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An insect, agronomic and sociological survey of groundnut fields in southern Africa[1]

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Abstract

An intensive survey of the insects in groundnut fields in Malawi, Zambia and Zimbabwe was carried out in the 1986–1987 production season. Less intensive surveys were also made in Tanzania and Botswana. Agronomic and socio-economic details of approximately 100 farms were collected simultaneously. The insect survey concentrated on soil insects. White grubs (scarabaeid larvae) were the predominant taxon and were likely to be causing considerable reductions in crop yield. About 40 species of the former were collected. They were followed in order of importance by termites. Pod borers (elaterids, tenebrionids, doryline ants and millipedes) were generally present but rarely at sufficient densities to warrant concern. *Hilda patruelis* was encountered in high densities when crops had been sown too early. White grubs were most likely to be encountered in areas of intensive agriculture, where rainfall exceeded 1000 mm year^{-1} and where soils were sandy or loamy. Termite damage was associated with drought, mainly at the end of the growing season. It was especially severe in Botswana. Insect pest management options should be restricted to high risk areas. Insecticides should be applied only to the preceding maize crop because of the risk of seed-oil contamination. Experimentation on other management options for the soil insects may demonstrate the benefits of fallowing and growing economically viable cleansing crops. Foliage feeders were apparently of no economic importance except where insecticides had been applied (entirely a research station activity). *Aphis craccivora*, the vector of groundnut rosette virus (GRV), was apparently controlled by natural processes. The low incidence of GRV in the region may be caused by early (and synchronous) sowing. The economic survey indicated that groundnut crops generated cash to a level that would enable farmers to purchase the inputs needed to give future groundnut crops a considerable boost in yield.

Keywords: Africa, South; *Arachis hypogaea*; Insect pest

1. Introduction

Groundnut (*Arachis hypogaea*) has long been grown in southern Africa because of its food value and free entry into domestic and international markets. It is usually grown as a sole crop in rotation with maize (the staple), tobacco, cotton and sweet potato. It often shares fields with Bambara groundnut (*Vigna subterranea*). The average productivity of 0.6–0.7 t dry pods ha^{-1} is well below what can be achieved on research farms (2.0 t ha^{-1}).

A survey of groundnut fields in Malawi during

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March 1986 revealed plants dying for no obvious reason (Wightman, 1986a). Inspection of their roots and the surrounding soil revealed white grubs (scarabaeid larvae) at a density of more than one per plant. This posed the question: were these large (5 cm long, 3 g) insects responsible for the death of the plants, reducing yields by eating roots and/or pods, or were they just part of the soil fauna? Because Feakin (1973) and Smith and Barfield (1982) have reported that this taxon has pest status in African groundnut fields it was decided that a more intensive study of the groundnut fauna, especially the soil fauna, was required. The objective of the survey was to determine whether insects contributed to the large yield gap characteristic of groundnut production by resource poor farmers of southern Africa. Previous general reports of groundnut pests in the region were country specific, reflected conditions 20 or more years ago and were of a general nature (Jepson, 1948; Rose, 1962; Broad, 1966).

The insect survey was put into context by carrying out a simultaneous interrogation of the farmers to learn about their perceptions of the biological constraints to groundnut production. The farmer survey also revealed details of the farms, the farming systems, and the economics of the groundnut enterprise in the region. Economic data were collected to find out whether groundnut generated sufficient cash to allow the purchase of inputs needed to improve groundnut productivity. Such inputs might include pesticides if the insect and farm surveys indicate that they could be beneficial. This multidisciplinary approach to understanding agricultural production problems has subsequently been endorsed by Lana (1992) as a requisite for the region.

Because the time available was restricted (December 1986 to April 1987) and the land mass large, activities were limited to surveying an arbitrary 100 fields and developing loss assessment techniques that could be adopted by National Program Scientists (Wightman, 1988, 1989; Logan et al., 1992). The latter were carried out to ensure that appropriate research technology was available in the region, should soil insects be of economic importance to groundnut farmers in southern Africa.

The information was collected in one season and from specific sites in contrasting production environments. The authors therefore do not draw firm conclusions about insect densities. Instead, the hitherto undetected diversity and biomass of the fauna is stressed. Several hypotheses are constructed as the preliminary stage of a detailed consideration of how an important production constraint can be overcome.

2. Materials and methods

Farm visits usually coincided with the late vegetative stage of the groundnut crops. Fields were often well separated and remote from a base. As a minimum of 1 h was spent in each only three to seven could be assessed in a day. The survey team included a minimum of one national program representative (NPR), either from a research or an extension branch. The farmers were selected by the NPRs. The survey engendered intense interest among officials and farmers so that the number of helpers tended to increase during a day. The NPR(s) interviewed the farmers to obtain background data following a proforma.

The size of the field was measured. The plant density and the general state of the crop (in terms of insect damage, foliar disease incidence, the number of virus loci and harvester termite activity) were also noted. Twenty plants per field were selected at random by taking the plant hit by, or closest to, a hat or trowel thrown over the shoulder. Insects living on the foliage were noted. The plants were dug up and the roots and pods examined for insect damage. The soil in a 30 cm cube centred on where each plant had been growing was then searched for insects.

A representative (qualitative) collection of the insects was made from each location, care being taken to include all the species located. Taxonomists of the CAB International Institute of Entomology and the British Museum of Natural History, London identified the specimens and retained samples.

3. Results

3.1. The sampling sites

The localities visited (Table 1) were spread in an arc across southern Africa (Fig. 1). Observations were also made at several research stations (Wightman, 1988, 1989). The soils in the survey areas were mainly red (ferruginous) or sandy loams. The mean annual rainfall was 600–1200 mm extending over a 3–6 month period. The exception was the Phalombe-Mulanje area of southern Malawi where rainfall averages 1800 mm. In 1986 in Malawi, the main ('planting') rains came late on 6 December. It was noticeable that in this country there was a high degree of synchrony of sowing, most crops being in the ground by mid-December. The data discussed come mainly from Malawi, Zambia and Zimbabwe. This is because agriculture was more permanent in these countries, in contrast to southern Tanzania where many farms were part of shifting agriculture. In these slash and burn systems crops presented a mosaic of six or more species growing over 0.1–3 ha. Although groundnut plants were prominent components of the system, the intense admixture of crops was not conducive to sampling in a way that would have permitted comparisons with the data collected from the other countries. Searches for insects were, however, made on an ad hoc basis. In central Tanzania, where a bimodal rainfall pattern is normal, crops had not been sown because of the failure of the second rainy season. However, information was gathered from farmers in both parts of Tanzania.

Groundnut is a minor crop in Botswana. Although research is carried out in the south of the country, it is mainly grown in the north west. However, the pest spectrum in the research station crops reflected the problems found in farmers' fields. The area of Botswana visited was suffering from a fourth year of drought (about 200 mm of rain for the season at the time of visit).

