SOIL PESTS STUDIES ON GROUNDNUT

BY

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DEDICATION

This thesis is dedicated to my parents Mr. and Mrs. J.A. Onu and all members of Onu family.

ABSTRACT

Surveys conducted on importance of soil pests on groundnut production indicated that the majority of farmers were aware of damage caused by soil pests to groundnut, Bakura, Mamudo, Sada, Ngurore, Girei and Gusau are areas where soil pests cause great damage to groundnut.

Experiments conducted elsewhere indicated that millipedes were found to be causing damage at germination and from the 5th to 7th week after planting. Termites on the other hand caused greater damage at crop maturity.

Biological studies were conducted to raise colonies of Macrotermef subhyalinus (Rambur) - (a minor pest of groundnut in the Guinea Savanna) in the laboratory. Two methods were successfully adopted, namely; the aluminium foil method and the glass plate method. Observations were made on colony development, brood development, foraging and fungus-comb establishment. This is a significant achievement not only for the purposes of obtaining further information on the biology, feeding habits and food preferences of termites in the laboratory but also for the bioassay of candidate insecticides for subsequent control measures in the field.

From the field trials it was found that carbofuran (Furadan 3G) did not give significant control of soil pests of groundnuts.

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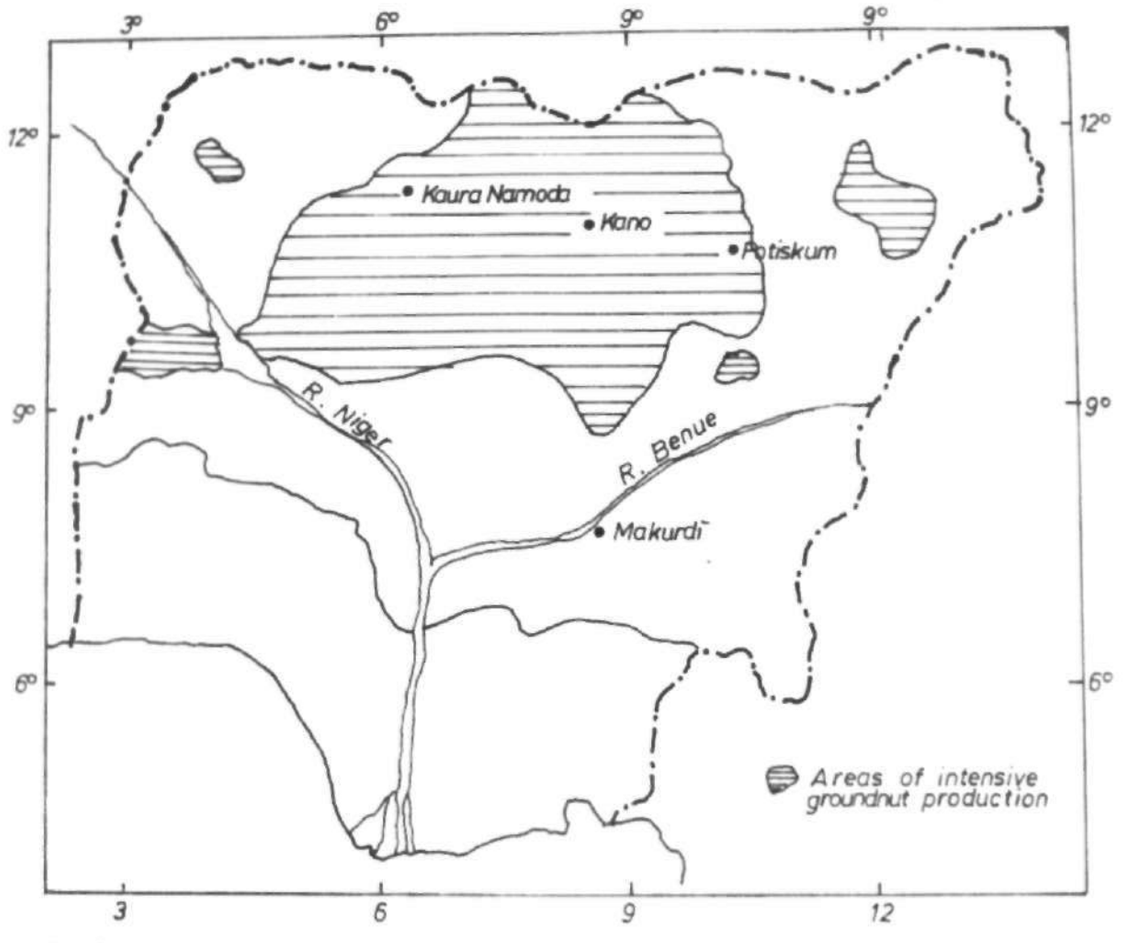


