms become a problem. Considering the fact that sweet potato has probably been grown in the highlands now for 200 - 300 years (Powell et al. 1975) without serious problems with diseases of this type arising, the likelihood of this happening may not be very great. However it is a situation which should be monitored.

Counts of some of the insects occurring on the foliage were made using a sampling unit of a half metre square. This is a useful method to use for obtaining population estimates for comparison between areas, crops in different stages of growth, time of year, etc. and could be useful if further studies are envisaged. The technique has already been widely used by Sutherland (e.g. 1981, 1982a, b). However there were certain problems with this method which became evident during the current surveys. These problems are not insurmountable but should be borne in mind when using the method. These constraints are discussed in more detail in Appendix 9.

(ii) Tuber insects

More work may be justified on tuber pests of sweet potato, particularly sweet potato weevil. Investigations on the incidence of this insect in relation to various factors could complement the work already carried out in the lowlands by Sutherland and at U.P.N.G. Sutherland (1984) gives his priorities for further research on this species.

Further work is probably also justified on various soil insects which could attack sweet potato tubers and roots, and which could be associated with the black rot/nematode problem already under investigation by the AFTSEMU team.

II SUGAR CANE

(i) Methods

In most gardens where it was present, sugar cane was examined and insects recorded and/or collected for later determination. As a result of the Pilot Survey in the Mendi area it had been decided to record the presence or absence of various pests on each of ten bundles of cane (see Appendix 4). This was carried out but the results are not presented here, since the differences in cane growing techniques between the areas would not allow the results to be compared meaningfully (e.g. in Mendi the cane is bound into bundles while in Pangia it is often grown as single plants dispersed throughout the garden; there was also a large variation in the age of cane from garden to garden). The results presented here are therefore mainly presence/absence per garden.

(ii) Lepidoptera

Four species of Lepidoptera have been recorded as borers of sugar cane in Papua New Guinea (Li 1970). Only one of these was found during the present survey, but a fifth was added to the list.

Chilo sp. ?terenellus (Pag.) (Pyralidae).

Lepidopterous borers were found in virtually all the cane crops examined. In all three areas larvae were examined and/or collected for later examination. All of these were Chilo sp. A specimen of an adult from Tari was sent for identification but was only determined as Chilo sp. (see Appendix 8). However it is likely that the species was Chilo terenellus (Pag.). This is the only species of Chilo recorded from sugar cane in P.N.G. to date. It has been found in the Markham Valley (M.P.) (e.g. Li 1970b), Fly River area (W.P.), Maprik (E.S.P.) and Keravat (E.N.B.P.) (Bourke 1968) and Tekin (W.S.P.) (B.M.T.). Further breeding of adults from the S.H.P. would be desirable to establish the identity of the species there.

Information is available on the life history, population dynamics, parasites, etc., of C.terenellus through studies carried out in the lowlands (e.g. Li 1970c, 1971; Li and Sands 1972; Sands 1973). This species, along with Sesamia grisescens, is the target for introduced parasites in the Markham Valley (Young 1982b).

Sesamia grisescens Walker (Noctuidae).

This species was not found during the present surveys although it has been found in localities up to 1600 metres in the Eastern Highlands Province (Szent-Ivany and Catley 1960; Szent-Ivany and Ardley 1963). It has been considered by some authors (Szent-Ivany and Ardley 1963; Bourke 1968) to be the most serious pest of sugar cane in P.N.G., but others have recorded C. terenellus as more important with this species only a minor pest (Li 1970c, 1971; Li and Sands 1972; Sands 1973). Both Sands (1973) and Young (1982b) state that the preferred host species appears to be Saccharum robustum .

** Trachycentra chlorogramma Meyrick (Tineidae).

One larva collected from a tunnel in a sugar cane stem at Tari (T3). This species was mainly a pest of pandanus in the survey areas (see below). In Fiji the species is a pest of coconut but also bores in sugar cane stalks (Swaine 1971). This appears to be a new record for P.N.G.

Heliothis armigera (Hubn.) (Noctuidae).

Larvae feeding on foliage, Mendi (M27).

Borers (presumably mainly Chilo sp.) were present in ten (out of ten), fifteen (fifteen) and six (six) gardens in Mendi, Tari and Pangia respectively. Numbers of canes infested varied from 3/10 to 10/10. The few canes dissected yielded up to five larvae per cane.

Techniques for assessing losses due to damage by borers have been worked out in great detail (e.g. Metcalf 1969, who quotes various other papers; later papers can be found in various issues of the "Proceedings of the International Society of Sugar Cane Technology"). If further investigations are considered desirable (see general discussion on sugar cane insects) this literature would provide the basis for the development of sampling techniques.

(iii) Coleoptera

Rhabdoscelus obscurus (Boisd.)(Curculionidae).

This species was found in all three study areas, but no detailed destructive sampling was carried out to assess the severity of the damage. The larvae bore inside the stalks.

Szent-Ivany and Ardley (1963) consider it to be the most important beetle pest of sugar cane in P.N.G. They note that Buzacott (1953) had stated that it is more common as a pest of sugar cane at lower altitudes (up to approximately 500 metres), but they also quote a record of the insect at 1600 metres in the Eastern Highlands Province.

The weevil is thought to be a native of New Guinea (Wilson 1960). The parasite Ceromasia (=Microceromasia) sphenophori (Vill.) (Diptera: Tachinidae) has been introduced from New Guinea into other countries (Australia, Wilson 1960; Hawaii, Fiji, Guam, Philippines and Samoa, Rao et al. 1971) in attempts to give control. This parasite has been recorded in the highlands of P.N.G. (Szent-Ivany and Ardley 1963).

Other hosts of the weevil include banana, sago palm, coconut palm, oil palm and papaya (Kranz et al. 1977).

Further work on this insect in the highlands may be warranted (see discussion on sugar cane insects).

Oribius inimicus Marshall. (Curculionidae).

Collected from leaf axils of sugar cane at Mendi (M12, two collected; M17, common) but no apparent damage.

Oribius destructor Marshall. (Curculionidae).

One only in association with O. inimicus at Mendi (M17).

** Agrypnus sp. (Elateridae).

Adults of this species of elaterid were common in the leaf sheaths of sugar cane in all three areas.

** Hapatesus tropicus Neboiss. (Elateridae).

Adults of this species also found in leaf sheaths of sugar cane but not as commonly as Agrypnus sp.

** Compsolacon gracilis Candeze. (Elateridae).

Found in the leaf sheaths of sugar cane in two gardens at Pangia (P9, P12).

Bourke (1968) records Agrypnus sp. from the central spindle of young cane in the Northern Province, and Compsolacon gracilis as commonly found in the same situation in the Markham Valley. Some species of elaterid are known to be predatory on various leaf hoppers on sugar cane and Bourke (1968) considers that both of these species are possibly filling this role.

However the larvae of some species of elaterid feed on plant roots and are the well known "wireworms" (other species have predatory larvae). In some countries certain species of wireworm can cause significant damage to sugar cane. The significance of the larvae of the above three species is not known and needs further investigation. In Australia Agrypnus variabilis larvae are pests of sugar cane, maize, sorghum and sunflowers (Gunning and Forrester 1984).

Chauliognathus bituberculatus Wittm. (Cantharidae).
Chauliognathus wareoensis Wittm. (Cantharidae).

Chauliognathus adults were found in the leaf sheaths in many stands of sugar cane in Tari and Mendi, but they were not noted in this situation in Pangia. The above two species were recorded in Mendi, but only C. wareoensis in Tari. Chauliognathus adults and larvae are predacious (Britton 1970) and they may be feeding on leaf hoppers found in this situation.

(iv) Orthoptera

Many sugar cane plants showed leaf feeding damage typical of Orthoptera (grasshoppers, crickets, etc.). The species collected from sugar cane were:

** Atractomorpha crenaticeps (Blanch). (Pyrgomorphidae).

Collected in Mendi (M2, adults and nymphs associated with chewed leaves, damage minor; M13, one collected) and Pangia (P9, associated with damage). This species also present in Tari but not specifically collected from sugar cane.

Although associated with the damage, feeding was not actually observed. However, although Key (1970) states that most species of Pygomorphidae feed on dicotyledons, A. crenaticeps has been recorded feeding on sugar cane in Papua New Guinea and Australia (Anon 1969, 1971; Bourke 1968; Szent-Ivany 1972).

** Oxya japonica vitticollis Blanchard (Acrididae).

Collected from sugar cane at Mendi (M3, adults and nymphs associated with chewed leaves, damage minor). Also collected at Pangia, but not from sugar cane.

O. gavisa and O. vittigera have previously been recorded feeding on sugar cane (Anon. 1969, 1971; Bourke 1968; Szent-Ivany 1972).

Acridid sp. A (Acrididae).

An unidentified acridid collected from sugar cane at Pangia (P11). Superficially similar to Gesonula mundata which is known to feed on sugar cane (Anon 1969, 1971; Bourke 1968; Szent-Ivany 1972).

Valanga sp. (Acrididae).

One collected from sugar cane at Pangia (P7).

Valanga irregularis has been recorded feeding on sugar cane (Anon 1969; Bourke 1968; Szent-Ivany 1972) and V. zehntneri is a minor pest of sugar cane in Java (Pemberton 1963).

In addition to the above four, Anon (1969, 1971), Bourke (1968) and Szent-Ivany (1972) list various other species of Orthoptera which feed on sugar cane . Of these the following were found in the study areas, but not specifically on sugar cane:

Heteropternis obscurella (Blanch) (Acrididae).

Collected at Tari and Pangia.

Phaneroptera brevis Serv. (Tettigoniidae).

Collected at Pangia.

Full collections of Orthoptera were not made in all areas. It is probable that some of the above species occur in other areas than those listed.

In general foliage damge by Orthoptera to sugar cane was not severe. A discussion of the effects of defoliation of sugar cane by locusts and grasshoppers can be found in Bullen and MacCuaig (1969).

(v) Hemiptera

Delphacids (Delphacidae).

Three species recorded as follows:

** Eumetopina flavipes (Muir).

Very common. Recorded in ten (out of eleven), sixteen (seventeen) and eight (ten) gardens in which it was searched for in Mendi, Tari and Pangia respectively. In most cases it was abundant and was present on 50 - 100% of the canes.

In some gardens at Pangia ants (Hymenoptera: Formicidae) of the species **Iridomyrmex sp. (P12, one stem only), **Iridomyrmex cordatus Smith or species near (P11, two stems only nesting) and **Tetramorium bicarinatum Nylander (P12, several stems) were present along with E.

flavipes. It is not known if the ants were attending the E. flavipes to obtain honeydew.

E. flavipes has previously been recorded in P.N.G. (e.g. Bourke 1968; Bourke et al. 1973). Bourke (1968) states that "the occurence of this species in such numbers in cane of all ages is of interest in that it could develop into a major pest. Besides the obvious damage caused by feeding, it may also serve as a virus vector". However E. flavipes is not listed by Pemberton and Charpentier (1969) in their lists of vectors of sugar cane viruses.

Perkinsiella sp. (?spp.).

Perkinsiella sp. were recorded in eight (out of eleven), three (seventeen) and two (ten) gardens in Mendi, Tari and Pangia respectively. In general they were much less common than E. flavipes.

Specimens from Mendi (M13) sent for identification were determined as **Perkinsiella diagoras Fennah. This species was described in 1979 from material collected on the Mendi to Hagen road at 3100 metres (?misprint for 2100 metres) (Fennah 1979). Other species may have been represented in the samples but not sent for identification. Perkinsiella sp. are potential vectors of diseases in the area.

A total of fifteen species of Perkinsiella have been recorded from P.N.G., many of them described from material collected from that country (Muir 1910; Fennah 1979). Of these, two species have been shown (overseas) to be vectors of Fiji disease, P.saccharicida Kirkaldy by Montgomery and Bell (1933) and P.vasatrix (Breddin) by Ocfemia (1933). These two species are also listed by Kula and Young (1981) as the only species recorded in P.N.G. known to be vectors. In addition to these species Pemberton and Charpentier (1969) list P. vitiensis as a vector; this species has not been recorded in P.N.G.

Various attempts have been made to gain biological control of P. saccharicida in Hawaii using hymenopterous parasites introduced from Taiwan and Fiji. Many of these became well established and gave considerable control (Rao et al 1971; also gives other references).

The egg predator Tytthus mundulus (Bredd.) (Hemiptera: Miridae) was introduced from Australia, Fiji and the Philippines to Hawaii. It became well established and effectively controlled the leafhopper (Rao et al. 1971; also gives other references). T. mundulus was recorded during the present survey from the Mendi area (see below).

** Sogata sp.

Collected at Mendi only (M20, two only).

Delphacid sp. 4.

Collected at Mendi (M20, one only).

Details of the biology and damage caused by delphacids to sugar cane are given in Fennah (1969). For Perkinsiella damage results from the laceration of the leaf tissue by the ovipositor with subsequent reddening and drying; dessication of the leaves as a result of feeding; development of sooty mould; and the transmission of diseases. There is apparently much variation between varieties and between plants of different nutritional status.

Derbids. (Derbidae).

** Swezeyia sp.

Collected at Pangia (P5, two only).

Other species of derbids have also been recorded in low numbers on sugar cane in P.N.G. (Bourke 1968; Bourke et al. 1973; Szent-Ivany and Ardley 1963). Nymphs of Derbidae feed on fungi growing in the cane trash amongst the stools (Fennah 1965, 1969).

Lophopids (Lophopidae).

Lophopid sp. 1.

A species of lophopid was collected in small numbers from cane at Tari (T22). Unfortunately the specimens were damaged and could not be sent for identification. However they agree well with the illustration of Lophops saccharicida Kirk in Woodward et al (1970).

L. saccharicida has previously been recorded in P.N.G. from the Morobe, Central and East New Britain Provinces (Greve and Ismay 1983). A species of lophopid (unidentified) was collected from sugar cane in the Markham Valley in reasonable numbers (Anon 1969; Bourke 1968) and a Lophops sp. has been recorded in moderate numbers on leaves at the same locality (Bourke et al. 1973) (the record for L. saccharicida from the Morobe Province given by Greve and Ismay presumably refers to these records). An undescribed species of Serida has also been collected from S. robustum in the Markham Valley (Szent-Ivany and Ardley 1963).

A species of lophopid, Pyrilla perpusilla (Walker) is an important pest of sugar cane overseas (Fennah 1969).

Cercopids (Cercopoidea: Cercopidae and Aphrophoridae).

Two species of cercopids (froghoppers) found, one from each of the two families:

Cercopid sp. 1 (Cercopidae).

One collected at Pangia (P5) and also a few others noted on sugar cane in the area; also noted at Tari. Uncommon. No evidence of breeding on the plants.

Cercopid sp. 2. (Aphrophidae).

Not found during the survey, but found in reasonable numbers on sugar cane at Kagua on 3 iii 83. Both adults and nymphs in "spittle" were found in the young leaf sheaths of the plants.

No other records for P.N.G. can be found.

Cercopids of a range of species are common pests of sugar cane overseas. The presence of these species on sugar cane in P.N.G. may warrant further investigation.

Aphids (Aphididae)

** Ceratovacuna lanigera Zehnt.

This aphid has a mealy covering and can be mistaken for a mealybug on superficial examination. It is usually found on the leaves of sugar cane, whereas mealybugs are found on the lower stems (see below).

This species was recorded from sugar cane in Pangia (P2, P13 - in this case mealybugs also found on the lower stems of the same plant) and Tari (T21).

The species was first recorded in P.N.G. by Buzacott (1953). Szent-Ivany and Catley give (1960) give records from the Central and Milne Bay Provinces, Szent-Ivany and Ardley (1963) from Eastern Highlands, Western Highlands, Central and Milne Bay Provinces Bourke et al. (1973) from Morobe Province and Greve and Ismay (1983) from Western Highlands Province.

Sands (1973) notes it as a potential pest of sugar cane in the Markham Valley, particularly during dry weather. He records the principal natural enemies as the predatory ladybird Leptotheca csikii Wse (Coleoptera: Coccinellidae) and the predatory moth larva Isauria aphidivora Meyr. (Lepidoptera: Pyralidae).

Simmonds (1969) records it as a serious pest in Taiwan, Java and the Phillipines, and states that it also occurs in other areas of the Far East.

Attempts at biological control of have been made in some countries. A eulophid parasite, Encarsia flavoscutellum Zehnt. (Hymenoptera: Eulophidae), was introduced from Java to Taiwan and the Phillipines. Predatory ladybirds (Coleoptera: Coccinellidae) of the species Coelophora biplagiata Swartz., C. saucia Muls. and Scymus sp. were introduced into Taiwan from Indo-China, and C. biplagiata was taken later from Taiwan to Java (Simmonds 1969; Rao et al. 1971; further references given in both of these).

Mealybugs (Pseudococcidae).

Two species were found:

** Trionymus sp. 1.

This was found at Pangia (P7, P9, P13).

** Trionymus sp. 2.

Also at Pangia (P9) in the same garden as sp. 1.

Mealybugs were also found in the Mendi (M3 and others) and Tari areas but have not been sent for identification. They are probably one of the above two species.

At Pangia mealybugs were almost always associated with ants of the species **Iridomyrmex cordatus Smith (or species near). This species nested on the lower stems, with earthy deposits round the stems up to one metre from ground level. Mealybugs were found in the earthy nests in association with the ants (see below for further treatment of the ants found on sugar cane).

Two species of mealybug have previously been collected from sugar cane in P.N.G., both from the Morobe Province. These are Sacchariococcus (=Trionymus) sacchari (Ckll.) (Anon 1969) and Dysmicoccus brevipes Walk (Li 1970c). S. sacchari is found in virtually all sugar cane countries and D. brevipes has been recorded from Egypt, Caroline Islands, Guam, Australia, Fiji, Puerto Rico and Hawaii (Dick 1969; also gives other references).

Although S. sacchari was previously in the genus Trionymus neither of the two species from Tari are apparently identical with this species. In his determination list Williams (C.I.E.) states that "these are two interesting species on sugar cane".

Other Hemiptera.

?Phaenacantha sp. (Colobathristidae).

Nymphs and adults in low numbers at Tari (T21) and Pangia (P1).

Buzacott (1953) recorded two species of Phaenacantha from P.N.G. a smaller species from the lowlands and a larger one from the Central Highlands. Apparently they caused only slight leaf spotting and seemed to be of no or very little economic importance. Szent-Ivany and Ardley (1963) recorded a Phaenacantha sp. in dense populations on sugar cane in a native garden near Port Moresby. Bourke (1968), Bourke et al.(1973) and Anon (1969) record two species from cane in the Morobe and Northern Provinces.

The species Phaenacantha distincta Distant was recorded from a grassy area at Pangia.

** Tytthus mundulus Breddin (Miridae).

This species was found in Mendi in six (out of thirteen) gardens examined, but was not found at Tari or Pangia. It is a known egg predator of Perkinsiella sp. It is not known if it attacks other leaf hoppers such as Eumetopina flavipes. It has been used in other countries for biological control (see under Perkinsiella sp.).

As shown above there are a large number of Hemiptera associated with sugar cane in P.N.G. The effect these have on the plants through sap sucking, oviposition, facilitation of sooty mould growth and disease transmission has not been fully evaluated and may warrant investigation.

(vi) Dermaptera.

Five species of Dermaptera (earwigs) were found inside the leaf sheaths of sugar cane. These were *sp.1 (coll. P5, T21, and noted in other gardens in the three areas), *sp.2 (coll. P9, P11, and noted in other gardens at Pangia), *sp.4 (coll. P6), sp.5 (coll. T21) and *sp.6 (coll. M17). Determinations of these species are still awaited. Dermaptera can be both plant and animal feeding, living and dead tissue.

One of the species found (sp.1) is believed to be Chelisoches morio F. Bourke (1968) recorded this species as being common at various localities in the Morobe and Northern Provinces sheltering in the leaf roll of sugar cane.

It is reported to be of considerable importance as a predator (Clausen 1940). Swaine (1971) records it as feeding on caterpillars and sugar cane leafhoppers but also says that it feeds on some vegetable matter and Terry (1905) records it as a predator of Perkinsiella saccharicida Kirk. In Papua New Guinea Catley (1966, quoting Simmonds, 1960) records it as a predator of Brontispa longissima (Coleoptera: Hispidae), Gagne (1977) considered that it might be a predator of larvae of Lepidoptera on maize and tomato and Smith (1977) demonstrated that it is a natural enemy of the banana fruit fly.

(vii) Hymenoptera.

Formicidae.

Six species of ants were found on sugar cane. Some of the species were nesting and were associated with mealybugs or leafhoppers.

** *Iridomyrmex* sp. *?glaber* Mayr.

Collected from sugar cane in Pangia (P8).

** *Iridomyrmex* sp.

Collected from one sugar cane plant in Pangia (P12) in association with *Eumetopina flavipes.*

** *Iridomyrmex cordatus* or species near.

Collected from several gardens at Pangia (P9, P11, P13). Nesting on the lower stems of plants in dead leaves, but frequently with an earthy deposit which extended up to one metre above ground level. This species was often associated with mealybugs.

?Leptomyrmex melanoticus Wheeler.

Collected from sugar cane in one garden at Tari (T21). Identified by comparison with specimen KK5140 from sweet potato.

** *Tapinoma melanocephalum* (F.)

Nesting in lower dried leaves to a height of about 50 centimetres in one garden at Pangia (P9). Mealybugs not associated with this species, although they were present and associated with *I. cordatus* in this garden.

** *Technomyrmex albipes* Smith.

Collected from sugar cane in one garden at Pangia (P17) and one garden at Tari (T21).

** *Tetramorium bicarinatum* (Nylander).

Collected from sugar cane at Pangia (P12) in close association with *Eumetopina flavipes* on several plants.

(viii) Diptera.