3.2. Characteristics of the farms visited

The average farm size varied considerably (Table 2). In Malawi, they were small and there was little variation in size. The farmers who were interviewed only cultivated with hand hoes. Farms were largest in Zambia, on average, but the largest (80 ha) was in Zimbabwe. Although the farms were comparatively large in Zambia, the cultivated areas were no more extensive than in the other countries. Cultivated areas in Zimbabwe were concentrated in pockets of communal land surrounded by 'bush'. A wide range of farm traction and land preparation methods was available in Zimbabwe and Zambia, although metal, bullock drawn implements predominated in the former. The most intensive agriculture encountered was in the Lilongwe Plains of Malawi, where uncultivated land was restricted to the lush riparian strips bordering the natural drainage courses ('dambos').

The area under groundnut had increased slightly since 1985. Extension officers explained that this was a response to a call from regional Governments for farmers to increase groundnut production.

'Chalimbana' was clearly the favourite variety in Malawi and Zambia. Varieties with a shorter duration were preferred in Zimbabwe. Most farmers saved their own seed. There were marked differences in sowing pattern. High ridges, 90–110 cm apart were normal in Malawi where waterlogging is a potential constraint to production. The sandy soils of Zimbabwe and parts of Zambia allow the rapid percolation of rain water. Groundnut was therefore grown 'on the flat' or on low, close ridges (40–50 cm apart) in these countries. This system involves less energy expenditure than the construction of wide ridges (cf. Malawi) and permitted the farmers to sow at higher rates. The reported average sowing rates were, remarkably, the same in Zimbabwe and Zambia (300 000 plants ha^{-1}).

More than half the farmers had applied fertiliser to their groundnut crop in Zimbabwe. Even more applied fertiliser to the previous crop, usually maize. This reflects the low nutrient status of the sandy soils and the high quality of the extension and farm supply services. The fertilisers that were available had been especially formulated to correct the macro- and micro-nutrient

Table 1
Location, number, soil type, rainfall and age of crop when main sample was taken

	Number of fields	Predominant soil type	Mean annual rainfall (mm)	Age of crop (weeks)[a]
Central Malawi[b,c]				
1 Chitedze[d]	2	Ferruginous loam	950	4
2 Chitala[d]	1	Alluvial	1200	4
3 Mitundu	6	Ferruginous loam	1000	4
4 Likuni	4	Ferruginous loam	1000	4–8
5 Chileka	6	Ferruginous loam	1000	4–5
6 Nsaru	3	Ferruginous loam	1000	4
S. Malawi[c]				
7 Makoka[d]	1	Lithosol	1000	4
8 Phalombe/Mulanje	3	Lithosol	1800	20
9 Blantyre Dist	5	Lithosol	1000	20
10 Ngabu[d]	1	Vertisol	1000	4
N. Malawi				
11 Mzimba[d]	1	Weathered ferraltic	1000	6
S. and C. Zambia				
12 Choma	3	Sandy to clay loams	600	10
13 Mumbwa	5	Sandy to clay loams	600	4–6
14 Kabwe	3	Sandy to clay loams	1160	12
E. Zambia				
15 Msekera[d]	1	Ferruginous loam	1200	16
16 Chipata Dist.	5	Ferruginous loam	1200	8–12
17 Luangwa Valley	5	Silty loam	900	6–10
18 Katete	3	Sandy loam	–	12
C. Zimbabwe				
19 Masvingo	5	Sandy loam	700	10–14
20 Chilimanzi	4	Sandy loam	575	9–13
21 Manyene	4	Sandy loam	950	9–11
N. Zimbabwe				
22 Harare[d]	1	Clay loam	1000	12
23 Chinhoyi	4	Sandy loam	1000	11–15
24 Mawengo	6	Sandy loam	1000	9–13
25 Wedza	7	Sandy loam/alfisol	1200	8–16
Tanzania				
26 South Tanzania	12	Sandy to clay loam		12–20
27 Central Tanzania	5	Sandy loams	850[e]	16
Botswana				
28 Sebele[d]	3	Sandy loam	600	6
29 Goodhope[d]	2	Sandy loam	600	6

[a] Weeks since sowing at time of first or only visit.
[b] A second visit was made just before harvest.
[c] Visit was made during the harvest period.
[d] Research stations.
[e] Bimodal rainfall in part of this area.

deficiencies that are characteristic of specific tracts of land and cropping systems.

In Malawi, the previous crop was maize (only one field was sown after fallow) to which fertiliser had been applied by 32% of the farmers. Few farmers in Zambia had applied fertiliser to their current groundnut crops or to the wider range of crops that they had grown on the same land dur-

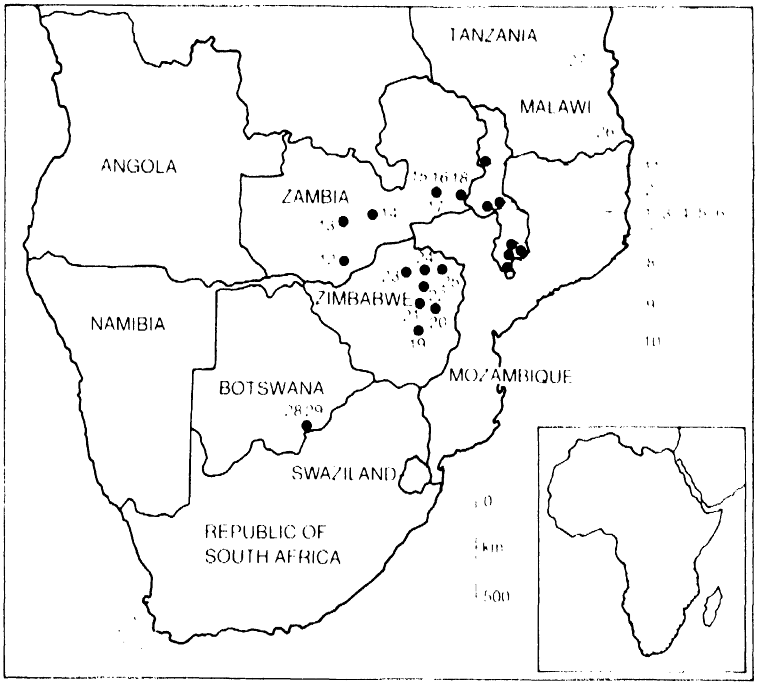

Fig. 1. Map of southern Africa showing the location of the sites at which observations were made. Table 1 includes the key to the site identification.

ing the previous season. Most farmers interviewed were male. The highest proportion of female farmers was in Zimbabwe.

3.3. Insect surveys – foliage feeders

Table 3 lists some of the foliage feeders that are of potential economic importance. Most were present on farms throughout Malawi, Zambia and Zimbabwe. Of the defoliators (mainly Orthoptera and Lepidoptera), the grasshoppers were often present in high densities. They were frequently observed basking on the upper leaves of groundnut plant but were never seen eating the foliage. Caterpillars caused minor defoliation, except on research stations where insecticides had been applied (unnecessarily) for *Helicoverpa armigera* control.