Fig 1 AREAS OF INTENSIVE GROUNDNUT PRODUCTION IN NORTHERN NIGERIA (Source AERLS Extension bulletin No 2)

INTRODUCTION

Groundnut (Arachis hypogaea, L.) is an oil crop that is important for its nutritional value. As a result of the importance attached to plant proteins during the post World War II, groundnut production and exportation became a national priority (Harkness, 1970).

Groundnut and groundnut products constituted about 20% or more of Nigeria's export earning during the decade 1956-1966, (Harkness, 1970). However, as a result of the numerous problems which have faced groundnut production recently namely; pests and disease-attack, lack of improved inputs and drought, Nigeria now imports groundnuts. A case in point was the 1975 groundnut crop failure due mainly to the rosette virus epidemic. Among the numerous arthropod pests that attack groundnut, termites (Johnson and Wood, 1980) and millipedes (Raheja, 1975) are the major soil pests of groundnut.

Whereas termites are most important in the Sudan Savannah, Wood et al. (1977), millipedes appear to be a serious problem in some parts of the savannah regions in Nigeria. In other West African countries like Senegal where groundnuts are grown, millipedes are also serious pests of the crop.

Groundnut being a crop of great economic importance, it is therefore necessary to quantify the damage done by these pest species with a view to designing control measures to combat their effects on the crop.

SECTION I

REVIEW OF LITERATURE

1.1 Origin and Economic Importance of Groundnuts

Groundnut (Arachis hypogaea L.) a legume known as peanut in other parts of the world, is an oil crop and one of the main cash crops of Nigeria.

The crop is a native of South America (Brazil) and was introduced into this country in the 16th century by the Portugese (Hammons, 1973).

Groundnut as the name implies, develops underground. It is a cultivated annual or weakly perennial herb grown in many tropical and subtropical countries. After fertilization the peg grows downwards, enter the soil and then bends into a horizontal plane. The tip of the peg contains two and occasionally three or four fertilized ovules. At maturity the economic part, the kernels are contained within the pods, which later become dry and brittle.

The major groundnut producing counttries in the world are Senegal, United States of America, India, China and Nigeria. The crop is grown extensively in West Africa and from the Sudan to South Africa in the East. Nigeria and Sudan are the major African producing nations, with a total

annual production of 2.2 million metric tons from 2.4 million hectare of land (Rachie, 1973). Africa's contribution to the world groundnut supply has declined considerably since the middle part of the 1960's from 5.6 million metric tons or 36% of the world total in 1965-1966 to 4.6 million metric tons or about 26% in 1978-1979 (Abdullah, 1979). Africa's share of world groundnut export market declined from 88% in 1968 to 43% in 1977. There was also a decline in Africa's oil export market from 78% in 1968 to 55% in 1977 (Abdullah, 1979).

Although groundnut is grown in most parts of Nigeria, the soil and climate, north of latitude $9^{o}N$ is most suitable for its production. The major groundnut producing states in Nigeria are Kano, Kaduna, Borno, Bauchi, Niger and parts of Sokoto state (Fig. 1).

Groundnut thrives best on soils which are sandy and free-draining (Food and Agricultural Organization F.A.O. 1966, Yayock, 1978). The crop requires alot of sunshine and regular rainfull during growth. A total of about 750 mm of rain well spread over 110-140 days is usually adequate to produce a good crop.

Harkness et al. (1976) estimated that a total of 1.2 million hectares are devoted to groundnut with an

estimated total output of nearly one million metric tons of kernels annually. Ninety percent of the yearly production comes from areas north of Latitude 11°N.