Several species of Diptera were reared from sugar cane stems from Tari (T22). The larvae were feeding inside short young stems approximately 30 centimetres tall growing from the bases of larger plants. When cut through at the base there was no damage by other boring insects but higher up the stems were dying and rotting and being eaten by the fly larvae. It is not known whether any of the larvae were causing primary damage or whether they were all feeding secondarily on rotting tissue.

The main species was a **Gaurax* sp. (Diptera: Chloropidae). Also reared were a lonchaeid (Diptera: Lonchaeidae), a neriid (Diptera: Neriidae), and an empid (Diptera: Empididae).

Other Diptera have been recorded feeding inside sugar cane stems in the Morobe Province (Anon 1969; Bourke 1968). These included a chloropid *Scoliophthalmus* sp. and a lonchaeid *Silba* sp.

Also at Tari (T21) another chloropid, ***Thressa punctifera* (de Meij.) was collected as adults from sugar cane leaves. This has previously been bred from larvae causing secondary damage to corn attacked by *Ostrinia* in the Morobe Province (Sutherland, pers comm).

(ix) Other insects.

Several other insects were collected as individuals or in low numbers. The status of these is uncertain and at present they will not be reported here.

(x) Discussion.

As shown there are a large number of insects associated with sugar cane in P.N.G. Some of these are potentially serious pests, particularly the moth and weevil stem borers and certain of the sucking insects (Hemiptera).

Research into the control of some of these pests (e.g. biological control of lepidopterous stem borers) in P.N.G. is already being carried out in commercial crops by the Ramu Sugar Company. Whether further work is justified on the significance and control of these insects in village plots depends on the importance placed on this plant as a subsistence crop by agronomists and nutritionists.

If further work is contemplated then the roles of each of the species should be investigated and crop loss assessment experiments carried out (if possible) to assess yield loss caused by the more important pests in the subsistence garden situation. A review of techniques for sampling sugar cane insects can be found in Southwood (1969).

III PITPIT, HIGHLAND AND LOWLAND

(i) General

For convenience the two different pitpit species are dealt with together in this section. They are the highlands pitpit, *Setaria palmifolia* and the lowlands pitpit, *Saccharum edule.*

Pitpit occurred in many of the gardens examined (Appendix 6). In Mendi and Tari only the short highlands pitpit was present, whereas in Pangia both this and the taller lowlands pitpit were grown.

Very little damage to the foliage was observed, and this appeared to be caused by grasshoppers (Orthoptera) of presumably the same species as were discussed under sugar cane. In one garden there was minor leaf damage by a species of *Oribius* weevil (Coleoptera: Curculionidae).

(ii) Lepidoptera

Chilo sp. *?terenellus* (Pag.) (Lepidoptera: Pyralidae)

Lepidopterous borers were found in most stands of pitpit examined. The larvae appeared to be identical to those recorded from sugar cane (see above).

In Mendi borers were present in nine (out of eleven) gardens examined and in Tari sixteen (twenty). Numbers of stems affected varied from one to two out of ten in Mendi, and from one to four out of ten in Tari. No detailed counts were made in Pangia, but borers were present in both species.

IV TARO (Colocasia and Xanthosoma)

(i) Methods

Taro, both Colocasia esculenta and Xanthosoma, was examined in all gardens in which it was present. Some of the foliage insects were assessed on a presence/absence basis on ten plants; others were recorded on a presence/absence basis for the plot as a whole.

(ii) Hemiptera

Several species of Hemiptera were recorded as follows:

Tarophagus proserpina (Kirkaldy) (Delphacidae)

Commonly found on C. esculenta in all three areas (Table 7), but not recorded from Xanthosoma sp. despite examination of this crop in several gardens in Tari and Pangia (T1, T3, T4, T6, T7, T9, T10, T11, T12, T14, T17, T18, T19 T20, P2, P10, P14, P17).

TABLE 7. Numbers of Colocasia esculenta with Tarophagus proserpina in the Mendi, Tari and Pangia areas, ten plants per garden.

3a. Mendi	M21	M23	M24	M26	M27	M29	M30	M31	M32
Total	10	0	10	10	0	10	6	10	10
3b. Tari	T1	T2	T4	T5	T6	T7	T9	T10	T11
Total	10	10	7	10	8	8	7	8	7
	T12	T13	T15	T16	T17	T18	T19	T20	
Total	5	0	6	6	7	4	2	7	
3c. Pangia	P8	P10	P11	P14	P17				
Total	1	5	8	0	+				

+ Present but no count made.

T. proserpina causes damage to the plant through its feeding and egg laying. Sap exuding from these punctures forms a reddish encrustation on the outside of the leaf stalks near the ground. In Fiji severe local outbreaks can cause stunting and wilting of the plant (Swaine 1971).

T. proserpina is a known vector of the large virus particle associated with the alomae and bobone diseases of C. esculenta (Gollifer et al. 1977) and it has been suggested that it might also transmit the small particle (Gollifer et al. 1977; Jackson 1978). These diseases have been mainly recorded from lowland areas (Shaw et al. 1979) although Jackson (pers. comm.) has suggested that some

symptoms on C. esculenta leaves which he observed in the Mendi and Mt Hagen areas could have been caused by one or other of these virus particles.
Perry (1977) considers direct feeding damage by T. proserpina to be insignificant in P.N.G.,the main role of the insect being in virus transmission. However no studies have been carried out on these aspects in the highlands.

** Mecomma sp. (Miridae)

This mirid species was found in all three areas (Table 8) on C. esculenta but not on Xanthosoma sp. It was always found in association with the previous species.

TABLE 8. Numbers of Colocasia esculenta with Mecomma sp. in the Mendi, Tari and Pangia areas, ten plants per garden.

3a. Mendi	M21	M23	M24	M26	M27	M29	M30	M31	M32
Total	2	0	0	5	0	2	0	0	2
3b. Tari	T1	T2	T4	T5	T6	T7	T9	T10	T11
Total	1	1	0	0	1	2	0	0	0
	T12	T13	T15	T16	T17	T18	T19	T20	
Total	0	0	0	0	0	0	0	0	
3c. Pangia	P8	P10	P11	P14	P17				
Total	0	1	1	0	0				

It was originally thought to be a Cytorhinus sp. one species of which, C. fulvus, is a known egg predator of T. proserpina . This occurs in the Philippines, Carolines, New Guinea, Java, Fiji and Samoa (Swaine 1971) and has been imported into Hawaii from Australia for biological control of this insect (Matsumoto and Nishida 1966).

It is quite probable that Mecomma sp. is also an egg predator of T. proserpina and further studies on this relationship may be of interest. Dr M. R. Wilson (C.I.E.) who made the determination is also of this opinion.

** Cicadella sp. sensu lato (Cicadellidae)

This large white cicadellid species is commonly found on taro throughout the highlands. Both nymphs and adults are found on taro plants and the insect presumably completes its full life cycle on the crop.

This insect was found in all three of the survey areas on both C. esculenta and Xanthosoma sp. (Table 9).

TABLE 9. Presence (+) and absence (-) data for Cicadella sp. s.l. on Colocasia esculenta and Xanthosoma sp.in the Mendi, Tari and Pangia areas.

3a. Mendi	M21	M23	M24	M26	M27	M29	M30	M31	M32
Coloc	-	+	-	-	-	+	-	-	-
Xanth									

3b. Tari	T1	T3	T2	T4	T5	T6	T7	T9	T10	T11
Coloc	+		+	+	+	+	+	-	+	-
Xanth	+	+		+		+	+	-	+	-

	T12	T13	T14	T15	T16	T17	T18	T19	T20
Coloc	+	-		-	-	+	-	+	+
Xanth	+		+			+		+	+

3c. Pangia	P8	P10	P11	P14	P17
Coloc	+	+	+	+	+
Xanth					

N.B. Where no record is given that particular species of taro was not examined in that garden.

The importance of this insect as a pest is uncertain. The damage caused by its feeding requires investigation. It is also a candidate for disease transmission (e.g. the sap inoculable dasheen mosaic virus which could be carried on the insect's mouthparts following feeding).

Aphis gossypii Glover (Aphididae).

Only recorded from two gardens at Pangia (P10, P11), although it was searched for in all taro plots examined.

This species is a known vector of dasheen mosaic virus (Gollifer et al. 1977).

(iii) Lepidoptera

Hippotion celerio L. (Sphingidae).

Recorded in one garden at Tari (T23) and two at Pangia (P5, P12). Not recorded at Mendi but it undoubtedly occurs at times; one of us (B.M.T.) has recorded it at Tambul at a similar altitude and only a short distance from the area under study. Perry (1977) gives details of this pest in P.N.G.

Agrotis ipsilon Hubner (Noctuidae).

Minor damage to corms and stems recorded in Mendi (M2, M16, M32).

(iv) Coleoptera

Papuana spp. (Scarabaeidae).

Damage by *Papuana* spp. ("taro beetles") is often serious in taro gardens in P.N.G. Damage was present in all three areas. The insects attack both *Colocasia esculenta* and *Xanthosoma* sp. The species involved were:

Papuana woodlarkiana Montr.

Recorded from Pangia (P1, P10, P12).

Papuana trinodosa Prell.

Recorded from Mendi (M2, M4, M30) and Pangia (P2, P5).

Specimens of taro beetles from Tari are still required to establish the identity of the species there. Also further specimens from Mendi as it is very likely that *P. woodlarkiana* occurs there also.

Pharotes torvus Marshall (Curculionidae).

Severe damage to stems caused by this weevil at one locality in Mendi (M32). Also recorded from Pangia (P7, one only found).

This insect has previously been recorded from H.A.E.S. (Aiyura) feeding on the stems (Greve and Ismay 1983) and by one of us (B.M.T.) from the Tekin Valley (near Oksapmin, E.S.P.) where it was common and was breeding in the taro corms and causing significant damage (Thistleton 1982).

Oribius sp. (Curculionidae).

At Tari (T23) this species was found feeding on the edges of the leaf stalks leaving a ragged appearance.

(v) Dermaptera

Two species (*sp.2 and 5) collected in the leaf axils of taro in a garden at Pangia (P10). Observed in other gardens but not noted. Possibly predatory on leaf hoppers (see sugar cane).

(vi) Discussion

There are two main entomological problems of taro which require further studies in the highlands. First, and probably more importantly, further studies on both the chemical and cultural control of Papuana spp. are required.

Damage by Papuana spp. is one of the main constraints to taro production in the highlands. Chemical control is possible and would be appropriate for taro grown for sale, but not for use in subsistence gardens. In this situation cultural control techniques would be more appropriate. Studies on the control of Papuana spp. are at present being carried out at Kuk A.R.S. These aim to increase our knowledge of the insects with the possibility of developing more efficient control measures. These studies are of three kinds:

Basic biology and ecology. At present the main aim here is to provide basic details on life history duration of some of the common highland species. This information is already available for two species in the lowlands (Perry 1977). This needs to be followed up with the more difficult task of studying life histories and breeding "seasons" in the field. A trial to study the rate of buildup of Papuana spp. numbers in a taro garden is also in progress.

Cultural control. A study at Kuk is nearing completion on the effect of frequency of weeding and depth of planting. Investigations on the effect of soil type, trap crops etc. would also be worthwhile. Studies carried out at Bubia A.R.C. (Sutherland 1982d) and at Kuk have failed to show any varietal differences in susceptibility despite various claims that this does exist.

Chemical control. At present chemical control relies on the use of lindane. The efficacy of this chemical has been established through trials at L.A.E.S., Keravat and in the Solomon Islands (Perry 1977; Jackson 1980). Last year trials carried out at Kuk A.R.S. and Bubia A.R.S. confirmed the effectiveness of lindane, but several other chemicals which were tested were found to be ineffective. Residue analyses have shown that residues are very low when this chemical is applied at the approved rates and are within acceptable levels (Keravat and Solomon studies). Studies on different rates, timing of applications and formulations of lindane (the present recommendation is based on granules, but dust formulations are also available) would be worthwhile carrying out, and further residue analyses could be performed on corms from these trials. Further testing of new chemicals, as and when they become available, would also be desirable.

Secondly the damage caused by the leafhoppers T. proserpina and Cicadella sp. requires quantification and their roles (and that of other sucking insects) in the transmission of virus diseases requires study. This would need to be in conjunction with studies of the severity of the virus diseases of taro in the highlands. While lethal virus diseases appear to be rare in the highlands, Jackson (pers. comm.) has observed symptoms on taro suggestive of the presence of large or small baccilliform virus particles and dasheen mosaic virus is certainly present. The effects on yield of these viruses have not been quantified.

The roles of predatory insects in controlling these leafhoppers also requires investigation. There are two aspects to this, reduction of direct damage and virus transmission. For example if, as is suspected, Mecomma sp. is filling the niche of Cytorhinus as an egg predator of T. proserpina it may be reducing populations enough to prevent serious direct damage, but not enough to prevent virus transmission.

Further discussion on taro pests in P.N.G. can be found in Masamdu (1984).

V LEGUMES

(i) General

Several species of legumes were examined during the course of the survey, but none of them were found very frequently (Appendix 6) and usually the plots were very small consisting of only a few plants. The most usual was the common bean (Phaseolus vulgaris) but also found were lablab bean, rice bean, snake bean, soy bean and pigeon pea. Since the insects associated with many of these are similar they will be covered in one section.

(ii) Lepidoptera

Three species were found feeding on foliage, flowers or pods.

Hedylepta indica (F) (Pyralidae)

Recorded feeding on the leaves of common bean in Mendi (M27, M29, M30) and Tari (T6, T17). Not recorded from Pangia, but only four plots of beans examined there.

Also recorded from soy bean at Kiburu (M1) folding and feeding on the leaves and causing moderate damage.

Young (1982a) considers this to be a minor pest in the lowlands due to control by parasites. He quotes Smith (pers. comm.) as maintaining that it could become a serious pest of soybeans in the highlands.

<u>Maruca testulalis</u> (Geyer) (Pyralidae)

Pod damage to common bean was recorded in Mendi (M27, M30), but not from the other two areas (but since only a few plots of beans were examined it could well have been overlooked). The damage was not considered to be serious.

This species has been recorded as causing serious damage to pigeon pea, snake, mung and adzuki bean at Lae (Young 1982a) and to common bean, rice bean, snake bean, cow pea and mung bean and slight damage to sugar pea at Kuk A.R.S. (Thistleton 1982). Also from Oksapmin (W.S.P.) causing much damage to lima bean but not to a particular variety of common bean (Thistleton 1982).

Potentially a serious pest which could warrant further investigation.

<u>Heliothis armiger</u> (Hubn.) (Noctuidae)

Causing moderate damage to leaves of pigeon pea at Kiburu (M1). Not recorded on other legumes in any of the three areas, although it occurred in them on other crops.

This species can also cause some damage to the pods of legumes (Young 1982a), and has been recorded causing this type of damage to legumes in the highlands (e.g. bad defoliation and damage to pods, pigeon pea, Wabag, E.P.; damage to foliage and pods of pigeon pea, pea and cowpea, Kuk A.R.S., W.H.P.; Thistleton 1982).

(iii) Coleoptera

<u>Oribius</u> spp. (Curculionidae)

Recorded feeding (causing shot-hole damage) on foliage at Mendi (M16, M27, M29, M31, M32, M33), Tari (T3, T5, T6, T12, T17) and Pangia (P2, P10, P17). In some cases the damage was quite severe.

The species implicated at Mendi was <u>O. inimicus</u> Marshall but <u>O. destructor</u> Marshall was also present in the area and could have been causing some damage; at Tari the species were <u>O. inimicus</u> and <u>O.</u> sp. A; and at Pangia <u>O. inimicus, O. destructor</u> and <u>O.</u> sp. B.

<u>O. inimicus</u> was also recorded causing shot-hole damage to soy bean at Kiburu (M1), but the damage was only minor.

Since the amount of damage by these insects and by other leaf feeding beetles (chrysomelids) was severe in some gardens experiments to determine yield loss in relation to amount of foliage lost may be worthwhile.

<u>Oribius</u> adults feed on a wide range of host plants causing a variety of damage, but mostly shot-hole damage to the foliage (Thistleton, 1984). Experiments at Kuk A.R.S. (W.H.P.) have indicated which chemicals are useful for control of the insects, but chemical control

is still difficult and expensive and not suitable for use in subsistence gardens.

The larvae of Oribius spp. live in the soil, presumably feeding on roots and other organic matter. Attempts to breed the insect in the laboratory at Kuk A.R.S. (W.H.P.) to obtain information on the length of the life cycle (etc.) have so far been unsuccessful. Studies on changes in population levels of larvae throughout the year are also in progress at Kuk A.R.S. (W.H.P.). These studies are aimed at providing information for the possible development of cultural control strategies.

Chrysomelid beetles (Chrysomelidae)

Damage to foliage of common bean by chrysomelid beetles was also found in all three areas(M27, M32, T2, T5, T17, P2). Some of the damage is difficult to distinguish from that produced by Oribius spp. particularly when both occur together. However Oribius spp. were found much more commonly than the chrysomelids and often the latter were completely missing. One of the species involved was Cassena sp. (M32, T5, T17, P2). This was probably Cassena intermedia (Jacoby) a species known to be associated with beans and which is only found in New Guinea (Young 1982a who used the synonym C. papuana; Kimoto et al 1984.

Cassena sp. was also recorded from soybean (M1) and lablab bean (P10), but in both cases the damage was minor.

Other chrysomelids which can attack beans include Aulacophora spp. (Young 1982a). Several species of this genus were recorded during this survey from pumpkin.

Young (1982a) is of the opinion that damage to legumes by chrysomelids is more severe in the highlands than in the lowlands. In the plots examined during the current survey it would appear that chrysomelid damage was relatively minor while damage by Oribius spp. was far more severe.

Bruchid beetles (Bruchidae)

A species of bruchid was found feeding on stored bean seeds and causing severe damage at Mendi (M11). It has not been sent for identification. Bruchids are common pests of stored legumes.

(iv) Hemiptera

A few species recorded as follows:

Riptortus sp. (Alydidae).

Recorded from Mendi and Tari (M27, M29, M30, M31, T3, T12, T17) on common bean. In a few gardens (M29, M30, T3) the damage to developing seeds within the pods was considered to be severe.

Six species are known to cause damage to legumes in P.N.G. (Young 1982a). The species found during the current survey have not been identified.

Nezara viridula L. (Pentatomidae).

Only recorded from soybean at Kiburu (M1) where adults and nymphs were severely damaging the pods. This species is probably also found in the other two areas and could become important if the amount of legumes planted becomes larger.

Details of the biology of this insect are given by Young (1982a, c). Attempts at biological control have been made (Young 1981a, 1982b).

Aleyrodidae.

Young (1982a) records *Bemisia tabaci* (Genn.) as being common in P.N.G. and a potential vector of virus diseases. One of us (B.M.T.) has also recorded *Orchamoplatus mammaeferus* (Quaintance and Baker) from common beans (and other vegetables) in the highlands. Neither of these species was recorded on the present survey but should be looked out for in the future.

(v) Diptera

Ophiomyia phaseoli (Tryon) (Agromyzidae)

Recorded from common bean at Mendi (M11, M27, M29, M30, M32, M33) and Tari (T2, T3, T5, T6, T7, T9, T12, T17) but not at Pangia (but almost certainly it would have been found if more plots of a younger age had been examined). Where present the proportion of damaged plants ranged from 20% to 80% with the more recently introduced dwarf varieties tending to have more damage than the more traditional varieties.

Bean fly damage was also recorded on soy bean (M1, medium damage).

Studies on the chemical control of bean flies have been carried out at Kuk A.R.S. (W.H.P.) and Bubia A.R.S. (M.P.) (Masamdu, unpublished data). Two parasites were imported from Hawaii and released in the Markham Valley (M.P.) (Young 1981a) but it is not known if they have established. They should also be tried in the highlands. These parasites had apparently given reasonable control of the bean fly in Hawaii (Greathead 1975). Some species and varities of legumes appear to show some resistance to the bean fly (Young 1982a, b) and these could be grown in areas where the problem is severe. The use of these varieties combined with the release of parasites may give acceptable control in village gardens without the need for application on insecticides.

(vi) Thysanoptera

An unidentified species of thrips was recorded from common bean at Mendi (M32) and Tari (T2).

(vii) Discussion

Several of the insects found during the present survey are, or have the potential to become, serious pests and further work on these would be justified to assess their affects on yield and to develop better control measures.

For O. phaseoli further work should include studies of percentage attack and its relation to yield reduction in various species and varieties of legumes, possibly further parasite introductions, and further insecticide trials to develop further the control measures already devised.

For foliage pests such as Oribius spp., chrysomelid beetles and H. indica the relation of foliage damage to yield loss requires investigation. Similarly with pod sucking (Riptortus spp. and Nezara viridula) and pod chewing (M. testulalis) insects further assessments of the amount of damage would be required before control measures could be recommended.

Pests of legumes in P.N.G. are discussed by Fenner (1974), Masamdu (1984) and Young (1982a, 1984) Young (1982a) suggests that resistant varieties and biological control should be the main methods of control developed for subsistence garden situations. These methods would also be important, together with insecticides, in market garden situations.

VI CABBAGES

(i) General

Cabbages are a common crop in the Mendi area (Appendix 6) where fifteen percent of gardens measured had cabbages as one of their crops (Merle Anders, per. comm, from A.F.T.S.E.M.U. garden measurement data). They were less frequent in Tari and very infrequent in Pangia (Appendix 6).

In the project proposal it was stated that little work would be carried out on cabbage, since this would be the subject of separate studies in the Mendi area. Some of these extra studies have been carried out and brief details of some of the results are presented here,although they will be written up in detail elsewhere.

(ii) Lepidoptera

The main pests of cabbages in P.N.G. belong to this group of insects. Six species were recorded:

Plutella xylostella (L.) (Yponomeutidae).