Wightman (1988) reported considerably heavier defoliation caused by *Spodoptera* sp. (probably *littoralis*) during following season in Malawi. These outbreaks were probably the result of migration from tobacco fields to which heavy applications of insecticide are customarily made. Besides eating the foliage, the caterpillars bored pods in much the same way as their Asian counterpart, *Spodoptera litura*.

Adult weevils (especially *Systates* sp.) were frequently found scalloping the edges of leaves, but only caused minor damage. Their larvae were found among the roots where they are potentially more damaging, especially if they attack the nodules, cf. *Sitona* spp. (Wightman, 1986b). Flea beetles were common early in the season. The symptoms of their attack were conspicuous but of no economic significance.

Large Heteroptera were associated with 'tip-wilting'. The term describes the temporary, afternoon condition of plants in fields where these insects were common.

Aphis craccivora is considered to be the most important insect pest of groundnut crops in Africa because it transmits the groundnut rosette complex of viruses (GRV) (Feakin, 1973). It

Table 2
Details of the farms surveyed and their management: farmers' responses to a questionnaire

	Malawi	Zambia	Zimbabwe
Farm size (ha)			
Mean	2.7	16.8	8.1
SE	0.4	3.3	3.3
Range	0.8–10.8	0.8–50	1.3–80
Area in groundnut (ha) (this season)			
Mean	0.59	0.66	0.59
SE	0.07	0.16	0.09
Range	0.2–1.5	0.02–3.0	0.1–2.0
Area in groundnut last season (ha)	0.54	0.54	0.52
Variety (%)			
Chalimbana	80	46	0
Kalitsere	4	0	0
'Local'	0	33	0
Makulu Red	0	10	0
Mani Pintar	8	0	0
Natal Common	0	12	42
Plover	0	0	11
RG 1	8	0	0
Spanish	0	0	24
Tumbwe+Makulu	0	0	3
Valencia	0	0	20
Seed			
Bought	28	21	38
Saved	72	62	62
Donated	0	17	0
Sowing pattern (%)			
Wide ridges	100	34	0
Narrow ridges	0	9	3
Flat in rows	0	31	45
Flat broadcast	0	26	52
Area of field sampled[a] (ha)	0.53	0.70	0.44
Distance between rows (m)[a,b]	0.94	0.81	0.34
Plants per 10 m^2 [a]	48.1	40.8	31.0
Plants ha^{-1} ($\times 10^{-4}$)			
Mean	11.4	30	30
SE	6.1	6.0	6.8
Range	2.7–20.0	1.2–100	2.2–200
Cultivation			
Hand hoe	100	29	52
Animal drawn tools	0	42	45
Tractor	0	29	7
Crop in sampled field			
Maize in previous year (%)	92	58	83
Cotton	0	4	0
Fallow	8	25	10
Sweet potato	0	8	0
Sunflower	0	4	0
Tobacco	0	0	7
Fertiliser applied to field (%)			
This year	8	8	52
Last year	32	8	69
Expected yield from fields			
Seeds (t ha^{-1})	0.32	–	–
Pods (t ha^{-1})	–	0.61	0.79
Male farmer (%)	84	75	59

[a] Authors' measurements.
[b] As applicable.

Table 3
Collection details of some common foliage insects of potential economic status, most of which were found throughout the main collection areas (collection lodged in the British Museum of Natural History)

Species	Location[a]		Date
Orthoptera			
Pyrgomorpha granulata	CARS	CM	4 Apr. 1987
Acrida spp.	CARS	CM	4 Apr. 1987
Zonocerus elegans	Throughout region		
Gryllotalpa africana	Mazvingo	CZi	14 Jan. 1987
Hemiptera-Heteroptera			
Nezara viridula	Mazvingo	CZi	14 Jan. 1987
Tropiconabis capsiformis	CARS	CM	4 Apr. 1987
Creontiades pallidus	CARS	CM	14 Apr. 1987
Helopeltis sp.	CARS	CM	14 Apr. 1987
Taylorilygus sp.	Mitundu	CM	20 Jan. 1987
Clavigralla elongata	Mitundu	CM	20 Jan. 1987
Hemiptera-Homoptera			
Empoasca singala	Chinhoyi	NZi	4 Feb. 1987
Oxyrachis sp.	Goodhope	B	3 Mar. 1987
Phenacoccus solani		Throughout region	
Thysanoptera			
Megalurothrips sjostedti		Throughout region	
Scirtothrips aurantii	Harare	NZi	20 Jan. 1987
Coleoptera			
Tetragonothorax angulicollis	Katete	EZa	19 Mar. 1987
Diaecoderus sp.	CARS	CM	4 Apr. 1987
Systates sp.		Throughout region	
Afroeurydemus hopei	CARS	CM	14 Apr. 1987
Monolepta sp.	CARS	CM	8 Jan. 1987
Hemipyxis sp.	CARS	CM	21 Jan. 1987
Lepidoptera			
Helicoverpa armigera	Sebele	B	2 Mar. 1987
	Nachingwea	Ta	26 Mar. 1987
Spodoptera littoralis	Common in Malawi		
Agrotis spp.	CARS	CM	26 Mar. 1987

[a] CARS, Chitedze Agricultural Research Station, near Lilongwe, Malawi; B, Botswana; CM, central Malawi; NM, northern Malawi; SM, southern Malawi; CZi, central Zimbabwe; NZi, northern Zimbabwe; CZa, central Zambia; SZa, southern Zambia; EZa, eastern Zambia.

was found on plants up to 6 weeks after sowing. The colonies tended to be small (20–30 per plant) and were attended by single coccinellid or syrphid larvae. It was assumed that the predators eliminated the aphid colonies as they were not found on older plants.

Few plants with GRV were found in farmers' fields across the whole region. The firm recommendation of A'Brook (1964) and Farrell (1976) to sow as soon as possible after the rains started as a cultural control for GRV was followed in Malawi. Heavy jassid (cicadellid) damage (leaf scorch) was seen in only a few fields in eastern Zambia. It was, however, present, but mild, throughout the region.