Groundnut is important in Nigerian diet as it is a rich source of protein (25%) and oil (40-45%). The seeds are eaten raw, roasted or boiled or made into groundnut flour. The oil is used in cooking and in the manufacture of margarine, cosmetics etc. The cake and husks are valuable livestock feeds (Ribah, 1975). The decline in Nigeria groundnut production could be attributable to many factors. Abdullah (1979) listed the major factors as follows:

1. Lack of good quality seeds that are early maturing disease and pest resistant.
2. A shift in weather patterns characterised by repeated drought.
3. Shortages of inputs as labour, fertilizers and chemicals.

Repeated crop failures have induced shifts in cropping patterns, mainly diverting land from groundnut to other crops that require less labour and entails less risks. Groundnut production is labour intensive, compared with millet and other crop options. Higher per capita income, resulting from higher petroleum incomes in recent years has

boosted the standard of living and large numbers of farm workers have migrated to the cities leaving a labour deficit in the agricultural areas (Abdullah, 1979).

Insect pests constitutes one of the greatest limiting factors in groundnut production in Nigeria. Misari (1975) has shown that over seventy-three species of insects from eight orders of insect do attack groundnut.

Misari and Raheja (1976) classified the major arthropod pests of groundnut into three groups namely:

1. Shoot and foliage feeders
2. Flower feeders
3. Root and Pod feeders

Amongst the pests of groundnut, Aphis craccivora Koch (family: Aphididae) and soil arthropods notably millipedes and termites constitute the major pests of groundnut (Taylor, 1967).

1.2 Aerial Pests

The most important of the aerial pests of groundnut is the aphid, Aphis craccivora (A'Brook, 1968, Akinfenwa, 1978). In addition to sucking sap which leads to loss in plant vigour, the most important damage done by this aphid is the transmission of groundnut rosette virus (Storey, 1925; Misari and Raheja, 1976). Crop damage

resulting from aphid activity has been estimated at 5% (Johnson et al., 1978). In 1975, more than half the Nigeria's crop of groundnut was destroyed by the groundnut rosette epidemic (Yayock et al., 1976). Observation has been made that the critical period for direct injury that would lead to economic loss is the first four weeks of the crop growth (Rossion, 1976).

Other very important aerial pests of groundnut include the phytophagous (Empoasca dolichi (family - Jassidae) and the flower beetles belonging to the family Meloidae (Misari, 1975). Of minor importance are Monolepta spp., Luperodes spp., Ootheca mutabilis (sahlb), red spider mites and grasshoppers (Misari, 1975).

1.3 Soil Pests

Soil pests of groundnut are those that attack the underground parts of the plant. These include pests which attack pegs, pods and roots. Termites (Wood et al. 1977) and millipedes (Raheja, 1975) are the major soil pests of groundnut. Unlike the foliage pests, very little work has been done on soil pests of groundnut and their control.

TERMITES (Isoptera)

About 2000 species of termites are known and as much as 10% of these are damaging to crops, (Sands, 1973). Termites are mainly tropical pests and in Nigeria, they are abundant

in the relatively drier savannah zones (Wood, et al. 1977). The major termite pests of agricultural importance belong to the family Termitidae. This family comprises 60% of the entire termite species recorded as crop pests (Sands, 1973). The subfamily Macrotermitinae which has been associated with the attack of major crops in Nigeria belong to the group known as "fungus growers". Some members of this subfamily for example Macrotermes bellicosus (Smeathman), construct above ground nests, while others such as Microtermes spp are completely subterranean. Some species like Macrotermes subhyalinus (Rambur) builds mounds in certain areas but are completely subterranean in others (Wood and Ohiagu, 1976, Onu and Ohiagu, 1980). Termite attack on crops is mostly confined to periods of high water stress. Furthermore, termites prefer their food dry and as such, crops harvested late are much more severely attacked than early harvested crops.

1.4 Termite Damage on Groundnut

Groundnut is very frequently attacked by termites. Most of the species of termite that cause damage in Nigeria belong to the subfamily Macrotermitinae. The important termite species that damage groundnuts in Nigeria are Microtermes lepidus (Sjostedt), Odontotermes spp.

(Harris, 1969; Johnson *et al*., 1981) and *Macrotermes subhyalinus* (Wood *et al*., 1977; Onu and Ohiagu, 1980).

Microtermes lepidus, is the most common and the most serious termite pest species on groundnut. They are the most abundant species in the northern and southern Guinea savannah zones of Nigeria, constituting about 62.2% in undisturbed secondary wood land of these zones (Wood *et al*. 1977). Members of this genus have subterranean nests, consisting of chambers 3-4 cm in diameter. They can survive bush clearing and cultivation. Wood *et al*. (1977) noted that on land cultivated for 8 to 24 years, *Microtermes* spp. and *Amitermes* spp. made up more than 90% of the termite population.