This is undoubtedly the most serious pest of cabbages in many areas of P.N.G. It was recorded in all three areas on virtually every plot of cabbages, but populations were generally quite low and the cabbages were producing reasonable heads. In Mendi damage levels from minor (most plots) to severe or very severe (M3, M2 respectively) were recorded, and in Tari and Pangia only minor damage was recorded.

Reasons for differences in damage levels would be varied, including length of time cabbages had been grown in a particular area which would affect the size of the population, rate of build up in relation to temperature (life cycle duration), environmental conditions at the time of, and in the period immediately before, the count, etc. The use of control measures would also affect the population but only in one plot in Pangia (P14) were we told that insecticides were being sprayed. There were no reports of insecticides being used in the Mendi area where populations were also low, and in Tari insecticides were only being used in institutions such as Tari High School.

This insect was studied in much greater detail in the Mendi area during 1983-4 when an introduced parasite was released and monitored, in conjunction with studies on plots in non-release areas (project HEN PX16.3). Table 10 summarises the first few counts for this experiment and also gives data from Kuk A.R.S. (W.H.P.) for comparison.

TABLE 10. Numbers of Plutella xylostella life history stages on eleven week old cabbages at ten sites in the Upper Mendi area and at K.A.R.S. (W.H.P.). Figures are the numbers per 30 plants.

10a Mendi, mean of four monthly counts.

LOCALITY	EGG	III	IV	PP	PUP
Komia	110	6	5	0	2
Birop	422	20	20	1	1
Kuma	250	17	9	0	1
Mogul	327	22	10	1	5
Kundaga	429	47	30	2	10
Dimifa	296	32	23	2	8
Nambip	149	24	25	2	7
Hum	218	20	9	0	2
Bela	893	94	56	6	25
Posulim	237	20	15	1	3
Mean	333.10	30.20	20.20	1.50	6.40

10b Kuk, mean of 24 monthly counts.

	643.42	72.71	73.13	5.21	29.58

Stages are egg (EGG), third instar larvae (III), fourth instar larvae (IV), prepupae (PP) and pupae (PUP).

The mean number of eggs for Mendi for the four months presented is about half of the long term mean for Kuk. However it can be seen that there is a great variation in population levels between the different plots, with one having far more than the mean for Kuk. At Kuk populations vary markedly throughout the year and monthly means for eggs range from 60 to 1653 per thirty cabbages (first 24 monthly counts), while at Mendi over the first four months eggs ranged from 28 to 1161 per thirty cabbages per site.

In the six months that this experiment was running most sites produced a large percentage of cabbages with good heads, and where this was not so it was usually due to other causes than damage by P. xylostella.

While the introduced parasite established at the release sites it remained in low numbers and the effect on populations was minimal. In fact other biocontrol agents already present, including another parasite and a fungal disease, were giving higher mortalities than the introduced parasite.

There is a vast amount of literature on P. xylostella available wordwide. This has been reviewed to 1972 by Baker (1972). Studies in P.N.G. have included life history and long term ecological studies, insecticide trials and investigations in biological control. These have recently been reviewed by one of us (Thistleton 1984).

<u>Crocidolomia binotalis</u> Zeller (Pyralidae).

This species can also be a serious pest of cabbages in P.N.G. although again was not found in large numbers on the present survey. It was recorded in Mendi (M8, M30) and Tari (T21), in both cases causing minor damage.

Life history studies on this species have been carried out by Makita (1978/9) and a review of other work on this insect is included in Thistleton (1984).

<u>Diachrysia orichalcea</u> (Fabr.) (Noctuidae).

Only found in one plot during the survey (M16) but frequently found in the plots being used for the <u>P. xylostella</u> experiment (HEN PX16.3) in Mendi.

<u>Spodoptera litura</u> (Fabr.) (Noctuidae).

Minor damage recorded in one garden only (M8).

<u>Heliothis armiger</u> (Hb.) (Noctuidae).

One only in one garden (M16). One or two in the plots for HEN PX16.3.

<u>Agrotis ipsilon</u> (Hfn.) (Noctuidae).

This species was only recorded cutting cabbage seedlings in Mendi (M3, M32) but it is also known to be present in the other two areas (see other crops). In the plots for HEN PX16.3 this insect caused a large amount of damage necessitating back-planting and insecticide soil drenches for control.

A review of work on this species in P.N.G. and overseas has recently been prepared (Thistleton 1984; see also maize for further references). Further work on the ecology and control (insecticidal, biological and cultural) of this insect is required.

(iii) Hemiptera

One species of aphid was common on cabbages in the Mendi area.

<u>Myzus persicae</u> (Sulz.) (Aphididae)

Identified from specimens collected at Mendi (M16) and also present in other gardens in this area. Not recorded from Tari and Pangia but this wide ranging species would almost certainly be found there. A known pest of brassicas in P.N.G. (e.g. Thistleton 1981;Greve and Ismay

1983) and overseas (Kranz et al. 1977), although populations in the highlands are not usually large enough to cause direct damage.

(iv) Orthoptera

Atractomorpha crenaticeps (Blanch) (Pyrgomorphidae).

One feeding on cabbage at Pangia (P5).

(v) Coleoptera

Oribius spp. (Curculionidae).

An *Oribius* sp. was recorded feeding on cabbage leaves in one garden at Tari (T11) and one or two *O. inimicus* also noted at times in cabbages in Upper Mendi (HEN PX16.3 plots).

Damage by *Oribius* sp. was also recorded on chinese cabbage at Tari (T7, T11).

(vi) Discussion

The most serious pest of cabbages in the study areas would appear to be *Agrotis ipsilon* and further studies on the control of this insect would be worthwhile.

Plutella xylostella is also potentially a serious pest but, in the detailed studies in the Upper Mendi, populations and damage were far lower than expected on experience of the pest in other areas of the highlands. This species is already the subject of research being carried out at Kuk A.R.S. (W.H.P.) (see discussion on this pest above).

Other species of Lepidoptera are also potentially serious pests of cabbages in the area.

It appears that, at least in the Mendi area, cabbages are considered to be quite an important crop. The authors are not aware of the relative amounts produced for sale and for home consumption, but this information is probably available from A.F.T.S.E.M.U.

VII MAIZE

(i) General

This crop was present in all three areas (Appendix 6). Plot sizes varied from just one or two plants to over 100 plants, but were generally small.

(ii) Lepidoptera

Three species of importance were found:

Heliothis armiger (Hb.) (Noctuidae).

This species was commonly encountered feeding on the developing kernals within maize cobs (M3, M4, M6, M27, M28, M29, M32, T7, T8, T11, P8). In most of the other gardens in which maize was present the plants were too young for damage by this insect, and only in two gardens (T13, P14) were cobs present but with no damage. The proportion of cobs infested varied from ten to forty percent (based on random samples of ten plants in each plot).

Heliothis caterpillars usually lay their eggs on the silks or, later, at the tip of the cob. The young larvae feed on the silks and then move on to the developing grains. Usually only those grains at the tip of the cob are damaged, although the damage often allows moisture to enter and moulds to develop. It has been stated that damage by this insect does not have a marked effect on yield (Young 1979), this statement being based on trial work in the Markham Valley (Young, pers. comm.). This is possibly due to the fact that the larvae tend to be cannibalistic and often only one survives in each cob. However White and Scott (1983), working with the related H. zea, demonstrated that the plant is able to compensate for caterpillar damage by increasing the weight of the remaining kernals.

Further studies on the effect of this insect on yield would be justified if maize is to be developed as an important crop in highland agriculture.

Mythimna separata (Walker) (Noctuidae).

This species commonly feeds on the foliage of maize. It was recorded on most, but not all, plots of maize in Mendi (M10, M23, M27, M28, M29, M30, M32) and Tari (T1, T7, T8, T9, T11, T12, T13), but not in Pangia, although it almost certainly occurs there. Where found the larvae were present on twenty to seventy percent of the plants, but damage was usually recorded as minor.

Studies of artificial defoliation of maize (Hoyt and Bradfield 1962; Allison and Watson 1966; Pendleton and Hammond 1969; Douglas et al. 1981) and of actual defoliation by M. separata (Hill and Atkins 1982) have indicated "that maize is able to tolerate substantial defoliation of the lower parts of the plant during and after silking without significantly reducing yield." Hill and Atkins found in their study that attack at the time of silking only caused a significant reduction in yield if defoliation was in excess of 67%, and concluded that chemical control was rarely economic.

These findings have not been confirmed in P.N.G. and further studies may be warranted.

Agrotis ipsilon (Hfn.) (Noctuidae)

Cutworms can seriously affect the establishment of young maize. Damage was only recorded in a few gardens (M1, M3, M10, T11) where young plants were present but it is known to be a problem in all three areas (A.F.T.S.E.M.U. staff, pers. comms.).

There has been a large amount of work carried out on this insect worldwide, both on maize and on other crops, and much of the available literature is reviewed by Rings et al. (1974), Rings and Arnold (1976) and Rings et al. (1978). Thistleton (1984) gives details of work carried out to date in P.N.G. and gives suggestions for further work.

On maize reliance is made on the use of chemicals for the control of this insect and Thistleton (1984) lists those recommended overseas. Further trials on this are necessary in P.N.G. and also on ecological work which could indicate possible cultural control measures (Thistleton 1984).

(iii) Hemiptera

Two species:

Rhopalosiphum maidis (Fitch) (Aphididae).

Recorded from maize in Mendi (M27, M28, M29) and Tari (T21).

This species can stop earing or prevent pollen shedding if present in large enough numbers and the honeydew produced can promote the growth of sooty mould (Kranz et al. 1977). It can also be important in the transmission of virus diseases.

?Phaenacantha sp. (Colobathristidae).

Two at Pangia (P8). See discussion under sugar cane.

(iv) Coleoptera

Elaterids.

As in sugar cane elaterids were also found occasionally in the leaf sheaths of corn. The most common species was Agrypnus sp. (M28, M29, M30, M32, P8), but Hapatesus tropicus (T3) and Compsolacon gracilis (P8) were also recorded. Their status is uncertain, see discussion on these insects under sugar cane.

Chauliognathus spp.

Recorded from the leaf sheaths (M32, T8). See sugar cane.

** Brachypeplus sp. (Nitidulidae).

Many recorded from inside cob (P8), probably feeding on kernels following initial damage from some other cause.

(v) Orthoptera

** Oxya japonica vitticollis Blanchard (Acrididae).

Adults and nymphs feeding on corn at Mendi (M1). Also recorded from sugar cane.

Damage by Orthoptera was noted in other areas but the insects were not observed. It is likely that many of the species which attack sugar cane would also feed on maize foliage.

(vi) Dermaptera

Several species found in the leaf sheaths. These included *sp.1 (P8), *sp.3 (P8), *sp.4 (P8) and *sp.6 (M29). Earwigs also noted in M32, T3, T7, T8 and T11 but were not collected for identification.

The significance of these insects in maize is not known.

(vii) Discussion

It is of interest that neither of us recorded damage by the borer Ostrinia furnacalis (Lepidoptera: Pyralidae) although this has been recorded in the East New Britain, Northern and Morobe Provinces (Greve and Ismay 1983). There also do not appear to be any other species of pyralid stem borer, even though these occur on sugar cane and pitpit.

Elsewhere the species of pyralid (usually Chilo or Diatraea) boring in graminaceous crops tend to attack several different kinds, including maize, although many tend to have a preferred host (see Kranz et al. 1977 for examples). The possibility of the Chilo sp. from sugar cane attacking maize should therefore not be overlooked in future studies.

Of the pests listed probably the most important to consider for further studies are the Lepidoptera and the aphid.

VIII PANDANUS

(i) General

Trees of the karuka nut pandanus (Pandanus brosimos and P. julianetti) were examined in the Mendi area and trees of the marita pandanus (P. conoideus) in Tari and Pangia.

(ii) Orthoptera

Leaves with damage probably caused by Orthoptera feeding was frequently observed on karuka pandanus in the Mendi area but only two collections were actually made:

Phyllophora boshmai de Jong. (Tettigoniidae).

Adults and nymphs feeding on foliage (M4).

Segestes sp. (Tettigoniidae: Sexavae).

Adults and nymphs severely damaging leaves (M2). One specimen collected. This appears to be close to the species of the Segestes stibicki/brevipennis/cornelii group of Willemse (1977) but does not fit any of them exactly. S. cornelii Willemse has previously been recorded from pandanus at Kandep (Willemse 1977).

In addition to the above another larger species of Sexavae, Segestidea montana, was described from the Eastern Highlands Province by Willemse (1979) and was recorded from several different host plants including pandanus (Willemse 1979; Greve and Ismay 1983). It is possible that this species is also present in the Mendi area.

Sexavae on coconut and oil palm generally feed at night and shelter in the spear of the palm during the day (Young 1981b). This may also be true of species attacking pandanus and further studies would require a technique for climbing the trees.

(iii) Lepidoptera

** *Trachycentra chlorogramma* Meyrick. (Tineidae).

This case moth was recorded causing moderate to severe damage to the younger leaves of karuka pandanus in the Mendi area (M2, M11, M18, M19, M21, M23, M25, M26, M27) and from marita pandanus in the Tari (T22) and Pangia (P12, P14) areas.

This species was also recorded from sugar cane in Tari (see above). In Fiji it is a pest of coconut, but also bores in sugar cane stalks (Swaine 1971).

IX PUMPKIN

(i) Coleoptera

Various damage to the foliage by leaf eating beetles of the families Chrysomelidae and Coccinellidae.

Henosepilachna signatipennis

Foliage damage by leaf-eating ladybirds was recorded in Mendi (M30) and Tari (T2, T6, T9, T15). Unfortunately specimens were not collected but they are all believed to be the above species.

Aulacophora spp.

Three types of *Aulacophora* were recorded feeding on pumpkin foliage in Tari (T1, T4, T5, T6, T7, T13, T15, T17) and Pangia (P2, P5, P10, P12).

The taxonomy of *Aulacophora* spp. appears to be rather confused. Identifications based on colour pattern and external characteristics are not terribly reliable and it seems that genitalia studies are necessary for accurate identification. There are over ten species of *Aulacophora* recorded from cucurbit foliage in P.N.G. Sutherland (1984) list fourteen species, although it is probable that some of these are synonyms.

The types found on the survey included one which was yellowish-brown all over, one with black and orange elytra and one with black elytra.

The yellow-brown type was found at Tari where it was the commonest form. This species appears to be similar to specimens in the Kuk insect collection which have been identified as Aulacophora sp. nr. abdominalis Fab and specimens in the Aiyura collection (also held at Kuk) identified as A. wallacei Baly. A. similis (Oliver), A. coffeae Hornstedt are also similar in colouration.

The black and orange type was found at Pangia. Specimens agree with the description of A. albofasciata Baly in Kimoto et al. (1984) rather than with A. pallidifasciata Jac. which apparently is similar in colouration but has a black head (Kimoto et al. 1984).

The black type was found in Tari and Pangia, and had previously (1978) been recorded by one of us (B.M.T.) on choco and pumpkin at Kiburu, Mendi. This species is probably A. melanopus Blanch. A. albofasciata does however have a black form (Kimoto et al. 1984) and specimens which would fit the more typical form of this species were found at Pangia in association with, but less common than, the black form. In one locality at Pangia (P2) a specimen intermediate in form between the two was found.

A series of specimens of Aulacophora spp. from various crops and localities in P.N.G. has been sent for identification (see Appendix 8). This series includes a range of intermediate forms between the above three types. The identifications received were A. ?pygidialis for all black or black and orange specimens, except one black and orange specimen which was A. ?quadrimaculata. All orange-yellow specimens were listed as A. sp. A. or A. sp. B. Dr Cox, in the identification sheet, gave the characters on which these species are separated but said the genus is in need of complete revision. He quotes Wilcox (1972) as listing c.40 species of Aulacophora from New Guinea.

X BANANA

(i) Lepidoptera

Artona sp. (Zygaenidae)

Larvae recorded feeding on leaves of banana in all three areas (M31, M33, T4, T6, T7, T10, P17). Previously recorded from Kuk A.R.S. (W.H.P.). This is a new species to be described by J. D. Holloway at the Commonwealth Institute of Entomology.

(ii) Coleoptera

Oribius sp. (Curculionidae).

Shot-hole damage to banana leaves in Pangia (P17).

<u>?Cosmopolites sordidus</u> Germ. (Curculionidae).

A weevil larva, possibly of this pest species was found in a corm at Pangia. This was the only garden in which a plant was dug for examination, so no comments can be made on the frequency of this pest. Worldwide this species is considered to be one of the most serious pests of bananas although in some areas it is not considered serious due to the presence of parasites and predators (Kranz et al. 1977).

(iii) Thysanoptera

A species of thrips was collected from banana leaves at Pangia (P17) where it was causing mottled brown scarring symptoms. These have been sent for identification.

XI ONION

(i) Hemiptera

<u>Neotoxoptera formosana</u> (Takahashi) (Aphididae).

Recorded from onions at Mendi (M20) and Pangia (P1). A common insect on onions in the highlands (Thistleton 1981; Greve and Ismay 1983).

This species, which is "more or less restricted to <u>Allium</u> spp. (onion, shallot, garlic, chives, leek, etc.) has previously been known from Japan, China, Taiwan, Korea, North America and Hawaii and is presumably oriental in origin" (Carver 1980). It has also been recorded in Australia (Carver 1980).

(ii) Thysanoptera

No records from onions on this survey, but thrips have been recorded from onions in the highlands (Thistleton 1981) and the onion thrips, <u>Thrips tabaci,</u> has been determined from material collected from pyrethrum (Thistleton 1982).

XII NATIVE GREENS

Various native greens were recorded in the three areas (Appendix 6). The insects found on them were as follows:

XIIa Aibika

(i) Coleoptera

?*Nisotra obliterata* Jac. (Chrysomelidae).

Flea beetles (presumed to be of this species) causing shot-hole damage to leaves at Tari (T4, T5). This species is widely distributed in New Guinea from sea level to 1600 metres (Kimoto et al 1984).

** *Rhyparidella sobrina* Bryant (Chrysomelidae).

Causing shot-hole type damage in one garden at Pangia (P10).

Oribius inimicus and *O.* sp. A. (Curculionidae).

Adults causing shot-hole damage in Tari (T4, T5) in association with *N. obliterata.*

XIIb Amaranthus

(i) Coleoptera

Oribius spp. (Curculionidae).

Adults causing minor shot-hole damage to leaves in Mendi (M21, M32) and Tari (T13) and severe damage in one garden in Tari (T11). The species were *O. inimicus* Marshall (M21, M32, T13) and *O.* spp.A (T11).

XIIc Loofah

Older leaves damaged by leaf eating Coleoptera at Mendi (M32), specimens not collected.

XIId Nasturtium

(i) Lepidoptera

<u>Plutella xylostella</u> (L.) (Yponomeutidae).

Feeding on leaves in several gardens at Mendi (M2, M10, M11, M30, M32).

<u>Crocidolomia binotalis</u> Zeller (Pyralidae).

Feeding in centre of plants and causing medium to severe damage in Mendi (M1, M8, M10, M30, M32).

XIIe Oenanthe

Observed in Pangia (P8, P17) but no insect damage recorded.

XIIf Rungia

Observed in all three areas (Appendix 6). Very little damage. Possible shot-hole damage by <u>?Oribius</u> sp. (P16) and possible grasshopper damage (P9) was all that was recorded.

XIII CASSAVA

(i) Hemiptera

A species of scale insect (Coccidae) was found on cassava at Mendi (M1).

XIV POTATO

(i) General

With one exception (T13) all the potatoes examined were in the Mendi area (M2, M5, M21, M26, M27, M31). Due to different stages of growth not all the insects were looked for in each garden.

(ii) Lepidoptera

Phthorimaea operculella (Zell.) (Gelechiidae).

The potato tuber moth was present in exposed tubers and/or tubers stored for seed in two gardens (M26, M27). In other gardens there were no suitable exposed tubers for attack by this insect.

This is potentially a very serious pest in P.N.G. although proper hilling of the developing tubers so that they are not exposed gives good control. Leaf mining damage by this insect is uncommon in P.N.G. Further details on this insect can be found in Thistleton (1980).

(iii) Coleoptera

?Papuana sp. (Scarabaeidae).

Damage by taro beetles noted only in one garden (M2) which was the only location in which harvested tubers were examined.

Damage by taro beetles to tubers is often found in potato crops in the highlands, but damage surveys and observations by growers have shown that the percentage of tubers damaged is usually very low, and control measures are not normally required.

Several trials have been carried out to find a suitable chemical for control of this insect in potato crops, but the only chemical at present known to work (lindane - see discussion under taro) is unsuitable for use on potatoes due to residue problems. As other chemicals become available they will be tested for control of Papuana spp. on taro. Any which are found to be effective could then also be tested on potato if it is found that damage by Papuana spp. is becoming more severe on this crop.

(iv) Hemiptera

A species of aphid was recorded on foliage in one garden (M2) but not identified. Aphids were searched for, but not found, in the other plots examined (M21, M26, M27, M31, T13).

Several species of aphids have been recorded on potatoes in the highlands of P.N.C. These are listed by Prior (1976) and Greve and Ismay (1983). Smith (1980) discusses their importance as vectors of potato virus diseases.

(v) Discussion

Work to date in P.N.G. on pests of potatoes has included the identification of damage caused by various species of soil insects to the tubers, assessment of amount of damage in various plots, insecticide trials on for control of soil insects, an aphid trapping project, an aphid insecticide trial etc. Refer to Thistleton (1980, 1984b) for further details.

XV TOMATO

(i) General

Only recorded in a few gardens in Tari and Pangia (Appendix 6).

(ii) Lepidoptera

Heliothis armiger (Hb). (Noctuidae).

This caterpillar was recorded feeding on tomato fruits at Tari (T11, T12). In one other garden at Tari (T5) and two at Pangia (P8, P17) fruit was present, but there was no damage although the insect was present on other crops in Pangia.