Few of the above insects were found in Tan-

Table 4
Termites found in groundnut fields in southern Africa

Species	Location[a]		Date
Allodontotermes tenax (Silvestri)	Mazvingo	CZi	27 Jan. 1987
	Mumbwa	CZa	11 Feb. 1987
Allodontotermes sp.	Mitundu	CM	20 Jan. 1987
Ancistrotermes latinotus (Holmgren)	CARS	CM	9 Apr. 1987
	Ngabu	CM	3 Dec. 1987
	Chitala	CM	6 Jan. 1987
	CARS	CM	13 Jan. 1987
	Mzimba	NM	14 Jan. 1987
	Mitundu	CM	20 Jan. 1987
	Chinhoyi	NZi	5 Feb. 1987
	Mawengo	NZi	6 Feb. 1987
	Luangwa V.	EZa	18 Mar. 1987
	Katete	EZa	19 Mar. 1987
	Ngabu	SM	12 Mar. 1987
	CARS	CM	15 Mar. 1987
	CARS	CM	9 Apr. 1987
Ancistrotermes sp.	Chitala	CM	6 Jan. 1987
	Chileka	CM	22 Jan. 1987
	Chinhoyi	NZi	5 Feb. 1987
	Mawengo	NZi	6 Feb. 1987
	Kabwe	CZa	12 Feb. 1987
	CARS	CM	9 Apr. 1987
Basidentitermes amicus Harris	record damaged		
Hodotermes mossambicus (Hagen)	Ngabu	CM	3 Dec. 1986
	Ngabu	CM	9 Dec. 1987
Macrotermes falciger (Gerst.)	Chileka	CM	22 Jan. 1987
	Nsaru	CM	23 Jan. 1987
Macrotermes natalensis (Haviland)	Kalima	CM	21 Jan. 1987
	Choma	SZa	10 Feb. 1987
	Katete	EZa	19 Mar. 1987
	Chitala	CM	11 Mar. 1987
	Malanje	SM	14 Apr. 1987
	CARS	CM	15 Mar. 1987
	CARS	CM	23 Apr. 1987
(Reproductives)	Ngabu	SM	9 Mar. 1987
Microtermes sp.	Mumbwa	CZa	11 Feb. 1987
	CARS	CM	9 Apr. 1987
	Sebele	B	2 Mar. 1987
Odontotermes amanicus (Sjost)	CARS	CM	9 Apr. 1987
O. bomaensis (Sjost)	Kabwe	CZa	12 Feb. 1987
(near)	Makoka	SM	4 Dec. 1986
O. kibarensis Fuller	Wedza	NZi	7 Feb. 1987
O. lacustris Harris	Chitala	CM	11 Mar. 1987
	CARS	CM	21 Jan. 1987
	CARS	CM	9 Apr. 1987
	CARS	CM	15 Mar. 1987
O. latericus Haviland	Kabwe	CZa	12 Feb. 1987
	CARS	CM	19 Jan. 1987

Species	Location[a]		Date
Om. montanus Harris	CARS	CM	15 Mar. 1987
O. rectanguloides Sjost	Harare	NZi	30 Jan. 1987
O. transvaalensis (Sjost)	CARS	CM	13 Jan. 1987
	Chilimanzi	CZi	29 Jan. 1987
O. transvaalensis	Good Hope	B	3 Mar. 1987
Odontotermes sp.	Chitala	CM	11 Mar. 1987
	Mumbwa	SZa	11 Feb. 1987
	CARS	CM	28 Nov. 1986
	Mbawa	NM	14 Jan. 1987
	Katete	EZa	19 Mar. 1987
	CARS	CM	15 Mar. 1987
	CARS	CM	9 Apr. 1987
Pseudoacanthotermes militaris (Hagen)	Makoka	SM	4 Dec. 1987
	Chitala	CM	6 Jan. 1987
	CARS	CM	13 Jan. 1987
	Mumbwa	SZa	11 Feb. 1987
(Reproductives)	CARS	CM	15 Mar. 1987
	CARS	CM	9 Apr. 1987
	CARS	CM	24 Apr. 1987
Pseudoacanthotermes sp.	Mzimba	NM	14 Jan. 1987
	Chitala	CM	11 Mar. 1987
Trinervitermes sp.	Kalima	CM	21 Jan. 1987
	Chipata	EZa	17 Mar. 1987

[a] For abbreviations see footnote to Table 3.

zania where fields tended to be in isolated bush clearings. It was assumed that the isolation of fields in dispersed bush clearings meant that it took several seasons for insects adapted to open field environments to colonise these plantations. Conversely, insects adapted to bush conditions could not colonise crop plants in clearings. The diverse multiple cropping system characteristic of these farms also presents sufficient environmental diversity to sustain the natural enemies of a number of the potential pests.

3.4. Insect survey—soil insects

Soil insects dominated the results of the survey. The diversity of species and their wide distribution (Tables 3–6) could not have been anticipated from the information available in the literature (e.g. reviews by Feakin, 1973; Smith and Barfield, 1982).

Table 4 shows that about 40 species of white grub were collected, with the genera *Schizonycha* and *Anomala* predominant. Smith and Barfield (1982) listed 18 genera from the world and eight from Africa. Table 7 shows that a wide range of white grub densities was encountered. In central Malawi and northern Zimbabwe white grub densities were high (from more than 20 per 100 plants and up to more than one per plant). In the drier parts of Zimbabwe (the southernmost zone sampled in that country) and Zambia, where farming intensity was comparatively low, white grub densities were comparatively low. None were found in Tanzania. An initial attempt to record which individuals and which instars were found in a given locality was not continued when the diversity of species involved (according to the rastal pattern[2]) became evident. Because eggs and first instar larvae were found alongside larvae that were close to full development there was

[2] The rasta is a brush of hairs around the anus of white grubs. The number of bristles and their arrangement often indicate the species.

Table 5
Larval scarabaeids (= white grubs), unless otherwise stated, found in groundnut fields in southern Africa

Species	Location[a]		date
Melolonthinae			
Schizonycha straminea Peringuey	Mitundu	CM	20 Jan. 1987
Schizonycha fusca Kolbe	CARS	CM	22 Apr. 1987
Schizonycha sp. (adult)	Makoka	SM	14 Apr. 1987
Schizonycha sp. 1	Chitala	CM	11 Mar. 1987
	Ngabu	SM	12 Mar. 1987
Schizonycha sp. 2	Ngabu	SM	12 Mar. 1987
Schizonycha sp. 3	Ngabu	SM	9 Mar. 1987
Schizonycha sp. 4	Mazvingo	CZi	27 Jan. 1987
	Chinhoyi	NZi	5 Feb. 1987
	Wedza	NZi	6 Feb. 1987
Schizonycha sp. 5	CARS	CM	13 Jan. 1987
	Nsaru	CM	23 Jan. 1987
Schizonycha sp. 6	Chitala	CM	11 Mar. 1987
Schizonycha sp. 7	Kalima	CM	21 Jan. 1987
Schizonycha sp. 8	Wedza	NZi	7 Feb. 1987
Schizonycha sp. 9	Ngabu	SM	12 Mar. 1987
Schizonycha sp. 10	Mbawa	NM	14 Jan. 1987
Schizonycha sp. 11	Chinhoyi	NZi	5 Feb. 1987
Trochalus sp. (adult)	CARS	CM	22 Apr. 1987
Tribe Sericini			
8 indet. genus and species			
Rutelinae			
Adoretus sp. 1	CARS	CM	13 Jan. 1987
	Chitala	CM	11 Mar. 1987
Adoretus sp. 2	Msekera	EZa	17 Mar. 1987
Adoretus sp. 3	Luangwa Valley	EZa	18 Mar. 1987
	Ngabu	SM	12 Mar. 1987
Adoretus sp. 4	Mazvingo	CZi	27 Jan. 1987
	Mawengo	NZi	6 Feb. 1987
	Wedza	NZi	7 Feb. 1987
	Ngabu	SM	12 Mar. 1987
Anomala sp. 1	Mzimba	NM	14 Jan. 1987
	Mazvingo	CZi	27 Jan. 1987
	Mawengo	NZi	6 Feb. 1987
	Wedza	NZi	7 Feb. 1987
	Mumbwa	CZa	11 Feb. 1987
	Ngabu	SM	12 Mar. 1987
Anomala sp. 2	Chitala	CM	6 Jan. 1987
	Chilimanzi	CZi	29 Jan. 1987
	Chinhoyi	NZi	5 Feb. 1987
Anomala sp. 3	Chilimanzi	CZi	29 Jan. 1987
	Wedza	NZi	7 Feb. 1987
Anomala sp. 4	CARS	CM	13 Jan. 1987
	Kalima	CM	21 Jan. 1987
	Nsaru	CM	23 Jan. 1987
	Mawengo	NZi	6 Feb. 1987
	Chipata	EZa	17 Mar. 1987
	Chitala	CM	11 Mar. 1987
	Phalombe	SM	15 Apr. 1987

Species	Location[a]		date
Anomala sp. 5	Mitundu	CM	20 Jan. 1987
	Chipata	EZa	17 Mar. 1987
Anomala sp. 6	Makoka	SM	14 Apr. 1987
	Chinhoyi	NZi	5 Feb. 1987
	Wedza	NZi	7 Feb. 1987
Anomala sp. 7	Makoka	SM	4 Dec. 1986
Anomala sp. 8	Mbawa	NM	14 Jan. 1987
Anomala sp. 9	Good hope	B	3 Mar. 1987
Anomala sp. 10	Mwumbe	Za	11 Feb. 1987
Anomala sp. 11	Msekera	EZa	17 Mar. 1987
	Makoka	SM	14 Apr. 1987

[a] For abbreviations see footnote to Table 3.

Table 6
Elateridae (wireworms) and Tenebrionidae (false wireworms) found in groundnut fields in southern Africa; larvae unless stated otherwise

Species	Location[a]		Date
Elateridae			
Prosephus 4 spp.	Chitala	CM	6 Jan. 1987
Cardiophorus sp.	Chitala	CM	6 Jan. 1987
Dyakus sp.	Chitala	CM	6 Jan. 1987
Subfamily Agrypninae			
2 indet. genus and sp.			
Subfamily Elaterinae			
6 indet. genus and sp.			
Tenebrionidae			
Zophosis sp. (adult)	CARS	CM	22 Apr. 1987
Gonocephalum nr. *simplex* F.	Ngabu	SM	3 Dec. 1986
Anchophthalmus plicipennis	Chileka	CM	22 Jan. 1987
Peringuey (adult)			14 Jan. 1987
Drosochrus sp. (adult)	Mbawa	NM	
Tribe Pimellinae			
13 indet. genus and sp.			

[a] For abbreviations see footnote to Table 3.

reason to suspect variation between and perhaps within the life cycles of the species involved. The third (final) instar larvae were often as large as an adult's thumb and weighed up to 5 g. They thus made a significant contribution to the subterranean biomass.

The influence of white grubs on plant growth was often clear. If individual plants or several plants in a row or in a small patch were smaller than healthy neighbours, one or more white grubs could often be found among the roots. An examination of the underground parts revealed that peripheral roots of up to 2 mm diameter were severed, and that depressions had been gouged out of the tap root. Small (less than 5 mm) pods were cut at the base of the peg and larger, soft pods were almost destroyed. It was not unusual to find a grub inside a pod.

The effects of root damage were particularly noticeable on the drought-prone, sandy soils of Zimbabwe. The depletion of the water and nutrient absorbing capacity of plants attacked by

Table 7
Density of soil insects in groundnut fields in central Malawi, Zambia and Zimbabwe

	Central Malawi	Zambia	Zimbabwe
Number of farms	19	25	31
White grubs per 100 plants			
Mean	42.4	16.5	46.2
SE	8.4	4.3	7.2
Range	0–144	0–71	0–162
Millipedes per 100 plants			
Mean	23.8	10.3	2.2
SE	4.9	4.6	0.6
Range	0–67	0–87	0–10
Wireworms per 100 plants			
Mean	11.6	4.9	4.6
SE	2.2	1.6	1.6
Range	0–30	0–33	0–35
Plants with *Dorylus* (%)	26	2	7.6
Plants with root-boring termites (%)	23	16	2
Plants with foliage and stem sheeting termites (%)	9	5	9
Plants with stem cutting termites (%)	3	4	0
Fields with *Hilda*	13	29	34

white grubs appeared to be major contributors to the unevenness of the stands, in terms of crop density and plant height. Damaged tap roots were also open to invasion by soil fungi and termites.

Among the termites, *Ancistrotermes* spp. and *Odontotermes* spp. attacked live plants (species list included in Table 5). They tunnelled through the stem from their entry hole, which was in or just below the crown. The surface active species covered stems and leaves with a layer of soil (sheeting) under which they removed plant tissue via the earthen galleries within the sheeting. They also removed the soft corky tissue from between the veins of the pod (scarification). This does not reduce yield per se but does render the pod vulnerable to invasion by soil fungi, including *Aspergillus flavus* and *Aspergillus parasiticus* that produce the carcinogenic aflatoxins. Scarification reached 30% in fields in the Mulanje–Phalombe area of Malawi at harvest.

Odontotermes also eat the pods as they dry in the field after harvest. Farmers throughout the region complained about this. Their estimate of 30, or even 40%, lost product at this critical stage is supported by experimental evidence (Wightman and Wightman, 1987).

The smaller root-boring termites, such as *Microtermes* spp., were found throughout the region but were most common in the more organic soils of Malawi and in Botswana. The late season survey in southern Malawi revealed that termite attack was severe (to 100%). Root boring termites were less of a potential problem in Zambia and were variable in distribution in Zimbabwe. *Microtermes* sp. was the major biotic constraint in Botswana. At the time of the visit, research station crops had 4–8% plant mortality even though the crop had emerged only 6 weeks previously. More than 40% plant mortality, as well as additional pod damage and scarification, was anticipated by the research station staff.

Macrotermes spp. and *Hodotermes* spp. (harvester termites) attacked the bases of the stems. They worked systematically down rows, 'felling' between 25 and 100% of the stems as they went. This kind of damage is easy to overlook, the severed stems disappearing rapidly because of the rapid rate of decay characteristic of the tropics.

Furthermore, surface active termites sheeted the cut stems and removed them within 2 or 3 days. The distribution of their activity in fields was highly localised and few of the plants that were sampled had been attacked. None were located in Zimbabwe.

Table 5 does not include reference to the small (7 mm long) grey, soldierless termites found about 15 cm below the soil surface. These unidentified termites eat soil organic matter. There was no indication that they had any influence on crop yield. They were found in many parts of the region.