This insect, and *Spodoptera litura* (Noctuidae), are potentially very serious pests of tomatoes and chemical control would probably be necessary on tomatoes grown on a market garden scale.

Agrotis ipsilon (Hufn.) (Noctuidae).

Cutworm damage to tomato seedlings recorded in Tari (T7).

XVI OTHER CROPS

Lettuce, peanut, ginger, pineapple and turnip were only examined in one or two gardens each (Appendix 6) and little damage was noted. Turnip had some foliage damage caused by *Oribius* sp. and grasshoppers.

GENERAL DISCUSSION

The above pages have indicated that there are a large number of different insect species associated with food crops in the three study areas of the Southern Highlands Province. Many of these insects, or closely related species, are widespread throughout the highlands, so that the comments made here will have a wider scope than just the study areas.

To set priorities for research work on these insects requires consideration of a range of factors. It is not merely enough to choose those pests which are more obviously serious. Attention must also be paid to the overall importance of the crop as assessed by the agricultural economists, agronomists and nutritionists etc. Again it is not enough merely to consider research work on a highland only basis. It must be considered on a countrywide basis, at least for those crops which occur in both the lowlands and the highlands. It is also important to consider the work already carried out, or in the process of being carried out on these pests. Much of this has been reviewed in the previous pages.

Research work on insect pests can be divided into three main activities, although all three overlap to a certain extent:

Firstly there is the initial survey and identification work. The present report can be taken as an example of the importance of this, since the surveys have yielded many new records of insects (and even new species of insects) on the various crops, which are, or could be, potential pests. As well as concentrated surveys such as this, D.P.I. entomologists are constantly recording new insects that they come across, and these are published in the Department of Primary Industry's Crop Insect Surveys. The latest of these (Greve and Ismay 1983) also provides a comprehensive index to all previously published records.

Secondly the importance of each of the insects as a pest needs to be evaluated. This is the field of crop loss assessment. Crop loss assessment experiments basically rely on the comparison of yields on plots in which the pests are present with those in which the pests have been excluded by some means. Often this exclusion relies on the use of insecticides to kill the insects as they enter the plots.

These experiments are difficult due to the variability of various factors:

1. variation in levels of infestation with time and location,

2. the insecticides used will often kill more than one species of insect making it difficult to isolate the effect of a particular pest, and

3. on a subsistence scale a crop loss assessment based on plots would not accurately mimic the diverse nature of a food garden.

Experiments will need to be repeated enough times that different population levels of the insect can be related (by, for example, regression analysis) to different degrees of yield reduction. Counts of insects in various locations and at various times can then be made to ascertain how often certain population levels occur and these can be compared with the regression equation to give a measure of the importance of the pest.

Before such work can be carried out sampling techniques will often have to be developed to give reliable estimates of the numbers of insects present, often in more than one stage of their life history. Factors needing consideration are the size of sampling unit and the number of sampling units per sample to give an estimate of the mean to a required degree of precision. These are normally decided from preliminary samples. The number of man-hours per sample is also required and, where more than one sampling scheme would give similar result, the time involved to take the samples can often be used to decide between them.

Such studies as these will obviously take a large amount of time and effort and, with the available man power, could only be carried out for a relatively small number of pests which we already know, or strongly suspect, to be of some importance.

Detailed discussions of methods and case studies of crop loss assessment techniques are given by Chiarappa (1971, 1973, 1977, 1981).

Thirdly research must be carried out into control measures for those pests shown to be of economic importance. This is a very diverse field of research and includes the use of cultural, biological and chemical control methods. Often information already collected during crop loss assessment trials, if these were carried out, can now be used to set economic thresholds for the implementation of control measures, particularly those based on the use of chemicals.

In the case of pests which are of major economic importance in a much wider geographical area than just P.N.G. a large amount of information is usually available in the literature, and experiments into their control can be mainly of an adaptive nature.

Contrasted to this are the pests which are restricted to New Guinea, or at least to a small geographical area around it. Often with these insects more fundamental research into life history and ecology of the pest is required before experiments on control measures can be carried out.

This biological information is very important for the development of cultural and biological types of control, but it is also of importance for chemical control where economic thresholds need to be set (and this also relies on the crop loss assessment techniques).

Decisions then need to be taken as to which type(s) of control it is most profitable to investigate, or whether the possibility of an integrated approach to the control of several pests on a crop is considered worth investigating.

Firstly the suitability of the control measures for the different types of farming need to be considered. For example chemical control may often be necessary and feasible in a market garden situation where large enough plots of each crop are being grown and where insect pest problems may be severe. It would not however be a practical proposition in a purely subsistence garden where the farming system is more diverse, where there is no cash income from the crops, and where the growers have little expertise in the use of chemicals. This situation, of course, is often not the case. Many gardens have both a cash crop and a subsistence function, and the situation is therefore more complex.

Cultural and biological control techniques can be of use in both situations, but these often involve a large number of man years of research, and even then are often not successful. A good example is the search for varieties of sweet potato which are resistant to <u>Cylas formicarius</u> and <u>C. puncticollis.</u> This has involved large amounts of research over many years by scientists at a range of institutions (A.V.R.D.C., U.S.D.A., I.I.T.A.), but there is still no truly resistant variety available.

These techniques can be used instead of, or as well as, chemical control and research into the integration of the various methods may be required. In some schemes overseas the use of integrated control has been developed even further into insect pest management methodologies. For this type of control a large amount of ecological information is required on all the pests, predators and parasites on a crop and their interrelationships. This information can then be used to construct models of population changes, which will allow decisions to be made on which control measures to use in which circumstances. These methods are usually only of use where the industry is large enough and profitable enough to (i) justify the large amount of research required and (ii) provide the necessary expertise for the scouting necessary to give information on the pest/parasite/predator situation at any particular time.

Decisions therefore need to be made on where most emphasis should be placed. Should the main priority be research into the control of insects on cash crops to increase rural welfare by increasing monetary gain, or should emphasis be placed on improving control in a subsistence situation? Again is it worthwhile spending large amounts of time and money finding control measures for pests which cause a large amount of damage on crops of relatively minor importance (or of importance only in small areas of P.N.G.) or would it be better to persuade the people to grow other crops with less insect problems?

There are of course no easy answers to these questions, but they are all aspects which should be given some thought when research priorities are discussed.

In the preceding pages suggestions have been made as to the possibilities for further work on each of the insects considered. Not all of these are obviously of high importance, but should be considered in the context of the previous discussion.

CHECKLISTS OF INSECTS FOUND ON EACH CROP IN EACH AREA.

*	indicates that specimens have been sent to a specialist for determination.
**	indicates that the name presented is that determined by a specialist, and is as precise as possible at this stage.
(+)	indicates that this species occurred in the area, but was not recorded from the crop being considered. Only used where the insect had been associated with that crop in other areas.

Crops arranged alphabetically.

Insect orders arranged alphabetically within crops.

Insect families arranged alphabetically within orders.

Insect species arranged alphabetically within families.

M = Mendi, T = Tari, P = Pangia

ORDER Family Species	CROP Significance	Area M	 T	 P
COLEOPTERA Chrysomelidae ?*Nisotra obliterata*	Aibika Adults chew leaves		+	
COLEOPTERA Chrysomelidae ***Rhyparidella sobrina*	Aibika Adults chew leaves			+
COLEOPTERA Curculionidae *Oribius inimicus*	Aibika Adults chew leaves	(+)	+	(+)
COLEOPTERA Curculionidae *Oribius* sp. A	Aibika Adults chew leaves		+	
COLEOPTERA Curculionidae *Oribius inimicus*	Amaranthus Adults chew leaves	+	+	(+)
COLEOPTERA Curculionidae *Oribius* sp. A	Amaranthus Adults chew leaves		+	
COLEOPTERA Curculionidae ?*Cosmopolites sordidus*	Banana Larvae bore in corms			+
COLEOPTERA Curculionidae *Oribius* sp.	Banana Adults chew leaves			+
LEPIDOPTERA Zygaenidae *Artona* sp.	Banana Larvae chew leaves	+	+	+
THYSANOPTERA ? * ?	Banana Adults and nymphs feed on leaves			+

ORDER Family Species	CROP Significance	Area M	 T	 P
COLEOPTERA Curculionidae Oribius inimicus	Cabbage Adults chew leaves	+	(+)	(+)
COLEOPTERA Curculionidae Oribius sp.	Cabbage Adults chew leaves		+	
HEMIPTERA Aphididae Myzus persicae	Cabbage Adults and nymphs suck sap	+		
LEPIDOPTERA Noctuidae Agrotis ipsilon	Cabbage Larvae chew and cut young plants	+	(+)	(+)
LEPIDOPTERA Noctuidae Diachrysia orichalcea	Cabbage Larvae chew leaves	+		
LEPIDOPTERA Noctuidae Heliothis armiger	Cabbage Larvae chew leaves	+	(+)	(+)
LEPIDOPTERA Noctuidae Spodoptera litura	Cabbage Larvae chew leaves	+		
LEPIDOPTERA Pyralidae Crocidolomia binotalis	Cabbage Larvae chew leaves	+	+	
LEPIDOPTERA Yponomeutidae Plutella xylostella	Cabbage Larvae chew leaves	+	+	+

ORDER Family Species	CROP Significance	Area M	 T	 P
ORTHOPTERA Pyrgomorphidae __**Atractomorpha crenaticeps__	Cabbage Adults and nymphs chew leaves	(+)	(+)	+
HEMIPTERA Coccidae ?	Cassava Adults and nymphs suck sap	+		
COLEOPTERA Curculionidae __Oribius__ sp.	Chinese cabbage Adults chew leaves		+	
COLEOPTERA Bruchidae ?	Common bean Larvae and adults feed in stored beans	+		
COLEOPTERA Chrysomelidae __Cassena ?intermedia__	Common bean Adults chew leaves	+	+	+
COLEOPTERA Curculionidae __Oribius destructor__	Common bean Adults chew leaves	(+)		+
COLEOPTERA Curculionidae __Oribius inimicus__	Common bean Adults chew leaves	+	+	+
COLEOPTERA Curculionidae __Oribius__ sp. A	Common bean Adults chew leaves		+	
COLEOPTERA Curculionidae __Oribius__ sp. B	Common bean Adults chew leaves			+
DIPTERA Agromyzidae __Ophiomyia phaseoli__	Common bean Larvae mine in leaves and stems	+	+	

ORDER Family Species	CROP Significance	Area M	 T	 P
HEMIPTERA Alydidae *Riptortus* sp.	Common bean Adults and nymphs suck developing seeds	+	+	
LEPIDOPTERA Pyralidae *Hedylepta indica*	Common bean Larvae chew leaves	+	+	
LEPIDOPTERA Pyralidae *Maruca testulalis*	Common bean Larvae bore in pods	+		
THYSANOPTERA ? ?	Common bean Adults and nymphs feed in flowers	+	+	
COLEOPTERA Chrysomelidae *Cassena ?intermedia*	Lablab bean Adults chew leaves	(+)	(+)	+
COLEOPTERA ? ?	Loofah Adults chew leaves	+		
COLEOPTERA Cantharidae *Chauliognathus* spp.	Maize ?	+	+	
COLEOPTERA Elateridae ***Agrypnus* sp.	Maize ?	+	(+)	+
COLEOPTERA Elateridae ***Compsolacon gracilis*	Maize ?			+

ORDER Family Species	CROP Significance	Area M	 T	 P
COLEOPTERA Elateridae ****Hapatesus tropicus*	Maize ?	(+)	+	(+)
COLEOPTERA Nitidulidae ****Brachypeplus* sp.	Maize ? Adults feed on grains ? Secondary			+
DERMAPTERA ? *Dermaptera sp.1 ?*Chelisoches morio*	Maize ?	(+)	(+)	+
DERMAPTERA ? *Dermaptera sp.3	Maize ?			+
DERMAPTERA ? *Dermaptera sp.4	Maize ?			+
DERMAPTERA ? *Dermaptera sp.6	Maize ?	+		
HEMIPTERA Aphididae *Rhopalosiphum maidis*	Maize Adults and nymphs suck sap Transmit diseases	+	+	
HEMIPTERA Colobathristidae ?*Phenacantha* sp.	Maize Adults and nymphs suck sap			+
LEPIDOPTERA Noctuidae *Agrotis ipsilon*	Maize Larvae chew and cut young plants	+	+	(+)

ORDER Family Species	CROP Significance	Area M	 T	 P
LEPIDOPTERA Noctuidae Heliothis armiger	Maize Larvae feed on developing grains	+	+	+
LEPIDOPTERA Noctuidae Mythimna separata	Maize Larvae chew leaves	+	+	
ORTHOPTERA Acrididae **Oxya japonica vitticollis	Maize Adults and nymphs chew leaves	+		(+)
LEPIDOPTERA Pyralidae Crocidolomia binotalis	Nasturtium Larvae chew leaves	+	(+)	
LEPIDOPTERA Yponomeutidae Plutella xylostella	Nasturtium Larvae chew leaves	+	(+)	(+)
HEMIPTERA Aphididae Neotoxoptera formosana	Onion Adults and nymphs suck sap	+		+
LEPIDOPTERA Tineidae **Trachycentra chlorogramma	Pandanus (karuka) Larvae chew leaves	+		
ORTHOPTERA Tettigoniidae Phyllophora boshmai	Pandanus (karuka) Adults and nymphs chew leaves	+		
ORTHOPTERA Tettigoniidae Segestes sp.	Pandanus (karuka) Adults and nymphs chew leaves	+		

ORDER Family Species	CROP Significance	Area M	 T	 P
LEPIDOPTERA Tineidae **Trachycentra chlorogramma**	Pandanus (marita) Larvae chew leaves		+	+
LEPIDOPTERA Noctuidae *Heliothis armiger*	Pigeon pea Larvae chew leaves	+	(+)	(+)
LEPIDOPTERA Pyralidae *Chilo ?terenellus*	Pit pit (S.e.) Larvae bore in stems	(+)	(+)	+
LEPIDOPTERA Pyralidae *Chilo ?terenellus*	Pit pit (S.p.) Larvae bore in stems	+	+	+
COLEOPTERA Scarabaeidae *?Papuana* spp.	Potato Adults bore in tubers	+		
HEMIPTERA Aphididae ?	Potato Adults and nymphs suck sap Transmit diseases	+		
LEPIDOPTERA Gelechiidae *Phthorimaea operculella*	Potato Larvae bore in tubers	+		
COLEOPTERA Chrysomelidae *Aulacophora* spp. See text	Pumpkin Adults chew leaves and flowers	+	+	+
COLEOPTERA Coccinellidae *Henosepilachna signatipennis*	Pumpkin Adults and larvae chew leaves	+	+	

ORDER Family Species	CROP Significance	Area M	 T	 P
COLEOPTERA Curculionidae *Oribius* sp.	Rungia ? Adults chew leaves			+
ORTHOPTERA ? ?	Rungia ? Adults and nymphs chew leaves			+
COLEOPTERA Chrysomelidae *Cassena ?intermedia*	Soy bean Adults chew leaves	+	(+)	(+)
COLEOPTERA Curculionidae *Oribius inimicus*	Soy bean Adults chew leaves	+	(+)	(+)
DIPTERA Agromyzidae *Ophiomyia phaseoli*	Soy bean Larvae mine in leaves and stems	+	(+)	
HEMIPTERA Pentatomidae *Nezara viridula*	Soy bean Adults and nymphs suck developing seeds	+		
LEPIDOPTERA Pyralidae *Hedylepta indica*	Soy bean Larvae chew leaves	+	(+)	
COLEOPTERA Cantharidae *Chauliognathus bituberculatus*	Sugar Cane ? Predator of leafhoppers	+		
COLEOPTERA Cantharidae *Chauliognathus wareoensis*	Sugar Cane ? Predator of leafhoppers	+	+	

ORDER Family Species	CROP Significance	Area M	 T	 P
COLEOPTERA Curculionidae Oribius destructor	Sugar Cane ?	+		(+)
COLEOPTERA Curculionidae Oribius inimicus	Sugar Cane ?	+	(+)	(+)
COLEOPTERA Curculionidae Rhabdoscelus obscurus	Sugar Cane Larvae bore in stems	+	+	+
COLEOPTERA Elateridae **Agrypnus sp.	Sugar Cane ? Predator of leafhoppers	+	+	+
COLEOPTERA Elateridae **Compsolacon gracilis	Sugar Cane ? Predator of leafhoppers			+
COLEOPTERA Elateridae **Hapatesus tropicus	Sugar Cane ? Predator of leafhoppers	+	+	+
DERMAPTERA ? *Dermaptera sp.1 ?Chelisoches morio	Sugar Cane ? predator of leafhoppers	+	+	+
DERMAPTERA ? *Dermaptera sp.2	Sugar Cane ? (possibly predatory)			+
DERMAPTERA ? *Dermaptera sp.4	Sugar Cane ? (possibly predatory)			+

ORDER Family Species	CROP Significance	Area M	Area T	Area P
DERMAPTERA ? Dermaptera sp.5	Sugar Cane ? (possibly predatory)		+	(+)
DERMAPTERA ? *Dermaptera sp.6	Sugar Cane ? (possibly predatory)	+		
DIPTERA Chloropidae **<u>Gaurax</u>	Sugar Cane Larvae feeding in rotting stem (?secondary)		+	
DIPTERA Chloropidae **<u>Thressa punctifera</u>	Sugar Cane ?		+	
DIPTERA Empididae * ?	Sugar Cane Larvae feeding in rotting stem (?secondary)		+	
DIPTERA Lonchaeidae * ?	Sugar Cane Larvae feeding in rotting stem (?secondary)		+	
DIPTERA Neriidae * ?	Sugar Cane Larvae feeding in rotting stem (?secondary)		+	
HEMIPTERA Aphididae **<u>Ceratovacuna lanigera</u>	Sugar Cane Adults and nymphs suck sap ? Transmit diseases		+	+
HEMIPTERA Cercopidae Cercopid sp. 1	Sugar Cane Adults and nymphs suck sap ? Transmit diseases		+	+

ORDER Family Species	CROP Significance	Area M	 T	 P
HEMIPTERA Cercopidae Cercopid sp. 2	Sugar Cane Adults and nymphs suck sap ? Transmit diseases			
HEMIPTERA Colobathristidae ?Phaenacantha sp.	Sugar Cane Adults and nymphs suck sap		+	+
HEMIPTERA Delphacidae Delphacid sp. 4	Sugar Cane Adults and nymphs suck sap ? Transmit diseases	+		
HEMIPTERA Delphacidae **Eumetopina flavipes	Sugar Cane Adults and nymphs suck sap ? Transmit diseases	+	+	+
HEMIPTERA Delphacidae **Perkinsiella diagoras ? and other species	Sugar Cane Adults and nymphs suck sap ? Transmit diseases	+	+	+
HEMIPTERA Delphacidae **Sogata sp.	Sugar Cane Adults and nymphs suck sap ? Transmit diseases	+		
HEMIPTERA Derbidae **Swezeyia sp.	Sugar Cane ?			+
HEMIPTERA Lophopidae Lophopid sp. 1 ?Lophops saccharicida	Sugar Cane Adults and nymphs suck sap ? Transmit diseases		+	
HEMIPTERA Miridae **Tytthus mundulus	Sugar Cane Adults and nymphs feed on leafhopper eggs	+		

ORDER Family Species	CROP Significance	Area M	 T	 P
HEMIPTERA Pseudococcidae **Trionymus sp. 1	Sugar Cane Adults and nymphs suck sap ? Transmit diseases			+
HEMIPTERA Pseudococcidae **Trionymus sp. 2	Sugar Cane Adults and nymphs suck sap ? Transmit diseases	+	+	+
HYMENOPTERA Formicidae **Iridomyrmex cordatus or species near	Sugar Cane Nesting on cane Associated with mealybugs			+
HYMENOPTERA Formicidae **Iridomyrmex sp.	Sugar Cane ? tending leafhoppers			+
HYMENOPTERA Formicidae **Iridomyrmex sp. ?glaber	Sugar Cane ?			+
HYMENOPTERA Formicidae ?Leptomyrmex melanoticus	Sugar Cane ?		+	
HYMENOPTERA Formicidae **Tapinoma melanocephalum	Sugar Cane Nesting on cane			+
HYMENOPTERA Formicidae **Technomyrmex albipes	Sugar Cane ?			+
HYMENOPTERA Formicidae **Tetramorium bicarinatum	Sugar Cane ? tending leafhoppers			+

ORDER Family Species	CROP Significance	Area M	 T	 P
LEPIDOPTERA Noctuidae Heliothis armiger	Sugar Cane Larvae feed on foliage	+	(+)	(+)
LEPIDOPTERA Pyralidae *Chilo ?terenellus	Sugar Cane Larvae bore in stems	+	+	+
LEPIDOPTERA Tineidae **Trachycentra chlorogramma	Sugar Cane Larvae bore in stems	(+)	+	(+)
ORTHOPTERA Acrididae Acidid sp. A	Sugar Cane ? Adults and nymphs chew leaves			+
ORTHOPTERA Acrididae Heteropternis obscurella	Sugar Cane ? Adults and nymphs chew leaves	(+)	(+)	
ORTHOPTERA Acrididae **Oxya japonica vitticollis	Sugar Cane Adults and nymphs chew leaves	+		(+)
ORTHOPTERA Acrididae Valanga sp.	Sugar Cane ? Adults and nymphs chew leaves			+
ORTHOPTERA Pyrgomorphidae **Atractomorpha crenaticeps	Sugar Cane ? Adults and nymphs chew leaves	+	(+)	+
ORTHOPTERA Tettigoniidae Phaneroptera brevis	Sugar Cane ? Adults and nymphs chew leaves			(+)