The wireworms (elaterids) and false wireworms (tenebrionids), both well recognised as pod borers on a world basis, were largely unidentified (Table 5). Their densities were relatively high in Malawi. No millipedes were named because no specialist was found to identify them. Millipedes attacked the developing pods. There is no evidence to show that they eat the roots. They were present in comparatively high densities in Malawi and in the river silts of the Luangwa Valley in Zambia.

The doryline ant *Dorylus* sp. was found under groundnut plants in most collection areas, except in Botswana and much of Zimbabwe. It was thus more likely to be found in loam soils than in sandy soils. In Zambia, this species was associated with up to 9.5% of plants around Kabwe and 8.5% of plants in the Luangwa Valley. The only evidence of crop damage came from a mature crop in Malawi. Members of this genus are widely recognised as a pod borers in Asia (Wightman et al., 1990). The workers characteristically make one or two 1–2 mm diameter holes in the shells of mature pods and remove the seeds, leaving no soil residue in the pod. This is a new record.

Hilda patruelis (Homoptera: Tettigometridae) is allegedly one of the most feared insects among the groundnut farmers of southern Africa. It lives on the underground parts of plants and is tended by small black ants. Weaving (1980) and Rose (1962) recorded extensive damage to groundnut crops in Zimbabwe and Malawi particularly in especially dry seasons. Although found at low densities on many farms (less than 5% of plants) it was only associated with serious damage in one cluster of fields southwest of Lilongwe. Examination of a crop that had been sown during light rain that had fallen 6 weeks before the 'planting rains' revealed extensive damage on the periphery of the field. The farmer subsequently abandoned this field because virtually no undamaged plants remained. Neighbouring fields were also badly affected by migrants. It appears that adults dispersing from weed hosts in search of fresh food sources towards the end of the dry season may aggregate in early sown groundnut crops. *Hilda* specimens were found in two fields in the south of Zambia.

A mealy bug (Homoptera, Pseudococcidae) was found on the roots of stunted plants in the Lilongwe Plains, Malawi. It was identified tentatively as *Phenacoccus solani* which is known from South Africa and Zimbabwe, although it differed slightly from this species in one important characteristic. The presence of this species was too infrequent to appear in routine samples, but it was revealed during the investigative sampling of sick and stunted plants.

3.5. Natural enemies of soil insects

Ants (e.g. *Camponotus* nr *vestitus*, *Pachycondyla* sp., *Myrmicaria* sp. and *Platythyrea* sp.) were usually to be seen in groundnut fields on or under the soil surface and in the foliage where they were often attending homopterans. Their voracity was displayed if a live white grub was exposed on the soil surface. It was inevitably surrounded by ants and dragged off alive to a burrow within minutes. The increase in *Macrotermes* population density following the application of a granular insecticide in a field trial is believed to have been because ants did not survive the treatment. It was assumed that the termites isolated themselves from the insecticide granules by means of their method of tunnel construction (Wightman and Wightman, 1987).

The survey revealed predacious larvae of the dipterous families Scenopinidae (Makoka, Malawi), Mydidae (Chitala and Chitedze, in Malawi, Goodhope in Botswana and Mawengo in

Zambia) and Therevidae (Chitala). All live in the soil and are potential predators of soil beetle larvae (such as white grubs) and other soil arthropods.

3.6. Implications of the distribution and relative abundance of soil insects

White grubs were most abundant in the higher rainfall (at least 1000 mm year^{-1}) areas, i.e. northern Zimbabwe and central Malawi. This accords with current knowledge of white grub physiology; their survival is dependent upon high levels of soil moisture (Wightman, 1973). They were noticeably absent from fields in Chipata District (east Zambia) where the red soil was hard, dry, powdery and hot to the touch to a depth of 15 cm. White grubs are favoured by light (sandy) soils that allow them to dig more easily in search of roots and, when necessary, moister (deeper) soil strata.

Revisits to fields in central Malawi and a late season survey of southern Malawi revealed low white grub densities. This suggested either that there had been high levels of mortality, that the larvae had completed their growth phase and had pupated deeper than the level of sampling or that they had been driven deeper by the low soil moisture and related high day time soil temperatures.

Termites, as a whole, were most numerous in central Malawi. However, a wide range of species and life systems is represented and not all species are necessarily pests. The rich fauna of the Lilongwe Plains is again demonstrated by the abundance of millipedes. Comparable levels were only found in the silty (riverside) soils of the Luangwa Valley in Zambia. Wireworms and false wireworm were not particularly abundant anywhere.

3.7. Farmers' perceptions of pests and their attitudes to pesticides

The farm survey questionnaire included a section which called for the interviewers to ask farmers to identify constraints to their production during recent years. They were also asked whether there were any other such 'pests' they would like to include (Table 8).

Groundnut rosette disease was considered a problem by about one-third of the farmers questioned. The aphid vectors were not recognised as being of consequence in Tanzania, in contrast to Zimbabwe, where they were considered to be of the greatest importance. *Hilda* and jassid damage were not rated highly, which may reflect their sporadic nature. Bored pods concerned about one-third of all farmers. It was clear that the farmers in white grub and termite endemic areas (Malawi and Zimbabwe) were aware of and concerned about these taxa.

It is difficult to draw any conclusion about the response to 'ants'. This is because some farmers believed that they were the causal agent of *Hilda* damage. This was especially so in coastal Tanzania where the cohost cashew is common. It is also noteworthy that no farmers in Zambia thought *Hilda* was important and few reacted negatively to questions about ants. Ants tend *Hilda*, often in large numbers, but do not, as far as is known, kill the plant with which they are incidentally associated. Other ant species are abundant and voracious predators. The only true ant pest encountered was *Dorylus*. It is doubtful if this species was sufficiently abundant and conspicuous to elicit a negative response from farmers.

About half the farmers thought that leaf spots were a problem, reflecting the intensity of this constraint in the region. Malawian farmers suffered most, particularly from early leaf spot, whereas few diseased plants were encountered in Tanzania, especially where slash and burn agriculture was practised.

Among the vertebrates, only rats were stated to be pests of note. Birds seemed to be a particular problem in Tanzania just before and during harvest. Hippopotami were stated to be particularly damaging along the banks of the Luangwa River (Zambia).

Table 9 shows that very few farmers had applied pesticides in the recent past. The reasons for this were mainly because they were considered too expensive or were not available. Lack of water, information and a sprayer were appar-

Table 8
Farmers' perceptions of the importance of biotic constraints to groundnut production on Malawi, Tanzania, Zambia and Zimbabwe

	Percentage of farmers concerned about a given constraint					
	All	Malawi central	Malawi south	Zimbabwe	Zambia	Tanzania
Aphids	49	47	33	81	32	0
GRV[a]	36	40	33	31	36	33
Hilda	16	20	11	25	0	8
Leaf scorch[b]	10	7	11	6	14	0
Wilting plants	38	33	56	50	23	8
Bored pods	29	13	33	38	18	17
White grubs	32	60	56	31	27	0
Termites	53	73	78	63	27	17
Ants	41	27	56	69	9	17
Leaf spots	46	80	67	38	23	17
Guinea fowl	3	0	0	0	5	17
Crows	6	0	0	0	5	25
Rats	37	13	33	69	23	50
Monkeys	8	0	11	6	9	17
Pigs	2	0	0	0	5	8

[a] Groundnut rosette virus.
[b] Jassid (leaf hopper) damage.

Table 9
Farmers' reaction to pesticides in Malawi, Zambia, Zimbabwe and Tanzania. Data are the percentage of positive responses to list of statements

	Responses of farmers to questions about pesticides (%)					
	All	Malawi central	Malawi south	Zimbabwe	Zambia	Tanzania
Insecticides used	1	0	0	4	0	0
Fungicides used	1	7	0	0	0	0
or not used because:						
No need	1	0	0	0	5	0
Not available	16	27	11	0	0	8
Too expensive	26	27	56	38	9	8
No sprayer	1	0	0	6	0	0
No information	3	7	0	5	0	0
No water	0	0	0	0	0	0

ently not constraints. However, if the farmers were presented with a pest problem and a suitable pesticide was available, the responses may have been different. Only about 50% of the farmers replied to these questions. The reason for such a low response is not known.

The comments of the farmers are generally supported by the data collected during the field survey. For instance, white grubs were seen as constraints in Malawi and Zimbabwe, but not in Zambia.

Table 10
Cash budget for the groundnut enterprise in Malawi, Zambia and Zimbabwe: average data for all fields surveyed (local prices for 1987)

	Malawi	Zambia	Zimbabwe
Currency	M Kwatcha	Z Kwatcha	Z Dollars
Cost of			
Seed	3.0	22.7	7.1
Fertiliser	2.0	1.7	15.4
Insecticides	0	0	0
Fungicides	4.0	0	0
Labour[a]	22.0	11.8	46.7
Total cost	31.0	36.2	69.2
Potential income[b]	255.7	520.0	523.8
Percentage of product sold	65	13	51
Gross income	166	67.6	336.3
Net income	135	31.4	267.1
In $US equivalents[c]			
Gross income	37.7	0.2	58.0
Net income	30.7	0.1	46.0

[a] Cost of family labour, reciprocal communal labour (Zimbabwe) and value of payments in kind are excluded.
[b] Expected yield × expected official price.
[c] 1993 rates: 4.4 MK/$US, 300 ZaK/$US, 5.8 Z$/$US.

3.8. Budget for the groundnut enterprise

Farmers in Malawi and Zimbabwe sold 50–65% of their product (Table 10). The investment of cash into inputs was low, labour being the most important. The budget highlights the role of groundnut as a cash generator, and as a family food source.

The amount of income reported or calculated is probably an underestimate because the official market rates offered at government trading posts were 25–50% of the prices that could be obtained on the alternative market. Most farmers turned in some of their saleable produce to the official markets. Additional income was generated when family members roasted the seeds and sold them in 'bunches' at the roadside. However, the quantification of such ramifications was beyond the scope of this survey. The real situation in Zambia was not as tabulated. The people who accompanied the authors thought that the farmers were wary of giving information about their income.

There appears to be sufficient income for farmers to be able to invest in inputs that will raise further the yields of their groundnut crops. Despite disclaimers by farmers during the survey, it was known that pre-season credit, hire-equipment and supporting information was available from the extension services to help with the application of fungicides, in particular. This alone can have considerable impact on yield (Kannaiyan et al., 1989).

4. Discussion

4.1. The insects and their distribution

This survey, being the first of its kind and being carried out over a wide geographic area, albeit in only one season and of a single crop, has pointed to several topics that need further investigation. It is, for instance, possible to surmise that soil insects have a previously unsuspected detrimental effect on the yield of groundnut crops. There are also several hypotheses that can be constructed from the data: these need to be tested under controlled conditions in farmers' fields or reasonable simulations thereof. It is also possible to make suggestions that may lead to increases in groundnut production associated with the management of these pests.

The survey revealed that the soil macrofauna was richer than previously suspected in terms of species diversity and density. It is noteworthy that the termites were abundant and for the most part identified, whereas knowledge of the taxonomy of the coleopteran species which were equally abundant is much more limited. The situation is even more extreme for millipedes, for which no specialist taxonomist was located. Basic research on the taxonomy, bionomics and ecology of the soil fauna of the agricultural land of the region is clearly required.

A subsequent survey in Mozambique by Ramanaiah et al. (1989) revealed a similar pattern of foliage and soil insects. They noted that false wireworms damaged as much as 30% of the pods. Rats, birds, moles and monkeys were the most important vertebrate pests.

Sithanantham et al. (1989) and Sohati and Sithanantham (1990) reviewed the information available on insects living on groundnut in Zambia. There is no disparity between their findings and the information reported here. Their 'avoidable yield loss caused by soil insects' experiments indicated 11-30% in 1988 and in 1989, 2-19% on research stations and 11-21% on farms. They commented on the high variability between years and seasons.

Farm size. The Lilongwe Plains of Malawi had the most intense agricultural system, i.e. most of the tillable land was cultivated. This meant that there was little fallow land. This contrasted with Zambia where holdings are large, but not all of the available land was cultivated in any one season. White grub densities were lower in Zambia than in Malawi. Zimbabwe presented intermediate data for farm size and white grub density. The least intensive agricultural system encountered was in southern Tanzania. Only wireworms at low densities were encountered in this area. The implication is that white grub density is related to the intensity of the agricultural production in a given locality.

Fallow. Only one of the fields sampled in central Malawi had been fallow (or virgin) in the previous season. Soil insect densities were generally high in Malawi. In Zambia, 25% of the 24 fields sampled had not been cultivated during the previous year. The average density of white grubs in the Zambian ex-fallow fields was only three per 100 plants, compared with the average (all fields) density of about 17 white grubs per 100 plants in that country. Research plots on two research stations in Malawi (Chitedze and Mzimba) also came out of fallow. Intensive sampling indicated low soil insect densities at these sites, compared with those at the other research stations (Wightman, 1989).

Rainfall. There was a tendency, most marked in Zimbabwe, for areas of high rainfall (over 1000 mm year^{-1}) to have high densities of white grubs. Farms in areas of lower rainfall suffered more from termites. This observation needs to be qualified to the extent that drought exacerbated termite attack, especially at the end of the season and especially in Botswana. Johnson et al. (1981) derived a relationship between annual rainfall (x) and the percentage of tap roots in a stand infested by *Microtermes* sp. (y), whereby

$$y = (24493/x) - 20.6$$

White grubs were encountered less frequently at the end of the season either because they had pupated or because they were in (cooler and moister) strata below the level sampled.

Soil type. Loamy and sandy soil favoured white grubs, whereas clay soil did not. Several farmers said that they did not sow groundnut close to dambos because of the risk of high levels of white grub damage. This may have been because the larvae were favoured by the higher soil moisture, the presence of trees that may have influenced the distribution of the adults (as a food source or aggregation site) (Farrell and Wightman, 1972) or because of the higher organic matter in the dambo soil.