ORDER Family Species	CROP Significance	Area M	 T	 P
ACARINA Eriophyoidea *Eriophyid sp.	Sweet potato Causes rust symptoms on leaves	+		
COLEOPTERA Chrysomelidae *Arsipoda tenimberensis	Sweet potato Adults strip upper epidermis	+	+	+
COLEOPTERA Chrysomelidae **Aspidomorpha australasiae	Sweet potato Adults and larvae chew leaves			+
COLEOPTERA Chrysomelidae **Aspidomorpha ?punctum	Sweet potato Adults and larvae chew leaves		+	+
COLEOPTERA Chrysomelidae **Cassida ?diomma	Sweet potato Adults and larvae chew leaves	+	+	+
COLEOPTERA Chrysomelidae **Laccoptera impressa	Sweet potato Adults and larvae chew leaves		+	
COLEOPTERA Chrysomelidae Monolepta semiviolacea	Sweet potato Adults chew leaves		+	
COLEOPTERA Curculionidae Cylas formicarius	Sweet potato Adults and larvae feed in stems and tubers	+	+	+
COLEOPTERA Curculionidae Oribius inimicus	Sweet potato Adults chew leaves	+	(+)	+

ORDER Family Species	CROP Significance	Area M	 T	 P
COLEOPTERA Elateridae Elaterid sp.	Sweet potato Larvae bore into tubers	+		
COLEOPTERA Scarabaeidae Scarabaeid spp. (e.g. Papuana spp.)	Sweet potato Adults bore into tubers	+	+	
HEMIPTERA Cicadellidae *Cicadellid sp. 1 **Zygina medioborealis **Zygina sp. sensu lato **Balclutha sp.	Sweet potato Adults and nymphs suck sap	+	+	+
HEMIPTERA Cicadellidae *Cicadellid sp. 3 **Cicadella wallacei	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Cicadellidae *Cicadellid sp. 4 **Genus near Orosius **Gen. et sp. indet.	Sweet potato Adults and nymphs suck sap		+	+
HEMIPTERA Cicadellidae *Cicadellid sp. 5 **Cicadella sp. sensu lato	Sweet potato Adults and nymphs suck sap	+		+
HEMIPTERA Cicadellidae *Cicadellid sp. 6	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Cicadellidae *Cicadellid sp. 7 **Zygina sp. sensu lato	Sweet potato Adults and nymphs suck sap	+		+

ORDER Family Species	CROP Significance	Area M	 T	 P
HEMIPTERA Cicadellidae Cicadellid sp. 9	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Cicadellidae Cicadellid sp. 10	Sweet potato Adults and nymphs suck sap	+		
HEMIPTERA Cicadellidae Cicadellid sp. 11	Sweet potato Adults and nymphs suck sap	+		
HEMIPTERA Cicadellidae Cicadellid sp. 12	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Cicadellidae Cicadellid sp. 13	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Cicadellidae Cicadellid sp. 14	Sweet potato Adults and nymphs suck sap	+		
HEMIPTERA Cicadellidae Cicadellid sp. 15	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Cicadellidae Cicadellid sp. 16	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Cicadellidae Cicadellid sp. 17	Sweet potato Adults and nymphs suck sap			+

ORDER Family Species	CROP Significance	Area M	 T	 P
HEMIPTERA Cicadellidae Cicadellid sp. 18	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Cicadellidae Cicadellid sp. 19	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Cicadellidae Cicadellid sp. 20	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Cicadellidae Cicadellid sp. 21	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Delphacidae Delphacid sp. 5	Sweet potato Adults and nymphs suck sap	+	+	
HEMIPTERA Delphacidae Delphacid sp. 7	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Delphacidae Delphacid sp. 9	Sweet potato Adults and nymphs suck sap			+
HEMIPTERA Delphacidae Delphacid sp. 10	Sweet potato Adults and nymphs suck sap		+	
HEMIPTERA Delphacidae Delphacid sp. 11	Sweet potato Adults and nymphs suck sap		+	

ORDER Family Species	CROP Significance	Area M	 T	 P
HEMIPTERA Delphacidae Delphacid sp. 12	Sweet potato Adults and nymphs suck sap		+	
HEMIPTERA Lygaeidae Nysius villicus	Sweet potato ?Adults suck sap	+	+	+
HEMIPTERA Miridae Halticus tibialis	Sweet potato Adults and nymphs suck cell contents		+	+
HEMIPTERA Miridae Helopeltis clavifer	Sweet potato Adults and nymphs suck cell contents	+	+	+
HEMIPTERA Pentatomidae **Antestiopsis chambereti	Sweet potato Unknown			+
LEPIDOPTERA ? Sp. B	Sweet potato Larvae chew leaves			+
LEPIDOPTERA ? Sp. D	Sweet potato Larvae chew leaves			+
LEPIDOPTERA ? Sp. F	Sweet potato Larvae chew leaves			+
LEPIDOPTERA ? Sp. G	Sweet potato Larvae chew leaves			+
LEPIDOPTERA ? Sp. H	Sweet potato Larvae chew leaves			+

ORDER Family Species	CROP Significance	Area M	 T	 P
LEPIDOPTERA Gracillariidae **<u>Acrocercops homalacta</u>	Sweet potato Larvae mine leaves	+	+	+
LEPIDOPTERA Lyonetiidae <u>Bedellia somnulentella</u>	Sweet potato Larvae mine and chew leaves	+	+	+
LEPIDOPTERA Noctuidae <u>Aedia sericea</u>	Sweet potato Larvae chew leaves			+
LEPIDOPTERA Noctuidae <u>Agrotis ipsilon</u>	Sweet potato Larvae chew and cut young plants	+	(+)	(+)
LEPIDOPTERA Pterophoridae <u>Onchyrotica concursa</u>	Sweet potato Larvae chew leaves	+		+
LEPIDOPTERA Pyralidae Sp. A	Sweet potato Larvae chew leaves			+
LEPIDOPTERA Sphingidae <u>Herse convolvuli</u>	Sweet potato Larvae chew leaves	+	+	
ORTHOPTERA Gryllidae Gryllid sp. 1	Sweet potato ? Adults chew leaves	+	+	+
ORTHOPTERA Gryllidae Gryllid sp. 2	Sweet potato ? Adults chew leaves	+		+
ORTHOPTERA Gryllidae <u>Teleogryllus commodus</u>	Sweet potato ? Adults and nymphs bore into tubers	+		

ORDER Family Species	CROP Significance	Area M	 T	 P
ORTHOPTERA Gryllotalpidae Gryllotalpa africana	Sweet potato Adults and nymphs bore into tubers	+		
ORTHOPTERA Pyrgomorphidae **Atractomorpha crenaticeps	Sweet potato ? Adults chew leaves	+	+	(+)
ORTHOPTERA Tettigoniidae Tettigoniid sp. 1	Sweet potato ? Adults chew leaves	?		+
ORTHOPTERA Tettigoniidae Phaneroptera brevis	Sweet potato ? Adults chew leaves			+
COLEOPTERA Curculionidae Oribius sp. A	Taro Adults feed on leaf stalks		+	
COLEOPTERA Curculionidae Pharotes torvus	Taro Adults feed on stems Larvae feed in corms	+		+
COLEOPTERA Scarabaeidae Papuana trinodosa	Taro Adults feed on corms	+		+
COLEOPTERA Scarabaeidae Papuana woodlarkiana	Taro Adults feed on corms	?		+
COLEOPTERA Scarabaeidae Papuana spp.	Taro Adults feed on corms	+	+	+

ORDER Family Species	CROP Significance	Area M	T	P
DERMAPTERA ? *Dermaptera sp.2	Taro ? predator			+
DERMAPTERA ? Dermaptera sp.5	Taro ? predator		(+)	+
HEMIPTERA Aphididae Aphis gossypii	Taro Adults and nymphs suck sap			+
HEMIPTERA Cicadellidae **Cicadella sp. sensu lato	Taro Adults and nymphs suck sap	+	+	+
HEMIPTERA Delphacidae Tarophagus proserpina	Taro Adults and nymphs suck sap Virus vector	+	+	+
HEMIPTERA Miridae **Mecomma sp.	Taro ? egg predator of Tarophagus proserpina	+	+	+
LEPIDOPTERA Noctuidae Agrotis ipsilon	Taro Larvae feed on corms and stems	+	(+)	(+)
LEPIDOPTERA Sphingidae Hippotion celerio	Taro Larvae chew leaves	(?)	+	+
LEPIDOPTERA Noctuidae Agrotis ipsilon	Tomato Larvae chew and cut young plants	(+)	+	(+)

ORDER Family Species	CROP Significance	Area M	 T	 P
LEPIDOPTERA Noctuidae _Heliothis armiger_	Tomato Larvae feed in fruits	(+)	+	(+)
COLEOPTERA Curculionidae _Oribius_ sp.	Turnip ? Adults chew leaves		+	
ORTHOPTERA ? ?	Turnip ? Adults and nymphs chew leaves		+	

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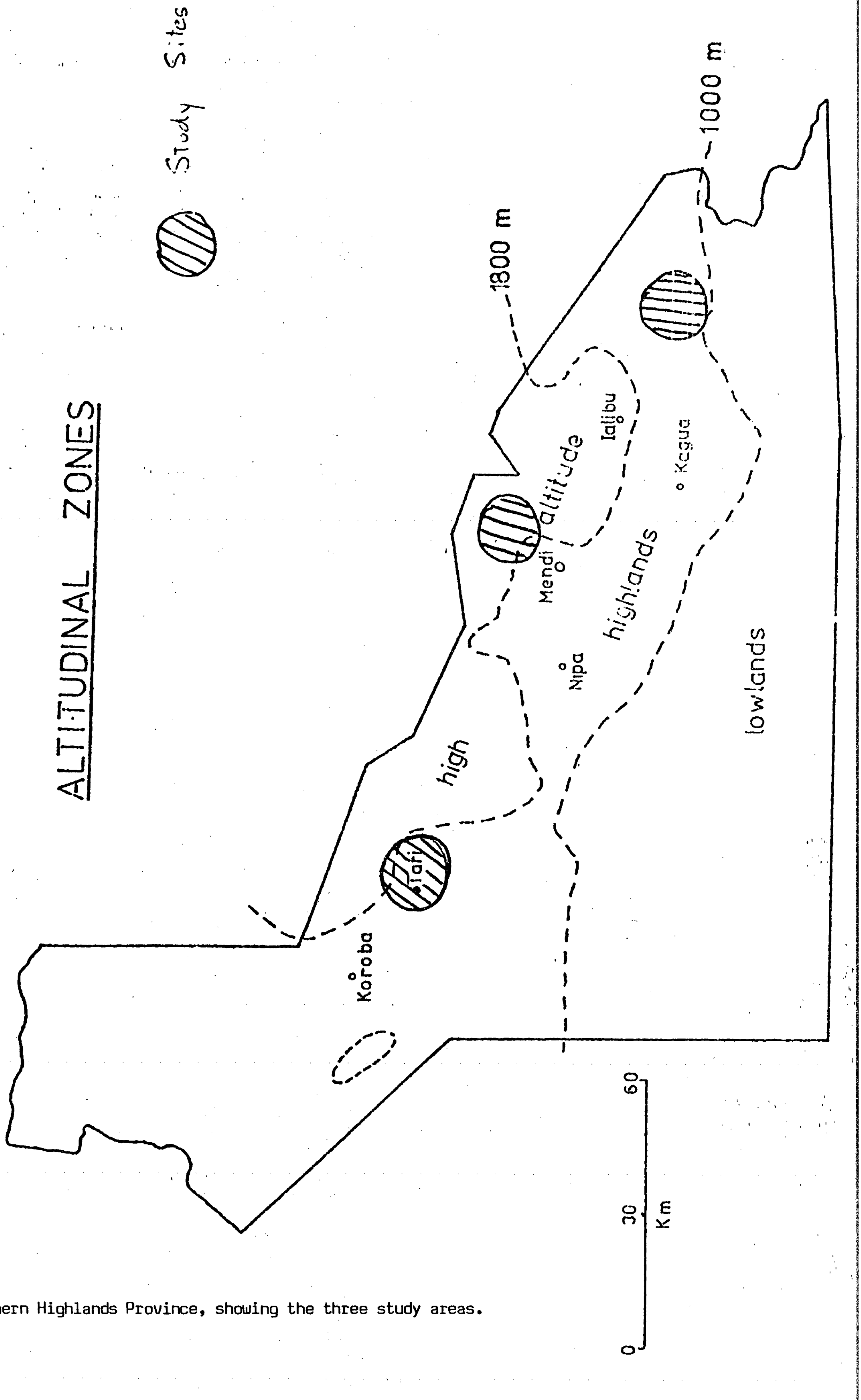
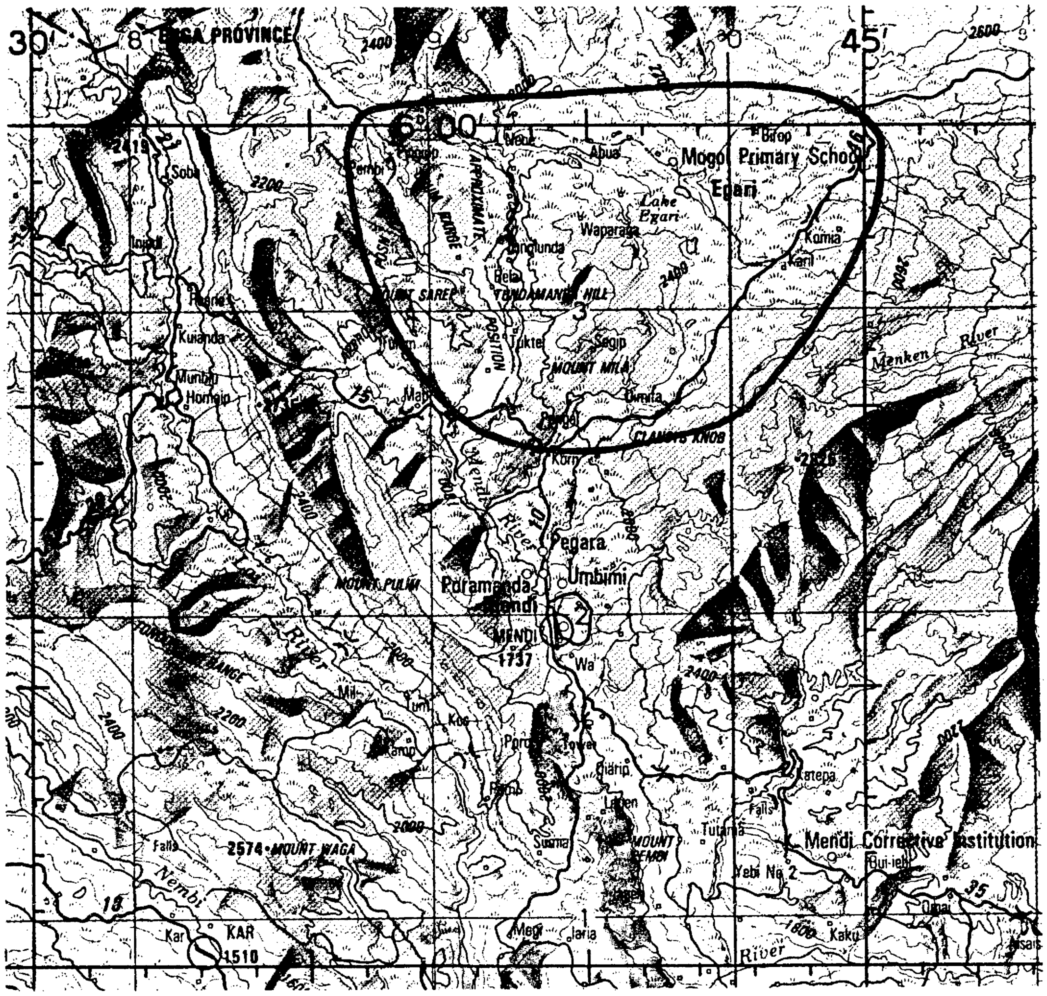
MAPS and APPENDICES

MAP 1.



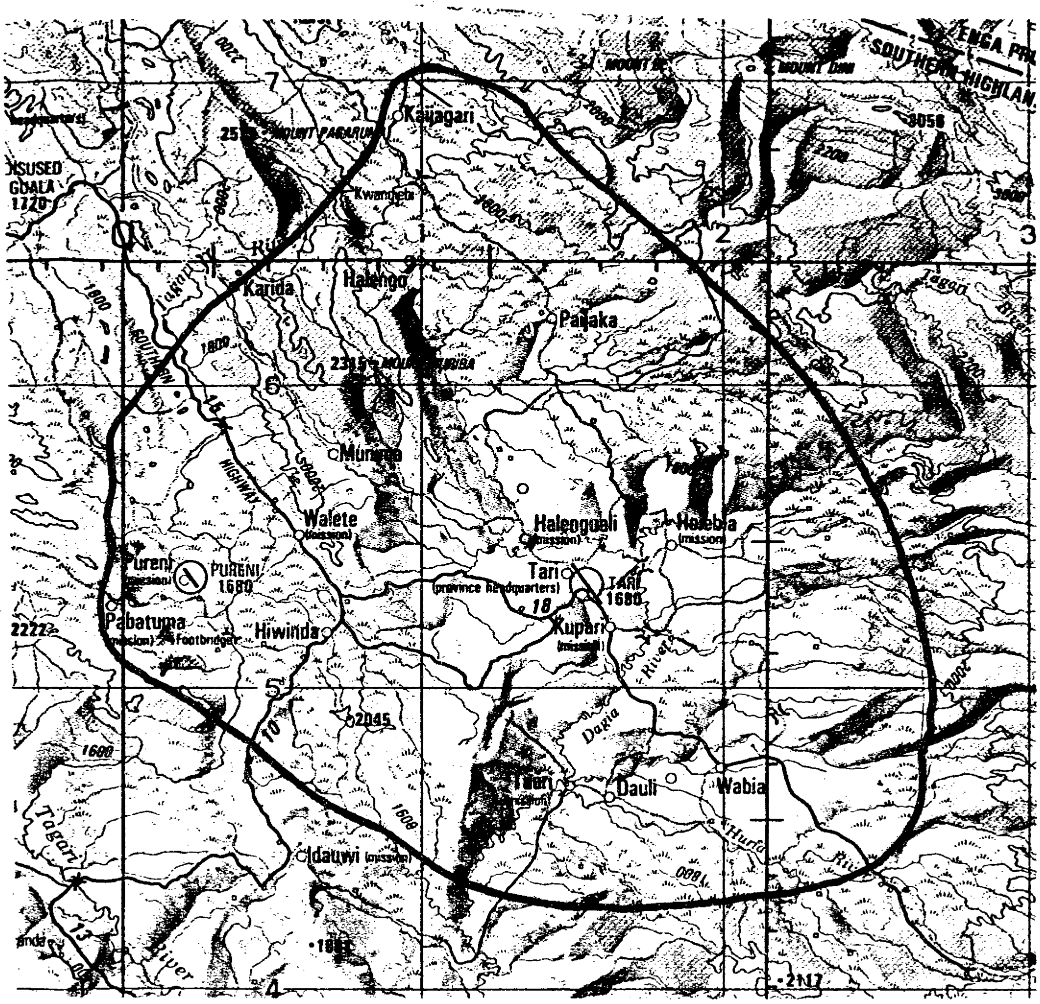
The Southern Highlands Province, showing the three study areas.

MAP 2.



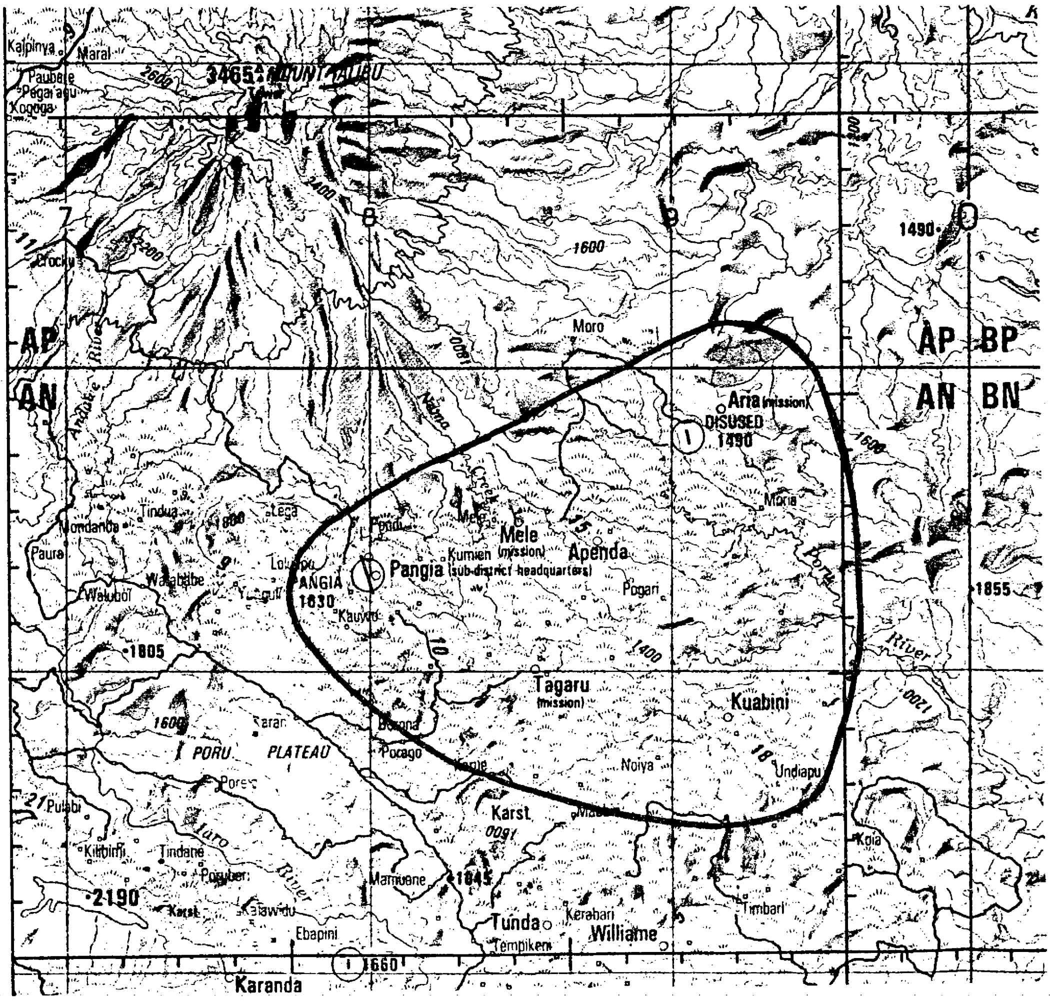
Mendi area, 1:250 000, showing approximate boundary of study area.

MAP 3.



Tari area, 1:250 000, showing approximate boundary of study area.

MAP 4.



Pangia area, 1:250 000, showing approximate boundary of study area.

APPENDIX 1

Extract from "Draft outline of the components of CROPPING SYSTEMS RESEARCH PROGRAMME in three areas of the Southern Highlands Province". AFTSEMU document, 1981.

2. Initial Site Description

The initial site description for each of the three areas will include the following components:

1. Weather data.

   A review of what weather data have been collected for the area. At this stage weather stations will be established in each area for the ongoing programme.

2. Landscape description and soils survey.

   Depending on availability of resources at time of initial description.

3. Demography from available records.

4. Preliminary Agricultural System Description for the general area.

5. Selection of households and initial description of their gardens.

   Will note - household size
   pig population
   total garden areas and description of crops, including cash crops
   garden history
   yields from existing gardens

6. Pest and disease profile for the crops grown in the area

7. Estimation of labour requirements for agricultural activities e.g. to prepare and plant kaukau mounds, harvesting, etc.

8. Enumeration of livestock and other projects in the area.

9. Establish system for ongoing market surveys.

10. Description of Nutritional Status of the area.
    To include: assessment of the general area
    assessment of households in monitoring programme

11. Preliminary food intake study

12. Health status from available sources.

13. Review of relevant anthropological and other studies for the area.

    Particularly for: clan structure
    labour availability
    land tenure
    food preferences
    non-garden resources

APPENDIX 2

Extract from "Draft outline of the components of CROPPING SYSTEMS RESEARCH PROGRAMME in three areas of the Southern Highlands Province". AFTSEMU document, 1981.

1. Cropping Systems Research Areas

1. Three areas in the Southern Highlands Province have been selected for cropping systems research.

   Factors which were taken into account in making the selection were:

   1.1 that the area should represent major agroclimatic zones

   1.2 the estimated potential for crop intensification

   1.3 government priority areas for development

   1.4 accessibility for research staff

2. Specific conditions and problems within areas were also considered; soil types, declining soil fertility, malnutrition rates, population density, recurrent frosts, reclamation of kunai grassland, erosion, social/cultural variability, cash cropping, specific insect and disease pests, projects in each area, basic staple, etc.

3. The three areas chosen are the Tari Basin, the Upper Mendi and Pangia. All are areas where sweet potato is the staple crop.

3.1 Tari basin

The Tari basin is a representative area of the medium altitude, heavily populated zone of the province. The Huli people are anxious to see 'development' of their land and, with the recent opening of the Mendi-Tari road, it is anticipated that rapid changes to cropping systems will take place in the next few years.

The Tari Basin has been the centre of a great deal of research activity. Good demographic, health and nutritional data are available and a soils and land use study has been undertaken there. The cropping systems research programme will build onto this research base.

Piwa Agricultural Station would provide a valuable asset for the programme.

3.2 Upper Mendi

The Upper Mendi area is a high altitude area (above 1800m) and is subject to periodic frosts. A significant population resides there (over 10,000). An obvious advantage is its proximity to Mendi and to the Kiburu Research Station.

3.3 Pangia

Pangia, at about 1400m, will provide a greater diversity of food cropping options for cropping systems research. In addition, the area to be studied will include the area of plantation development of tea and coffee. Smallholder coffee has already had an impact on the agricultural systems in this area.

APPENDIX 3

Surveys of pests and diseases on crops in three areas of the Southern Highlands Province. (AFTSEMU proposal 1981.)

Entomology: Plant Pathology: Nematology

The AFTSEMU team, within the Southern Highlands Rural Development Project, has requested assistance from National DPI for surveys of pests and diseases of food crops to be carried out in the three areas of the province currently under intensive study by the team - Tari, Upper Mendi and Pangia.

General Objectives

Assessment of existing and potential pests and diseases for cultivated and propagated crops is required for the following reasons:

1. To determine what is or could be causing damage to currently grown crops,
2. To assist local agronomists in the choice of appropriate plant introductions,
3. To assist research institutions to determine priorities for programmes to screen for resistant crops, and
4. To assist in determining requirements for pest and disease control programmes.

Priority will be given to food crops within the subsistence system, but some attention should be given to crops with commercial potential. It is anticipated that some investigation of surrounding vegetation will be necessary.

It is acknowledged that the value of the initial surveys will be limited for several reasons (see Church, 1971). However, they will serve to guide planning of further work relevant to the current conditions, when considered in conjunction with the other information being obtained by the team in the three areas. (Soils, climate, agricultural practises, etc.).

Procedural considerations (for discussion)

Stage 1: It is suggested that, initially, a checklist of pests and diseases occurring on cultivated and propagated crops, and nearby vegetation if necessary, in sample gardens be drawn up.

Stage 2: On the basis of the findings during the first stage, and of a list of priority crops drawn up by AFTSEMU staff, measurements of pest and disease incidence will be made for specified pests on specified crops.

Care will be taken at this stage to properly define methods being used so that:

a. follow-up surveillance will yield comparable data, and
b. any experimental work which follows should use similar evaluation techniques to assist extrapolation of results to the field.

Stage 3: will be devoted to interpretation of results, recommendations, and development of strategies for further survey or experimental work. This will be combined exercise with AFTSEMU staff.

The survey reports will be incorporated within an AFTSEMU report - essentially an agricultural profile for each area with recommendations for extension work and further research work. A programme outline for AFTSEMU future activities should be included. It is anticipated that pest and disease surveillance on a six monthly basis will be necessary.

Reference:

Church, B.M. "The Place of Sample in Crops Loss Estimation" in C.A.B. Misc. Pub. "Crop Loss Assessment Methods" 1971.

DEPARTMENT OF PRIMARY INDUSTRY

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OUR REFERENCE: HEN AFT
DATE: 6 November 1981
YOUR REFERENCE:
DATE:

AFTSEMU PROJECT - INSECT PEST SURVEY

Brief report of Pilot Surveys and proposed methods for Main Survey.*

ACTION TO DATE

A pilot survey has been carried out in the periods 27 July to 7 August and 2 November to 6 November. The aims of these surveys were to look at gardens in various parts of the Upper Mendi area and to examine all crops in these gardens for insect pests. This information will be used to form a checklist of the pests and potential pests present. The following notes are based on information gained during this pilot survey.

1. Sweet potato

Although a vast range of species of insects have been collected from sweet potato foliage many of these were predatory insects, parasitic Hymenoptera and Diptera, and various other adult Diptera merely resting on the crop.

A species of Lepidoptera mines the leaves. It is frequent throughout the highlands although its identity is not yet known. Specimens from Kuk A.R.S. have been bred through to yield adults and similar breeding will be carried out in the S.H.P. project areas**. It is not thought to be the sweet potato leaf miner, *Bedellia somnulentella*, which is also present in some areas of the highlands.

A species of flea beetle (Coleoptera: Chrysomelidae: Alticinae) has also been found. This species is also common in the highlands and lowlands of P.N.G. Specimens have been sent for identification. Damage is in the form of small brown dots where the beetle has fed on the upper epidermis of the leaf.

Neither of these two species seems to cause serious damage, the amount of foliage removed being very small.

None of the tortoise-beetles (Coleoptera: Chrysomelidae), which are common in the lowlands and do occur in the Wahgi Valley, have yet been found at Mendi. These will be

* Originally submitted as a hand written draft for discussion with AFTSEMU staff immediately on completion of the Pilot Survey.

** This was an error. The species which had been bred at Kuk was *Onchyrotica concursa* Walker (Lepidoptera: Pterophoridae), a foliage feeder but not a leaf miner. B.M.T. 25 viii 83.

looked for, but at this altitude damage will probably be slight.

Several species of leaf hopper (Hemiptera: Cicadellidae and Delphacidae) have been collected. Identifications for many of these are available at Kuk. Their significance in damaging the crop is not known and can only be established by experiment.

As far as tuber pests are concerned, scarabaeid beetles (Papuana spp. and Clysterius angustus) are known to feed on sweet potato tubers. The significance of these will be investigated.

More importantly, although nematodes have been implicated in the sweet potato problem in the Upper Mendi, the role of soil insects will still be examined (see details below).

2. Sugar Cane

Attacked by sugar cane borers, Sesamia sp. and probably also Chilo sp.* Larvae will be reared to adults for identification.

Also attacked by the weevil Rhabdoscellus.

Various species of leaf hopper (Hemiptera: Delphacidae) are present on sugar cane. One of these, Perkinsiella sp., is a known vector of Fiji disease. The incidence of these will be evaluated.

3. Potato

Not examined this trip. Potential pests to be looked for are aphids (only important in crops produced for seed) and taro beetle, cutworm and tuber moth damage to the tubers.

4. Cabbage

Pests are diamond-back moth (Plutella xylostella), cabbage cluster caterpillar (Crocidolomia binotalis), cutworms (Agrotis ipsilon) and aphids. Damage levels very low at present.

5. Pitpit

Attacked by borers. Chilo sp. has been found. Sesamia sp. may also attack. See notes on sugar cane.

6. Taro

Taro beetle damage needs to be assessed. Also present is the leaf hopper Tarophagus proserpina (Hem: Delphacidae) which has been found in some numbers. Its usual importance is as a vector of the large bacilliform virus particle which causes the diseases Alomae and Bobone. These diseases seem rare in the highlands. Despite the presence of Cytorhinus sp.** (Hem: Miridae), an egg predator of Tarophagus, populations of the latter are high and may be doing physical damage themselves.

7. Corn

Potential pests are corn earworm, Heliothis armiger, and armyworm, Mythimna separata.

PROPOSED SAMPLING PROGRAMME

At this stage we still do not have enough information for quantitative samples on the basis of the FAO Crop Loss Assessment Survey Methods (Church 1971). One of the problems is finding enough of a given plant at a suitable age in a large enough sample of gardens.

* This turned out to be wrong, see main report. B.M.T., 25 viii 83.

** This has now been identified as another species of predatory mirid. B.M.T., 7 ix 83.

For the present survey the following information will be obtained for each garden:

1. Sweet potato

(i) Foliage pests

At each garden ten (10) half metre square quadrat counts will be made on sweet potato mounds with reasonably mature plants covering the mounds. Counts will be made of:

1. Lepidoptera larvae
2. Flea beetles
3. Tortoise beetles
4. Cicadellid sp. 1 (the commonest cicadellid).

Other insects on the foliage not noted before will be collected.

(ii) Soil insects

Where sweet potato is being harvested a sample of ten to twenty tubers will be assessed for damage by scarabaeid beetles. Specimens of the beetles to be collected if present. Record number of holes and estimate percentage of tuber removed.

A sample of soil fauna will be collected from three mounds at each site and the presence of the stem rotting problem noted.

2. Sugar cane

Note how much cane is present (nos. of bundles + size).

Take ten bundles of sugar and note presence or absence on each of:

1. Delphacid sp. 1
2. " 2
3. " 3 (Collect more specimens)
4. " 4 " " "
5. ?Cytorhinus sp.

Note presence/absence in the sugar of the following (but do not record per bundle):

6. Elaterid sp. 1
7. " 2
8. Chauliognathus sp.
9. Earwig sp.

Assess presence of stem borer, if possible number of stems affected. Collect more specimens for breeding.

Assess presence/absence of Rhabdoscellus.

3. Potato

Note how many plants and age.

Collect aphids.

If being harvested take sample of 20 tubers and assess for cutworm/taro beetle damage. Collect sample of insects.

Take 20 green tubers and assess for presence/absence of tuber moth.

4. Cabbage

At present damage levels are very low. To be left, see further work below.

5. Taro

Record number of plants and size.

Sample ten plants for the presence/absence of Tarophagus and Cytorhinus.

Collect aphids, mealybugs, whitefly larvae or adults, into alcohol.

If taro is old enough for harvest, buy plants (sample of ten) and assess for taro beetle damage, as for sweet potato. Try to find out variety of taro and keep plants. Collect taro beetle adults.

6. Corn

Record number and size of plants.

Assess for presence/absence of Heliothis armiger and Mythimna separata on ten plants.

Look for aphids and collect.

Also look for delphacids and cicadellids.

7. Pitpit

How much present? Sample several plants for presence/absence of borers. Breed specimens.

8. Pandanus

Assess several stands in various areas for the presence of lepidopterous pest and, if possible, Segestidea.

9. Other vegetables

Record numbers of each present.

Look for damaging insects, collect and rate as minor, medium or major damage.

Beans, in particular, sample ten for presence/absence of beanfly. Record type and variety of beans. Collect aphids, thrips. Are Riptortus or Nezara present?

GARDENS, MENDI

Suggest:

Two in Komia, Birop area.
Two in Karel area.
Two in bush above Birop
Two at Egari
Two at Bela
Two at Pingirip
Two at Hoai
Two at Dimifa

16 at two per day gives 8 days.

In each of these areas, if possible, examine one or two pandanus patches.

Take a similar range of gardens in Tari and Pangia.

FURTHER WORK INCLUDING POSSIBLE METHODS FOR QUANTITATIVE SAMPLING

1. Sweet potato

Based on the results of the present survey, a decision will be made as to whether more detailed sampling of foliage and tuber pests is required.

It is proposed that an entomologist (and hopefully also a Plant Pathologist) are present when the fertilizer/nematicide trials are harvested to assess soil arthropod and nematode fauna in each treatment.

2. Sugar cane

More detailed sampling of sugar cane borers may be necessary. Samples should ideally be taken on mature canes and a number of canes sampled in each garden for numbers of borers.

Unfortuneately since the canes are bound together this sampling cannot be done without buying and cutting the canes. We were told that a well grown bundle would cost K10-K20.

3. Potatoes

Studies on damage by taro beetles and cutworms to potatoes have shown that these are seldom a problem. If more detailed sampling is required this should be done on mature tubers at harvest using a rating system worked out for trials at Kuk.

Similarly for tuber moth. This can easily be controlled by effective hilling so that tubers are not exposed.

4. Cabbages

Population counts of all stages (eggs, larva I, II, III, IV, and pupae)of Plutella xylostella and also some stages (eggs, larvae)of Crocidolomia binotalis on cabbages seven, eleven and fifteen weeks of age have been made monthly at Kuk for the past three years.

Numbers of eggs of Plutella have been found to be affected by the rainfall which fell four and five weeks before the count. This rainfall has a mortality effect on the young larvae and affects the population of adults present four to five weeks later. Predictive equations using rainfall to predict numbers of eggs have been developed and are being refined.

It is hoped that plots of cabbages can be planted in a few areas in Upper Mendi at different times of the year and counts of insects made at specific ages. This will enable the predictive equations to be modified for use in the Upper Mendi area, and they can then be used to monitor populations in the future.

Since no insecticides are used in the Upper Mendi it is suggested that three parasites which it is proposed to introduce into PNG be released in this area.

5. Taro

Taro beetle is likely to be a problem. More detailed sampling of corms at harvest, rated on a damage scale, would be desirable. Damage rating could be correlated with variety.

6. Corn

At maturity, population levels of pests and numbers of damaged cobs.

7. Other vegetables

Further work to be decided as a result of the present survey.

REFERENCE

Church, B.M. (1971). The place of sample survey in crop loss estimation. In Chiarappa, L. (ed.) (1971). Crop loss assessment methods. FAO Manual on the evaluation and prevention of losses by pests, diseases and weeds. C.A.B.: Slough, U.K. 8 pp.

B.M. Thistleton

Dr B. M. Thistleton,
a/Senior Entomologist

APPENDIX 5

List of gardens visited during the survey, with dates and names of the officers who carried out the fieldwork.

MENDI

M1	28 vii 81	Kiburu	R.T. Masamdu
M2	29 vii 81	Birop	R.T. Masamdu
M3	29 vii 81	Karil	R.T. Masamdu
M4	30 vii 81	Komia	R.T. Masamdu
M5	30 vii 81	Karenda	R.T. Masamdu
M6	30 vii 81	Kuma	R.T. Masamdu
M7	31 vii 81	Pongai	R.T. Masamdu
M8	5 viii 81	Orlea	R.T. Masamdu
M9	5 viii 81	Pembi	R.T. Masamdu
M10	6 viii 81	Pingrip	R.T. Masamdu
M11	6 viii 81	Paip	R.T. Masamdu
M12	3 xi 81	Karil	R.T. Masamdu & B.M. Thistleton
M13	3 xi 81	Dimifa	R.T. Masamdu & B.M. Thistleton
M14	3 xi 81	Poipa	R.T. Masamdu & B.M. Thistleton
M15	3 xi 81	Was	R.T. Masamdu & B.M. Thistleton
M16	4 xi 81	Bela	R.T. Masamdu & B.M. Thistleton
M17	4 xi 81	Hoai	R.T. Masamdu & B.M. Thistleton
M18	4 xi 81	Abua	R.T. Masamdu & B.M. Thistleton
M19	5 xi 81	Komia	R.T. Masamdu & B.M. Thistleton
M20	5 xi 81	Komia	R.T. Masamdu & B.M. Thistleton
M21	9 xi 81	Dimifa	R.T. Masamdu
M22	9 xi 81	Kendaga	R.T. Masamdu
M23	10 xi 81	Karil	R.T. Masamdu
M24	11 xi 81	Kuma	R.T. Masamdu
M25	11 xi 81	Kuma	R.T. Masamdu
M26	12 xi 81	Komia	R.T. Masamdu
M27	12 xi 81	Birop	R.T. Masamdu
M28	16 xi 81	Egari	R.T. Masamdu
M29	17 xi 81	Bela	R.T. Masamdu
M30	17 xi 81	Hoai	R.T. Masamdu
M31	18 xi 81	Pembi	R.T. Masamdu
M32	18 xi 81	Pingirip	R.T. Masamdu
M33	19 xi 81	Semp	R.T. Masamdu
M34	iv & vi 84	Komia	B.M. Thistleton
M35	iv & vi 84	Birop	B.M. Thistleton
M36	iv & vi 84	Mogul	B.M. Thistleton
M37	iv & vi 84	Kundaga	B.M. Thistleton
M38	iv & vi 84	Kuma	B.M. Thistleton
M39	27 iv 84	Kiburu	B.M. Thistleton

TARI

T1	24 xi 81	Wabia	R.T. Masamdu
T2	24 xi 81	Piagwanda	R.T. Masamdu
T3	24 xi 81	Tigisbi	R.T. Masamdu
T4	25 xi 81	Hiwanda	R.T. Masamdu
T5	25 xi 81	Walete	R.T. Masamdu
T6	25 xi 81	Wololo	R.T. Masamdu
T7	25 xi 81	Halenguali	R.T. Masamdu
T8	26 xi 81	Munima	R.T. Masamdu
T9	26 xi 81	Dauli	R.T. Masamdu
T10	27 xi 81	Urumu	R.T. Masamdu
T11	27 xi 81	Tari High School	R.T. Masamdu
T12	30 xi 81	Paijaka	R.T. Masamdu

T13	30 xi 81	Paijaka	R.T. Masamdu
T14	30 xi 81	Heganda	R.T. Masamdu
T15	30 xi 81	Habare	R.T. Masamdu
T16	1 xii 81	Andowari	R.T. Masamdu
T17	1 xii 81	Itapu	R.T. Masamdu
T18	1 xii 81	Kugu	R.T. Masamdu
T19	2 xii 81	Hoebia	R.T. Masamdu
T20	2 xii 81	Piwa	R.T. Masamdu
T21	9 ii 83	Piwa	B.M. Thistleton
T22	11 ii 83	Piwa	B.M. Thistleton
T23	11 ii 83	Hiwanda	B.M. Thistleton
T24	11 ii 83	Hiwanda	B.M. Thistleton
T25	20 vii 84	Piwa	B.M. Thistleton

PANGIA

P1	20 iv 82	Tagaru	B.M. Thistleton
P2	20 iv 82	Tagaru	B.M. Thistleton
P3	20 iv 82	Tagaru	B.M. Thistleton
P4	20 iv 82	Tagaru	B.M. Thistleton
P5	21 iv 82	Mele	B.M. Thistleton
P6	21 iv 82	Talipiko	B.M. Thistleton
P7	21 iv 82	Apenda	B.M. Thistleton
P8	22 iv 82	Maia	B.M. Thistleton
P9	23 iv 82	Apenda	B.M. Thistleton
P10	23 iv 82	Apenda	B.M. Thistleton
P11	26 & 27 iv 82	Talipiko	B.M. Thistleton
P12	27 iv 82	Talipiko	B.M. Thistleton
P13	27 iv 82	Mele	B.M. Thistleton
P14	28 iv 82	Maia	B.M. Thistleton
P15	29 iv 82	Tagaru	B.M. Thistleton
P16	29 iv 82	Tagaru	B.M. Thistleton
P17	29 iv 82	Tagaru	B.M. Thistleton
P18	1 xii 82	Pomiorine	B.M. Thistleton
P19	1 xii 82	Mele	B.M. Thistleton
P20	1 xii 82	Apenda	B.M. Thistleton

M1 to M11 were Pilot Survey, part 1; M12 to M20, Pilot Survey, part 2; M21 to M33, T1 to T20 & P1 to P17, Main Survey; M34 to M39, T21 to T25 & P18 to P20, follow-up visits.