The only silty soil encountered was in the Luangwa Valley. Here, millipede densities were exceptionally high. Light red-clay soil, which was infrequently encountered (in eastern Zambia and northern Zimbabwe), did not favour any of the soil insects found elsewhere.

4.2. Loss assessment

The high densities of soil insects, and white grubs in particular, that were detected in Malawi, Zambia and Zimbabwe are in excess of previous perceptions and indicate that they represent an avoidable constraint to production. The damage caused by termites in Botswana is well known there but is not widely documented (Wightman, 1989).

There is evidence from other parts of the world that white grubs can have considerable impact on groundnut yield at relatively low densities (i.e. densities well below those detected in this study). In Australia, Gough and Brown (1988) calculated that one white grub (*Lepidiota* sp.) per metre row (six to eight plants) reduced the yield of a crop by 381 kg ha^{-1} (yields of over 2 t ha^{-1} are anticipated in this area). Yadav (1981) states, as a rule of thumb, that in India the economic threshold is one white grub per metre row. Xiesong et al. (1985) calculated an action threshold of two third instar *Holotrichia* spp. per square metre. If these data are related to conditions in southern Africa, it is clear that white grubs would have contributed to the low yields that are well below the potential for the genotypes listed in most of the areas sampled in the 1986–1987 season. Kisyombe and Wightman (1987) compared soil insect density and groundnut yields in Malawi in plots that had remained untreated or that had been treated with heavy rates of a soil-incorporated insecticide. The benefits of killing soil insects ranged from 0 to 60% in terms of pod yield. Two of the five sites selected came out of fallow and registered zero benefit from insecticide on pod yield because of the low soil insect density. Further series of on-farm experiments were carried out by Kisyombe and Wightman (1987) and Sohati and Sithanantham (1990) with similar results. Wightman (1989) noted that white grubs are likely to have most effect on the seedling stage and could account for 45% of the yield potential. Termites and pod borers usually act late in the season. Although they may remove 40% of the potential yield that is available when they are active, this represents only 18% of the original yield potential.

4.3. Soil pest management

Soil pests are among the most difficult to manage because they cannot be detected without considerable effort. This means that farmers have to be convinced that investment in their control will produce sufficient returns to cover the costs of any benefits.

Prophylactic control by the routine application of insecticides to the soil should be approached with circumspection. (1) The oil in the seed can accumulate pesticides (Logan et al., 1992). This presents a health hazard and is a potential bar to the export of produce thus contaminated. (2) Pest activity can increase following pesticide application to groundnut fields in southern Africa (Wightman, 1989), perhaps because predators (ants) are also killed.

However, these insects are not unique to groundnuts. They are part of the cropping system and undoubtedly have a detrimental effect on the yield of the other crops in the rotation. Maize predominates in most cropping systems and it was observed that termites attacked this crop. It is likely that the fibrous root systems of this and other graminaceous crops confer some tolerance to white grub attack once the stand is established, even though *Heteronychus arator*, for instance, is recognised as a serious maize pest (Scholtz and Holm, 1985). A further hypothesis is that the cereal component of the more intensive agroecosystems permits the build-up of white grubs (Yadav, 1981). Future research should therefore examine the possibility that, in white grub endemic areas, a granular insecticide added to the soil in which the preceding maize crops are grown would depress the population of soil insects in that field and give partial protection to a subsequent groundnut crop. The risk of seed-oil contamination would be reduced. The assumption is that there is no more than one white grub generation per year and that the females oviposit close to where they develop. The insecticide could be added at a suitable rate to the fertiliser that many farmers apply to maize. Alternatively, a localised effect could be ensured by putting insecticide granules into the dibble hole.

The cultivation of a cleansing crop is an alternative management strategy that is worthy of consideration. There is evidence that sunn hemp (*Crotolaria fistularia*, *Crotolaria juncea* and *Crotolaria ochroleuca*) has an antibiotic action on soil insects (Gerold, 1989; Gold and Wightman, 1991). This crop is also valuable as a fibre source and as green manure. Alternatively, a crop with a deep, woody root system such as pigeonpea (*Cajanus cajan*) may also have a depressant effect on soil pests, because it would present a poor food source.

Gold et al. (1989) showed that, in India, groundnut pods lying on a mulch of chopped *Ipomaea fistulosa* foliage and branches were protected from termites (*Odontotermes*). This is considered to be relevant to African conditions. Other species of *Ipomaea* (morning glory trees and bushes), which produce a range of 'anti-insect' compounds (Steward and Keeler, 1988) may also be considered.

Groundnut seedlings are particularly susceptible to white grub attack because their roots are comparatively small, tender and unbranched. However, the comparative phenology of the insect and host are such that early sowing should afford at least partial avoidance of attack. Although the information collected during the survey indicated that exceptions exist, it appears that most species will have a 'conventional' tropical life cycle. The fully grown larvae pupate below the normal feeding depth where they stay during the dry (cool) season. Eclosion is stimulated by the 'planting rains' and the adults emerge, mate and oviposit over the following 3 weeks. This means that the larvae may not appear in the first 3–4 weeks of the rainy season. This pattern was confirmed by examining the insect catches in a light trap operated by the authors at the Chitedze Agricultural Research Station during the 1986–1987 growing season. However, should certain species live throughout the dry season as larvae these could cause considerable damage to seedlings, hence the need for bionomic studies of this taxon in southern Africa.

5. Conclusions

The soil fauna of farming systems that include groundnut in southern Africa is much richer than previously suspected. White grubs predominate and are almost certainly greatly affecting groundnut yields across the region, as well as those of other crops in the system. This is particularly so in areas of intense cultivation such as the Lilongwe Plain and the communal areas in the high rainfall zones of Zimbabwe. Southern Tanzania presented the opposite picture, where soil insects of potential pest status were rare in the low intensity or shifting agriculture systems of this part of southern Africa. There is thus a need for further research on taxonomy and other basic and applied aspects of the problems exposed by this survey. Groundnut is a source of cash even though farmers retain about half of their crop for home consumption. Farmers do not obtain credit or use the cash generated to buy inputs for groundnut crops but have the means to do so.

The major hypotheses developed from this exploratory study are as follows.

(1) White grubs are likely to be pests in agricultural systems where rainfall exceeds 1000 mm per year and termites will be pests where it does not. The latter will also be more damaging (up to 100%) in sandy soils and during end-of-season drought.

(2) White grubs are favoured by sandy or loamy soils, but not clays and silts.

(3) White grubs and possibly termites are components of intensive and permanent agricultural systems, especially those that do not include fallow seasons. In contrast, shifting agricultural systems had no detectable pest and disease problems.

(4) Natural control processes were keeping the densities of most potential pests at levels where they were not pests. Insecticide application would disrupt these processes. The soil pest problem revealed by this study was induced by the land

management system and should be redressed by modifying current management practices.

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