Where a place name is mentioned more than once for the same date more than one garden was examined at this place. Some of the gardens examined for the Pilot Survey were revisited for the Main Survey.

APPENDIX 6

List of crops examined during the survey with localities (for key to locality numbers see Appendix 5).

Aibika	Mendi	-
Hibiscus manihot	Tari	T4, 5
	Pangia	P7, 10, 12, 14
Amaranthus	Mendi	M21, 32
Amaranthus sp.	Tari	T11, 13
	Pangia	-
Banana	Mendi	M31, 33
Musa sp.	Tari	T4, 6, 7, 10
	Pangia	P1, 5, 8, 17
Bean, common	Mendi	M11, 16, 27, 29, 30, 31, 32, 33
Phaseolus vulgaris	Tari	T2, 3, 5, 6, 7, 9, 12, 17
	Pangia	P2, 10, 14, 17
Bean, lablab	Mendi	-
Dolichos lablab	Tari	-
	Pangia	P10
Bean, rice	Mendi	-
Vigna umbellata	Tari	-
	Pangia	P14
Bean, snake	Mendi	M8, 11
Vigna unguiculata	Tari	T11
	Pangia	-
Bean, soy	Mendi	M1
Glycine max	Tari	T11
	Pangia	-
Cabbage	Mendi	M2, 3, 4, 5, 6, 8, 10, 11, 16, 20, 21, 23, 28, 29, 30, 31, 32, 33
Brassica oleracea	Tari	T1, 5, 7, 11, 12, 13
	Pangia	P1, 5, 12, 14
Cassava	Mendi	M1
Manihot esculenta	Tari	T4, 9
	Pangia	P1, 8, 9, 14
Chinese cabbage	Mendi	-
Brassica chinensis	Tari	T7, 11
	Pangia	-
Ginger	Mendi	-
Zinziber sp.	Tari	T1
	Pangia	-
Loofah	Mendi	M32
Luffa acutangula	Tari	-
	Pangia	-

Lettuce	Mendi	-
<u>Latuca sativa</u>	Tari	-
	Pangia	P3
Maize	Mendi	M1, 3, 4, 6, 10, 23, 27, 28, 29, 30, 32
<u>Zea mays</u>	Tari	T1, 2, 3, 7, 8, 9, 11, 12, 13, 21, 22
	Pangia	P7, 8, 11, 14
Nasturtium	Mendi	M1, 2, 8, 10, 11, 30, 32
<u>Nasturtium officinale</u>	Tari	-
	Pangia	-
Oenanthe	Mendi	-
<u>Oenanthe javanica</u>	Tari	-
	Pangia	P8, 17
Onion	Mendi	M20, 28
<u>Allium cepa</u>	Tari	T4, 7, 11, 12, 13
	Pangia	P1, 14, 17
Pandanus, karuka	Mendi	M2, 3, 4, 11, 18, 19, 21, 23, 25, 26, 27
<u>Pandanus brosimos</u>	Tari	-
& <u>P. julianetti</u>	Pangia	-
Pandanus, marita	Mendi	-
<u>Pandanus conoideus</u>	Tari	T22
	Pangia	P11, 12, 14
Peanut	Mendi	-
<u>Arachis hypogaea</u>	Tari	-
	Pangia	P8
Pigeon pea	Mendi	M1
<u>Cajanus cajan</u>	Tari	-
	Pangia	-
Pineapple	Mendi	-
<u>Ananas comosus</u>	Tari	T9
	Pangia	P7
Pitpit, highland	Mendi	M2, 5, 11, 13, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32
<u>Setaria palmifolia</u>	Tari	T1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 23, 24
	Pangia	P1, 8, 9, 14, 15, 16
Pitpit, lowland	Mendi	-
<u>Saccharum edule</u>	Tari	-
	Pangi	P1, 8, 9
Potato	Mendi	M2, 21, 26, 27, 31
<u>Solanum tuberosum</u>	Tari	T13
	Pangia	-
Pumpkin	Mendi	M30
<u>Cucurbita</u> sp.	Tari	T1, 2, 4, 5, 6, 7, 9, 13, 15, 17
	Pangia	P2, 5, 10, 12, 14, 17

Rungia Rungia klossii	Mendi	M21, 27
	Tari	T4
	Pangia	P1, 8, 9, 10, 16, 17
Sugar cane Saccharum officinarum	Mendi	M1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 16, 17, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 32
	Tari	T1, 2, 3, 4, 5, 6, 7, 9, 10, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24
	Pangia	P1, 2, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17
Sweet potato Ipomoea batatas	Mendi	M1, 2, 3, 5, 6, 9, 10, 11, 12, 13, 15, 16, 17, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 32, 33, 34, 35, 36, 37, 38, 39
	Tari	T1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25
	Pangia	P1, 3, 8, 9, 10, 11, 14, 15, 16
Taro Colocasia esculenta	Mendi	M2, 4, 5, 8, 9, 10, 11, 13, 16, 20, 21, 23, 24, 26, 27, 29, 30, 31, 32
	Tari	T1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23
	Pangia	P1, 5, 7, 8, 10, 11, 12, 14, 17
Taro Xanthosoma sagittifolium	Mendi	-
	Tari	T1, 3, 4, 6, 7, 9, 10, 11, 12, 14, 17, 18, 19, 20
	Pangia	P2, 10, 14, 17
Tomato Lycopersicon esculentum	Mendi	-
	Tari	T5, 6, 7, 11, 12
	Pangia	P8, 17
Turnip Brassica rapa	Mendi	-
	Tari	T11
	Pangia	-

APPENDIX 7

Analysis of counts of Arsipoda tenimberensis Jacoby (Coleoptera:Chrysomelidae) adults on foliage of sweet potato.

A summary of these counts is given in Table 3. Each value presented there is a sum of ten half metre square quadrats.

A nested analysis of variance was performed on the counts per quadrat [$\log_{10}(x+1)$ transformation]. The results were:

	D.F.	S.S.	M.S.	F.	P
Areas	2	3.41	1.71	5.07 (d.f. 2 & 33)	.012 *
Gardens in areas	33	11.10	0.34	5.16 (d.f. 37 & 324)	.000000001 ***
Counts in gardens	324	21.12	0.07		
Total	359	35.64			

There is a significant difference betwee nareas and a very highly significant difference between gardens within areas. Various possible reasons for this are discussed in the main text.

One of the possible causes of variation is difference in altitude between areas and even between gardens within areas. Figure A7-1 shows the shows the values per garden (as tabulated in Table 3, but transformed to $\log_{10}y$) plotted against altitude.

Line A is the regression line for all data (Mendi, Tari and Pangia). The regression equation is:

$$\log_{10}y = 2.715 - .0007x$$

t for deviation of the slope from zero is 4.061 with 34 d.f., $P<0.001$ ***

r is -.563 with 34 d.f., $P<0.001$ ***

There is a very highly significant correlation with altitude, although the regression equation only accounts for 31.7% of the total variation.

Lines B, C and D are for Mendi, Tari and Pangia data respectively. Even though these regressions are not significant it is of interest that as the mean altitude of each area decreases (in the order B, C, D) the slope of the lines decreases.

Considering line A, the value for y at sea level is $\text{antilog}_{10}2.715$, which is 518. This is far higher than data collected by Sutherland (1981) at Laloki (50m) and it is evident that, if indeed there is a relationship with altitude, it is non-linear. Line E is the regression for data from Laloki, Wau (Sutherland 1982) and Kuk. This is a line of positive slope.

It is therefore possible that A. tenimberensis reaches its highest densities at mid-altitudes. A quadratic equation was fitted to the data (line F) and gave a good fit. The regression equation for this line is:

$$\log_{10} y = .958 + .0009x - .00000035x^2$$

F is 6.168 with 2 and 45 d.f., $P<0.01$ **

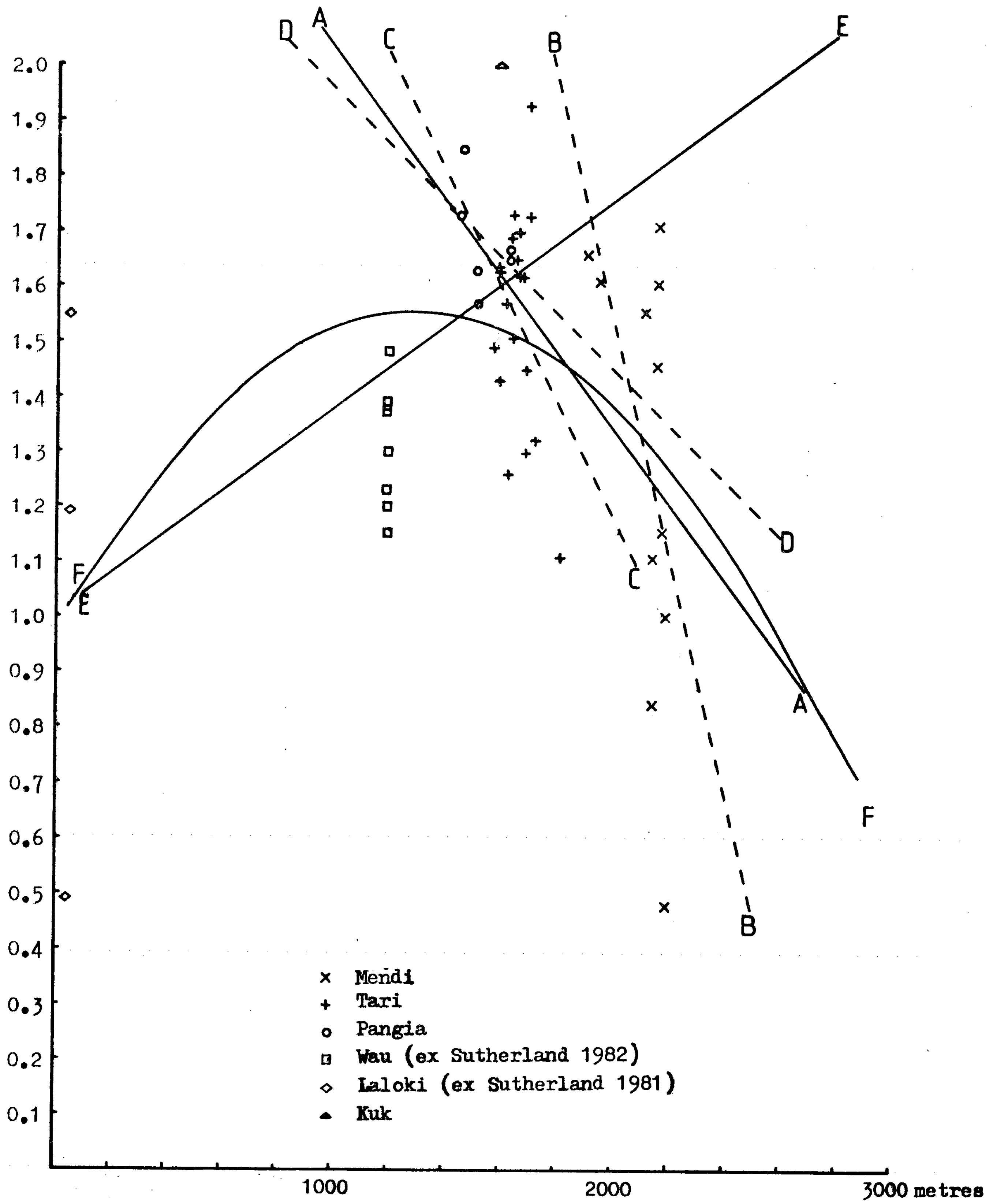
The F value is highly significant, although the equation only accounts for 21.5% of the total variation.

There is obviously much variation in the data from other causes (possible varietal differences, age of crops, etc.). However altitude appears to account for some of the variation although the main effect is probably through some other variable (e.g. temperature) which varies with altitude. These results are presented only as a possible theory at this stage. Much more data, and more rigorous analysis, would be necessary to give more weight to this possibility.

For further analysis of sampling precision for this species see Appendix 9.

Figure A7-1. Plots of numbers of <u>*A. tenimberensis*</u> adults per five square metres of sweet potato foliage (y) and altitude (x). Counts transformed to $\log_{10} y$.

(For explanation of the lines A to F see text, Appendix 7).



APPENDIX 8 List of insect specimens sent to specialists for identification.

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date
KK4882 146 (iv 82) 33257	Mendi, Dimifa, (M13), 3 xi 81, sweet potato	Arsipoda tenimberensis (Jacoby) (Col: Chrysomelidae)	
KK4856 146 (iv 82) 33256	Mendi, Kuma, (M24), 11 xi 81, sweet potato	Arsipoda tenimberensis (Jacoby) (Col: Chrysomelidae)	
KK4907 146 (iv 82) 33253	Mendi, Was, (M15), 3 xi 81, sweet potato	Arsipoda tenimberensis (Jacoby) (Col: Chrysomelidae)	
KK4947 147 (iv 82) 33260	Tari, Tigisbi, (T3), 24 xi 81, pitpit	Chilo sp. (Lep: Pyralidae)	Chilo sp. (Lep: Pyralidae) det. J.D. Bradley 13 vii 82
KK4946 147 (iv 82) 33261	Tari, Tigisbi, (T3), 24 xi 81, sugar cane	(Lepidoptera)	Trachycentra chlorogramma Meyrick (Lep: Tineidae) det. J.D. Bradley 13 vii 82
KK4958 148 (iv 82) 33351	Mendi, Birop, (M27), 12 xi 81, sweet potato	Cassid sp. 4 Cassida sp. ?diomma (Col: Chrysomelidae)	Cassida sp. ?diomma Boisduval (Col: Chrysomelidae) det. T.G. Vazirani 27 vii 82
KK4982 148 (iv 82) 33352	Tari, Tigisbi, (T3), 24 xi 81, sweet potato	Cassid sp. 1 (Col: Chrysomelidae)	Laccoptera impressa (Blanchard) (Col: Chrysomelidae) det. T.G. Vazirani 27 vii 82

* Kuk specimen no., Kuk identification sheet no. & date sent (month and year), Konedobu (Central Reference Collection) no.

** Identification prior to sending specimen(s).

++ Identification from specialist, name of specialist & date of memorandum from Konedobu with identification (file 8-4-3(5)).

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date
KK5046 151 (vi 82)	Pangia, Apenda, (P10), 23 iv 82, taro	Dermaptera sp. 2 (Dermaptera)	
KK5047 151 (vi 82)	Pangia, Apenda, (P10), 23 iv 82, sugar cane	Dermaptera sp. 2 (Dermaptera)	
KK5048 151 (vi 82)	Pangia, Talipiko, (P12), 27 iv 82, sugar cane	Dermaptera sp. 2 (Dermaptera)	
KK5049 152 (vi 82)	Pangia, Mele, (P5), 21 iv 82, sugar cane	Dermaptera sp. 1 ?Chelisoches morio (Dermaptera)	
KK5050 152 (vi 82)	Pangia, Maia, (P8), 22 iv 82, maize	Dermaptera sp. 1 ?Chelisoches morio (Dermaptera)	
KK5051 152 (vi 82)	Pangia, Maia, (P8), 22 iv 82, maize	?Dermaptera sp. 1 ?Chelisoches morio (Dermaptera)	
KK5052 152 (vi 82)	Pangia, Maia, (P8), 22 iv 82, maize	Dermaptera sp. 3 (Dermaptera)	
KK5053 152 (vi 82)	Pangia, Tagaru, (P2), 20 iv 82, sweet potato	Dermaptera sp. 4 (Dermaptera)	
KK5054 152 (vi 82)	Pangia, Talipiko, (P6), 21 iv 82, sugar cane	Dermaptera sp. 4 (Dermaptera)	
KK4919 152 (vi 82)	Mendi, Hoai, (M17), 4 xi 81, sugar cane	Dermaptera sp. 6 (Dermaptera)	
KK5055 153 (vi 82) 33458-61	Pangia, Appenda, (P9), 23 iv 82, sweet potato	(Hem: Pentatomidae)	Antestiopis chambereti Le Guillon (Hem: Pentatomidae) det. M.S.K. Ghauri 4 v 83

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date
KK4921 153 (vi 82) 33462-69	Mendi, Hoai, (M17), 4 ix 81, sugar cane	Delphacid sp. 1 (Hem: Delphacidae)	Eumetopina flavipes Muir (Hem: Delphacidae) det. M.R. Wilson 7 i 83
KK4890 153 (vi 82) 33470-74	Mendi, Dimifa, (M13), 3 ix 81, sugar cane	Delphacid sp. 2 (Hem: Delphacidae)	Perkinsiella diagoras Fennah (Hem: Delphacidae) det. M.R. Wilson 7 i 83
KK4928 153 (vi 82) 33475	Mendi, Komia, (M20), 5 ix 81, sugar cane	Delphacid sp. 3 (Hem: Delphacidae)	Sogata sp. (Hem: Delphacidae) det. M.R. Wilson 7 i 83
KK5056 153 (vi 82) 33476	Pangia, Mele, (P5), 21 iv 82, sugar cane	(Hemiptera)	Swezeyia sp. (Hem: Derbidae) det. M.R. Wilson 7 i 83
KK4881 153 (vi 82) 33477	Mendi, Dimifa, (M13), 3 xi 81, sweet potato	Cicadellid sp. 1 (Hem: Cicadellidae)	Baclutha sp. (Hem: Cicadellidae) det. M.S.K. Ghauri 4 v 83
KK4881 153 (vi 82) 33478-79	Mendi, Dimifa, (M13), 3 xi 81, sweet potato	Cicadellid sp. 1 (Hem: Cicadellidae)	Zygina medioborealis Ghauri (Hem: Cicadellidae) det. M.S.K. Ghauri 4 v 83
KK4881 153 (vi 82) 33480-82	Mendi, Dimifa, (M13), 3 xi 81, sweet potato	Cicadellid sp. 1 (Hem: Cicadellidae)	Zygina sp. sensu lato (Hem: Cicadellidae) det. M.S.K. Ghauri 30 iv 83
KK4881 153 (vi 82) 33483-84	Mendi, Dimifa, (M13), 3 xi 81, sweet potato	Cicadellid sp. 1 (Hem: Cicadellidae)	Baclutha sp. (Hem: Cicadellidae) det. M.S.K. Ghauri 30 iv 83

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date
KK4915 153 (vi 82) 33485	Mendi, Bela, (M16), 4 xi 81, taro	Cicadellid sp. 2 (Hem: Cicadellidae)	Cicadella sp. sensu lato (Hem: Cicadellidae) det. M.S.K. Ghauri 30 iv 83
KK5057 154 (vi 82) 33486	Pangia, Mele, (P5), 21 iv 82, sugar cane	Cicadellid sp. 2 (Hem: Cicadellidae)	Cicadella sp. sensu lato (Hem: Cicadellidae) det. M.S.K. Ghauri 30 iv 83
KK5058 154 (vi 82) 33487	Pangia, Tagaru, (P2), 20 iv 82, sweet potato	Cicadellid sp. 3 (Hem: Cicadellidae)	Cicadella wallacei Distant (Hem: Cicadellidae) det. M.S.K. Ghauri 30 iv 83
KK5059 154 (vi 82) 33488	Pangia, Tagaru, (P4), 20 iv 82, sweet potato	Cicadellid sp. 3 (Hem: Cicadellidae)	Cicadella wallacei Distant (Hem: Cicadellidae) det. M.S.K. Ghauri 30 iv 83
KK5060 154 (vi 82) 33489	Pangia, Maia, (P8), 22 iv 82, sweet potato	Cicadellid sp. 3 (Hem: Cicadellidae)	Cicadella wallacei Distant (Hem: Cicadellidae) det. M.S.K. Ghauri 30 iv 83
KK5061 154 (vi 82) 33490-92 &33494	Pangia, Maia, (P8), 22 iv 82, sweet potato	Cicadellid sp. 4 (Hem: Cicadellidae)	Gen. et sp. indet. (Hem: Cicadellidae) det. M.S.K. Ghauri 30 iv 83
KK5061 154 (vi 82) 33495	Pangia, Maia, (P8), 22 iv 82, sweet potato	Cicadellid sp. 4 (Hem: Cicadellidae)	Genus near Orosius (Hem: Cicadellidae) det. M.S.K. Ghauri 30 iv 83
KK4859 154 (vi 82) 33496	Mendi, Karil, (M12), 3 xi 81, sweet potato	Cicadellid sp. 5 (Hem: Cicadellidae)	Cicadella sp. sensu lato (Hem: Cicadellidae) det. M.S.K. Ghauri 30 iv 83

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date
KK5062 154 (vi 82) 33497	Pangia, Tagaru, (P15), 29 iv 82, sweet potato	Cicadellid sp. 6 (Hem: Cicadellidae)	(Specimen lost in transit) (Hem: Cicadellidae)
KK5063 155 (vi 82) 33384-85	Pangia, Tagaru, (P2), 20 iv 82, sweet potato	Cicadellid sp. 7 (Hem: Cicadellidae)	_Cicadella_ sp. _sensu lato_ (Hem: Cicadellidae) det. M.S.K. Ghauri 30 iv 83
KK5064 155 (vi 82) 33386-87	Pangia, Tagaru, (P4), 20 iv 82, grassy area	Cicadellid sp. 8 (Hem: Cicadellidae)	_Zygina_ sp. _sensu lato_ (Hem: Cicadellidae) det. M.S.K. Ghauri 30 iv 83
KK5065 155 (vi 82) 33388-89	Pangia, Tagaru, (P4), 20 iv 82, grassy area	(Hemiptera)	_Phaenacantha distincta_ (Distant) (Hem: Colobathristidae det. M.S.K. Ghauri 30 iv 83
KK4923 155 (vi 82) 33393-94	Mendi, Hoai, (M17), 4 xi 81, sugar cane	_?Cytorhinus_ sp. (Hem: Miridae)	_Tyttus mundulus_ Breddin (Hem: Miridae) det. M.R. Wilson 7 i 83
KK4932 155 (vi 82) 33395-97	Mendi, Komia, (M20), 5 xi 81, sugar cane	_?Cytorhinus_ sp. (Hem: Miridae)	_Tyttus mundulus_ Breddin (Hem: Miridae) det. M.R. Wilson 7 i 83
KK5072 156 (vi 82) 33403-08	Pangia, Apenda, (P10), 23 iv 82, sweet potato	Cassid sp. 2 (Col: Chrysomelidae)	_Aspidomorpha ?punctum_ (Fabricius) (Col: Chrysomelidae) det. M.L. Cox
KK5073 156 (vi 82) 33409-11	Pangia, Apenda, (P10), 23 iv 82, sweet potato	Cassid sp. 3 (Col: Chrysomelidae)	_Aspidomorpha australasiae_ Boisduval (Col: Chrysomelidae) det. M.L. Cox

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date
KK5074 156 (vi 82) 33412-13	Pangia, Maia, (P8), 22 iv 82, sweet potato	Cassid sp. 4 Cassida sp. ?diomma (Col: Chrysomelidae)	Cassida diomma Boisduval (Col: Chrysomelidae) det. M.L. Cox
KK5075 156 (vi 82) 33414-15	Pangia, Tagaru, (P2), 20 iv 82, sweet potato	(Coleoptera)	Sphaerarthrum sp. (Col: Cantharidae) det. R. Madge
KK5076 156 (vi 82) 33416-18	Pangia, Maia, (P8), 22 iv 82, maize	(Coleoptera)	Brachypeplus sp. (Col: Nitidulidae) det. R. Madge
KK5077 156 (vi 82) 33419-20	Pangia, Talipiko, (P6), 21 iv 82, sugar cane	(Col: Curculionidae)	Laogenia geminata Faust (Col: Curculionidae) det. M.L. Cox
KK5078 156 (vi 82) 33421-23	Pangia, Apenda, (P10), 23 iv 82, aibika	(Col: Chrysomelidae)	Rhyparidella sobrina Bryant (Col: Chrysomelidae) det. M.L. Cox
KK4873 157 (vi 82) 33440-41	Mendi, Karil, (M12), 3 xi 81, sugar cane	Elaterid sp. 1 (Col: Elateridae)	Agrypnus sp. (Col: Elateridae) det. C.M.F. von Hayek 17 i 83
KK4936 157 (vi 82) 33442	Mendi, Komia, (M20), 5 xi 81, sugar cane	Elaterid sp. 2 (Col: Elateridae)	Hapatesus tropicus Neboiss (Col: Elateridae) det. C.M.F. von Hayek 17 i 83
KK4872 157 (vi 82) 33443	Mendi, Karil, (M12), 3 xi 81, sugar cane	Elaterid sp. 2 (Col: Elateridae)	Hapatesus tropicus Neboiss (Col: Elateridae) det. C.M.F. von Hayek 17 i 83

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date
KK5083 157 (vi 82) 33444-46	Pangia, Maia, (P8), 22 iv 82, maize	(Coleoptera)	Anadastus sp. (Col: Languriidae) det. R. Madge 17 i 83
KK4734 158 (vi 82) 33430	Mendi, Kiburu, (M1), 28 vii 81, maize	(Orth: Acridoidea)	Oxya japonica vitticollis Blanchard (Orth: Acridoidea) det. N.D. Jago 24 iii 83
KK4738 158 (vi 82) 33431-32	Mendi, Birop, (M2), 29 vii 81, sugar cane	?Atractomorpha sp. (Orth: Acridoidea)	Atractomorpha crenaticeps Blanchard (Orth: Acridoidea) det. N.D. Jago 24 iii 83
KK4893 158 (vi 82) 33433	Mendi, Dimifa, (M13), 3 xi 81, sugar cane	?Atractomorpha sp. (Orth: Acridoidea)	Atractomorpha crenaticeps Blanchard (Orth: Acridoidea) det. N.D. Jago 24 iii 83
KK5084 158 (vi 82) 33434	Pangia, Maia, (P8), 22 iv 82	(Orth: Tettigoniidae	Pseudorhynchus cornutus Redtenbacher (Orth: Tettigoniidae) det. J.A. Marshall 24 iii 83
KK5128 163 (x 82) 33749	Pangia, Appenda (P7), 21 iv 82, sugar cane	(Hem: Pseudococcidae)	Trionymus sp. (1) (Hem: Pseudococcidae) det. D.J. Williams 29 iv 83
KK5129 163 (x 82) 33750	Pangia, Appenda (P9), 23 iv 82, sugar cane	(Hem: Pseudococcidae)	Trionymus sp. (1) (Hem: Pseudococcidae) det. D.J. Williams 29 iv 83
KK5133 163 (x 82) 33750	Pangia, Mele, (P13), 27 iv 82, sugar cane	(Hem: Pseudococcidae)	Trionymus sp. (1) (Hem: Pseudococcidae) det. D.J. Williams 29 iv 83

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date
KK5132 163 (x 82) 33751	Pangia, Apenda, (P9), 23 iv 82, sugar cane	(Hem: Pseudococcidae)	Trionymus sp. (2) (Hem: Pseudococcidae) det. D.J. Williams 29 iv 83
KK5136 164 (x 82) 33845	Pangia, Appenda, (P9), 23 iv 82, sugar cane	(Hym: Formicidae)	Tapinoma melanocephalum (F.) (Hym: Formicidae) det. B. Bolton 22 vi 83
KK5135 164 (x 82) 33844	Pangia, Maia, (P8), 22 iv 82, sugar cane	(Hym: Formicidae)	Iridomyrmex sp. ?glaber (Mayr) (Hym: Formicidae) det. B. Bolton 22 vi 83
KK5137 164 (x 82) 33846	Pangia, Apenda, (P9), 23 iv 82, sugar cane	(Hym: Formicidae)	Iridomyrmex cordatus (Smith) or sp. nr. (Hym: Formicidae) det. B. Bolton 22 vi 83
KK5138 164 (x 82) 33847	Pangia, Apenda, (P9), 23 iv 82, sugar cane	(Hym: Formicidae)	Iridomyrmex cordatus (Smith) or sp. nr. (Hym: Formicidae) det. B. Bolton 22 vi 83
KK5141 164 (x 82) 33849	Pangia, Talipiko, (P11), 27 iv 82, sugar cane	(Hym: Formicidae)	Iridomyrmex cordatus (Smith) or sp. nr. (Hym: Formicidae) det. B. Bolton 22 vi 83
KK5142 165 (x 82) 33850	Pangia, Talipiko, (P11), 27 iv 82, sugar cane	(Hym: Formicidae)	Iridomyrmex cordatus (Smith) or sp. nr. (Hym: Formicidae) det. B. Bolton 22 vi 83
KK5143 165 (x 82) 33851	Pangia, Talipiko, (P11), 27 iv 82, sugar cane	(Hym: Formicidae)	Iridomyrmex cordatus (Smith) or sp. nr. (Hym: Formicidae) det. B. Bolton 22 vi 83

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date
KK5146 165 (x 82) 33854	Pangia, Mele, (P13), 27 iv 82, sugar cane	(Hym: Formicidae)	Iridomyrmex cordatus (Smith) or sp. nr. (Hym: Formicidae) det. B. Bolton 22 vi 83
KK5144 165 (x 82) 33852	Pangia, Talipiko, (P12), 27 iv 82, sugar cane	(Hym: Formicidae)	Iridomyrmex sp. (Hym: Formicidae) det. B. Bolton 22 vi 83
KK5140 164 (x 82) 33848	Pangia, Talipiko, (P11), 26 iv 82, sweet potato	(Hym: Formicidae)	Leptomyrmex melanoticus Wheeler (Hym: Formicidae) det. B. Bolton 22 vi 83
KK5145 165 (x 82) 33853	Pangia, Talipiko, (P12), 27 iv 82, sugar cane	(Hym: Formicidae)	Tetramorium bicarinatum (Nylander) (Hym: Formicidae) det. B. Bolton 22 vi 83
KK5147 165 (x 82) 33855	Pangia, Tagaru, (P17), 29 iv 82, sugar cane	(Hym: Formicidae)	Technomymex albipes (Smith) (Hym: Formicidae) det. B. Bolton 22 vi 83
KK5158 169 (x 82) 33744	Pangia, Tagaru, (P17), 29 iv 82, banana	(Thysanoptera)	
KK5127 171 (x 82) 33761	Pangia, Tagaru, (P6), 20 iv 82, sugar cane	(Hem: Aphididae)	Ceratovacuna lanigera (Zehntner) (Hem: Aphididae) det. J.H. Martin 29 vi 83
KK5134 171 (x 82) 33762	Pangia, Mele, (P13), 27 iv 82, sugar cane	(Hem: Aphididae)	Ceratovacuna lanigera (Zehntner) (Hem: Aphididae) det. J.H. Martin 29 vi 83

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date
KK5452 177 (iii 84)	Mendi, 2 iii 84 sweet potato	Eriophyid mite (Acarina: Prostigmata Eriophyoidea)	
KK5424 178 (v 84)	Kuk A.R.S., 5 ix 83, sweet potato	?Acrocercops sp. (Lep: Gracillariidae)	Acrocercops homalacta Meyrick (Lep: Gracillariidae) det. J.D. Bradley 17 viii 84

The following are a range of Aulacophora specimens from various localities, see text:

1. All black, A. ?melanopus.

KK5475 179 (viii 84) 35359-60	Pangia, Tagaru, 20 iv 82, pumpkin	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84

2. Like A. ?melanopus, but with small orange-yellow triangle on elytra.

KK5476 179 (viii 84) 35361	Pangia, Tagaru, 20 iv 82, pumpkin	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84

3. Like A. ?melanopus, but with small orange-yellow triangle on sides of elytra. Approaching A. ?albofasciatus.

KK5479 179 (viii 84) 35362	Aiyura, 24 vi 76	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84

4. A. ?albofasciata. Orange-yellow band constricted at sides of elytra.

KK5480 179 (viii 84) 35363	Aiyura, 11 v 76, zucchini	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84

5. A. ?albofasciata. Black/orange-yellow/black bands on elytra.

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date
KK5477 179 (viii 84) 35364	Pangia, Tagaru, 20 iv 82, pumpkin	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84
KK1752 179 (viii 84) 35365-66	Kuk A.R.S., 4 vii 78, common bean	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84
KK5481 179 (viii 84) 35367	Aiyura, 11 v 76, zucchini	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84
KK4707 180 (viii 84) 35368	Maprik, 16 vii 81	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?quadrimaculata (F.) (Col: Chrysomelidae) det. M.L. Cox 12 xi 84

6. A. ?albofasciata. Black/orange-yellow/black bands on elytra, with slight touch of orange-yellow on tips of elytra.

KK5478 180 (viii 84) 35369	Kuk A.R.S., 19 ix 73, pumpkin	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84
KK2 180 (viii 84) 35370	Minj, 11 xii 75, pumpkin	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84

7. A. ?albofasciata. Black/orange-yellow/black bands on elytra, with black on tips of elytra broken with orange-yellow.

KK2a 180 (viii 84) 35371	Minj, 11 xii 75, pumpkin	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date

8. A. ?albofasciata. Black/orange-yellow/black bands on elytra, with only small black dots on outer posterior edges of elytra.

KK5482 180 (viii 84) 35372	Aiyura, 24 vi 76	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84
KK5483 180 (viii 84) 35373	Henganofi, 6 ii 77	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84
KK5484 180 (viii 84) 35374	Aiyura, 11 v 76	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84
KK1688 181 (viii 84) 35375	Mt Hagen, 9 vi 78, pumkin	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84

9. A. ?albofasciata. Black/orange-yellow/black bands on elytra, with only very small black dots on outer posterior edges of elytra, spots at bases of elytra very much reduced.

KK5485 181 (viii 84) 35376	Aiyura, 24 vi 76	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora ?pygidialis Baly (Col: Chrysomelidae) det. M.L. Cox 12 xi 84

10. A. ?sp. nr. abdomalis/A. ?similis/A. wallacei. Orange-yellow all over.

KK80a 181 (viii 84) 35377	Kuk A.R.S., 16 xii 75, cucumber	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora sp. A (Col: Chrysomelidae) det. M.L. Cox 12 xi 84
KK5486 181 (viii 84) 35378	Aiyura, 5 v 76, mung bean	Aulacophora sp. (Col: Chrysomelidae)	Aulacophora sp. A (Col: Chrysomelidae) det. M.L. Cox 12 xi 84

*Ref. nos.	Locality, date & crop	**Provisional identification	++Confirmed identification, specialist & date
KK4983 181 (viii 84) 35379	Tari, Halenguali, 25 xi 81, pumpkin	<u>Aulacophora</u> sp. (Col: Chrysomelidae)	<u>Aulacophora</u> sp. B (Col: Chrysomelidae) det. M.L. Cox 12 xi 84
KK4710 181 (viii 84) 35380	Maprik, 16 vii 81	<u>Aulacophora</u> sp. (Col: Chrysomelidae)	<u>Aulacophora</u> sp. A (Col: Chrysomelidae) det. M.L. Cox 12 xi 84
KK5172 181 (viii 84) 35381	Lae, 20 viii 82	<u>Aulacophora</u> sp. (Col: Chrysomelidae)	<u>Aulacophora</u> sp. A (Col: Chrysomelidae) det. M.L. Cox 12 xi 84

APPENDIX 9

Some constraints to the use of quadrats for counts of foliage insects on sweet potato.

When carrying out the counts of foliage insects on sweet potato, some problems with this method became apparent. While these are not insurmountable, they should be borne in mind if this technique is used for further studies.

The main problem was the mobility of some of the insects concerned. This was particularly a problem with the leaf hoppers (Hem: Cicadelidae) and flea beetles (Col: Chrysomelidae) which tended to move about through the quadrat as they were counted, and would also move into or out of the quadrat. When populations of these insects were high this made accurate counting very difficult. Also a problem was the many layers of leaves of the plant which needed to be inspected. As these were moved there was yet more disturbance to the mobile insects.

These factors seemed to vary with the weather conditions at the time of the count. In hot, sunny weather the insects tended to be more active increasing the movement through the quadrat. In dull, overcast weather many of the insects tended to hide beneath the leaves. This was not always the case however; Helopeltis clavifer tended to be present on the foliage more often in dull weather, sheltering under the leaves when it became hot and the humidity dropped.

Obviously for relatively static insects, such as the larvae of Lepidoptera, these problems did not exist, and one was able to move foliage at will when searching for these. The technique developed was therefore to count the mobile insects first, as soon as the quadrat was laid down, and then to return to the less mobile insects later.

The following variables probably also affected the counts:

1. Variety of sweet potato, usually mixed, but different combinations in different gardens, or different varieties in different areas.

2. Plant density and plant size, both of which affect the area of actual plant surface which is sampled.

3. Plant age which may affect its suitability as food for the different species of insects.

4 Time of year, in relation to climatic factors and their effects on insect populations.

5. Weather at time of count, as discussed above.

Another constraint, common to much sampling of insects, not just to this particular case, is the large number of samples which it is necessary to take to obtain a reasonably accurate estimate of the population mean. This is often due to the fact that many insect populations are aggregated, rather than randomly or regularly dispersed. Various indices of dispersion have been devised to compare the different patterns of dispersion in populations, and these are summarised by Greig-Smith (1964), Southwood (1978) and Elliott (1977). Many of these are based on the variance to mean ratio, and nearly all are strongly influenced by the number of individuals in the sample. These can therefore only be used as comparative indices of dispersion when the sum, mean and number are the same in each sample (Elliott 1977).

One index which is not influenced by the total number of individuals is Morisita's index of dispersion (Morisita 1959, 1962, 1964). This index is independent of sample mean and sum, but is strongly influenced by the number of sampling units. It is therefore a useful comparative index when the number of sampling units is the same in each sample.

The formula for the calculation of Morisita's index is:

$$I_{\delta} = n \frac{\Sigma(x^2) - \Sigma x}{(\Sigma x)^2 - \Sigma x}$$

For random distribution patterns this is equal to unity, and aggregated populations have values greater than unity. Departures from randomness can be tested by chi-squared using the formula:

$$\text{Chi-squared} = I_{\delta}(\Sigma x - 1) + n - \Sigma x \text{, for } n-1 \text{ degrees of freedom.}$$

The number of samples necessary to obtain a given degree of precision can also be calculated from data obtained in preliminary sampling.. Formulae are given by several workers (Church 1971; Elliott 1977; Southwood 1978) but all are based on similar computations. The formula given by Elliott is:

$$n = \frac{s^2}{D^2 \bar{x}^2}$$

where D is the degree of precision required in terms of relationship of standard error to arithmetic mean. For example if we can tolerate a standard error of 20% of the mean a value of D = 0.2 would be used in the above equation.

Different degrees of precision are recommended by different authors and for different purposes. Southwood (1978) recommends SE of 5% of the mean (95% confidence limits of 10%), Church (1971) an SE of 10% of the mean and Elliott (1977) an SE of 20% of the mean.

Table A9-1 gives values of various statistics calculated for Arsipoda tenimberensis in each garden sampled. The values are based on ten half square metre quadrats per garden. Morisita's index shows a great range in the degree of aggregation from garden to garden, and this is reflected in the number of samples required for a given degree of precision.

The degree of precision chosen will obviously depend on the objects of any further sampling. For example if it is desired to merely compare the populations between the different areas and if these differences are expected to be reasonably large, a standard error of 20% of the mean may be adequate. If on the other hand one wants to detect small differences between gardens within an area a much higher degree of precision (e.g. SE of 5% of mean) may be required. The importance of the information has also to be weighed against the cost in time of obtaining it.

This analysis is given as an example of the sort of preliminary analysis required before more detailed sampling can be undertaken. Data gained on this survey or from further preliminary sampling should be analysed on these lines before more detailed studies are planned. These aspects are discussed in more detail by Church (1971), Elliott (1977) and Southwood (1978).

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TABLE A9-1 Totals, means, standard deviations, variances, Morisita's index of dispersion (I_δ) and chi squared values for deviation of this from unity, and numbers of samples necessary to obtain standard errors of five, ten and twenty percent of the mean for Arsipoda tenimberensis counts of adults on sweet potato foliage in the Mendi, Tari and Pangia areas, ten half square metre quadrats per garden.

	x	$\bar{x}$	s	s^2	I_δ	chi^2	sig	n5%	n10%	n20%
M21	14	1.4	1.96	3.82	2.20	24.57	**	780	195	49
M22	3	0.3	0.48	0.23	0	7.00	NS	1037	259	65
M23	10	1.0	2.83	8.00	8.00	72.00	***	3200	800	200
M24	13	1.3	1.16	1.34	1.03	9.31	NS	318	80	20
M25	29	2.9	3.28	10.77	1.87	33.41	***	512	128	32
M26	7	0.7	1.64	2.68	5.24	34.43	***	2185	546	136
M27	51	5.1	3.70	13.66	1.30	24.10	**	210	53	13
M28	41	4.1	1.85	3.43	0.96	7.54	NS	82	20	5
M29	41	4.1	3.51	12.32	1.45	27.05	**	293	72	18
M31	36	3.6	1.84	3.38	0.98	8.44	NS	104	26	7
M33	46	4.6	2.22	4.93	1.01	9.65	NS	93	23	6
T1	31	3.1	1.97	3.88	1.08	11.26	NS	161	40	10
T2	18	1.8	1.32	1.73	0.98	8.67	NS	214	53	13
T3	54	5.4	1.84	3.38	0.94	5.63	NS	46	12	3
T4	49	4.9	1.73	3.00	0.93	5.49	NS	50	12	3
T5	54	5.4	2.76	7.60	1.07	12.67	NS	104	26	7
T6	42	4.2	2.66	7.07	1.15	15.14	NS	160	40	10
T7	42	4.2	2.90	8.40	1.22	18.00	*	190	48	12
T8	28	2.8	1.40	1.96	0.90	6.29	NS	100	25	6
T9	43	4.3	2.50	6.23	1.10	13.05	NS	135	34	8
T10	27	2.7	2.67	7.12	1.57	23.74	**	391	98	24
T12	13	1.3	0.95	0.90	0.77	6.23	NS	213	53	13
T13	45	4.5	2.80	7.83	1.15	15.67	NS	155	39	10
T14	20	2.0	1.05	1.11	0.79	5.00	NS	111	28	7
T15	86	8.6	2.17	4.71	0.95	4.93	NS	25	6	2
T16	21	2.1	1.91	3.66	1.33	15.67	NS	332	83	21
T17	32	3.2	2.04	4.18	1.09	11.75	NS	163	41	10
T18	38	3.8	2.49	6.18	1.15	14.63	NS	171	43	11
T19	50	5.0	3.20	10.22	1.19	18.40	*	164	41	10
T20	44	4.4	2.99	8.93	1.22	18.27	*	185	46	12
P8	70	7.0	4.62	21.33	1.27	27.43	**	174	44	11
P9	54	5.4	4.45	19.82	1.45	33.04	***	272	68	17
P11	45	4.5	5.06	25.61	1.96	51.22	***	506	126	32
P11	47	4.7	3.40	11.57	1.29	22.15	**	209	52	13
P15	43	4.3	2.06	4.23	1.00	8.86	NS	92	23	6
P16	37	3.7	2.79	7.79	1.28	18.95	*	228	57	14
M(tot)	291	2.6	2.85	8.12	-	-	-	464	116	29
T(tot)	737	3.9	2.72	7.40	-	-	-	197	49	12
P(tot)	296	4.9	3.86	14.91	-	-	-	245	61	15
TOTAL	1324	3.68	3.07	9.42	-	-	-	279	70	17

NS Not significant * P = 0.05
** P = 0.01 *** P = 0.001