1.5 *Mode of attack on groundnut*

Microtermes spp. attack groundnut in different ways in Nigeria. Johnson, (1978) and Johnson *et al*. (1981) classified the attack of *Microtermes* spp. on groundnut into three categories.

1. Attack on tap root and stems
2. Attack on pegs
3. Attack on pods and seeds.

Generally termite damage to groundnut in all the major groundnut growing countries in Africa consists of initial

entry through the root collar (Sands, 1962). Microtermes attacks the tap roots, hollows it out and works its way up the stem resulting in a reduction of the flow of sap up the shoot (Perry, 1967). This mode of attack results in the wilting and premature death of the plant. In some instances the roots could be severed at ground level, leading to a complete loss of the crop. Sand, (1962) recorded up to 30% of groundnut plants killed by Microtermes spp. in northern Nigeria and in northern India. Odontoterms obesus (Rambur) is reported to have killed up to 50% of the plants (Kraushal and Deshpande, 1967). Attack on the root and stem also leads to the reduction in the amount of haulms (harawa), available for dry season feeding of livestock (Johnson, 1978).

Attack on the Pods

Damage to pods is in most cases caused by Microtermes spp. They usually enter the pods just behind the beak, leaving one or more small rounded holes in the shell, approximately 1 mm. in diameter. They attack the kernel, removing the inner linning of the shell, which they replace with soil. Johnson et al. (1981) reported that scarification of pods is caused by Microtermes lepidus. They reported that such damage are restricted to the more mature

pods. More incidences of scarification are reported in the dead stands (40.9-87.9%) than in the healthy stands (7.9-31.6%).

Johnson (1978), noted that in Talata-Mafara (Sokoto State), 88% of the kernels from heavily scarified pods were infected by various fungi, compared with only 14% in unattacked pods. The commonest fungi found in this location was Macrophomina phaseoli (Maubl.) , a fungus known to cause seedling disease and strongly implicated in the condition known as concealed damage (internal decay) and deterioration of the seed. This type of damage can produce an unpleasant taste and can result in an unacceptable increase in the level of free fatty acids.

Attack on Pegs

Microtermes spp. attack the pegs and severe the pods from the haulms thereby increasing the percentage gleanings at harvest (Johnson, 1978). Such detached pods could be attacked by soil fungi.

Different species of termites attack groundnut in different parts of the world where groundnuts are grown in commercial quantities. Microtermes spp. is common to both Nigeria and the Gambia. Other species found in the Gambia are Microcerotermes spp. and Ancistrotermes thorocalis

(Sjostedt), Macrotermes bellicosus and Macrotermes natulensis (Haviland) (Magar, 1976).

Sands (1962) reported only 10% loss in crops in northern Nigeria due to termite attack. However, yield loss attributable to termite damage on groundnut could be as high as 40% in the Sudan Savannah (Johnson, et al. 1981). Johnson (1981) found a close correlation between the number of stands attacked by termites and the resulting yield loss. It was his view that if future work substantiated this relationship, then survey work would be simplified.

Losses resulting from termite attack on groundnut can be minimised by good crop husbandry such as early planting of good quality, uniform variety seeds (Misari, 1975; Johnson and Wood, 1980). Prompt hoeing and weed ing or ridging soon after rain disrupts the foraging galleries of termite and exposes them to predatory insects, thus reducing their numbers.

1.6 Millipede damage on Groundnut

Raheja (1975) identified millipedes as one of the potential arthropod pests of groundnut in Nigeria. Except for some investigatory work done by Misari (1975; 1981) and Johnson (1978) there has been no concerted effort in

quantifying the damage done by millipedes on groundnut in Nigeria.

Millipedes (Diplopoda) are found in soils from depths ranging from 10-80 cm. Activities of millipedes are confined to the rainy season when they appear on the surface of the soil. They may also be seen in the dry season where they avoid high temperature light and dry air. Thus they occur during the day time in hidden places which are cool, dark and moist (Toye, 1966).

Millipedes have been found to damage groundnut in nearly all the major groundnut growing countries in Africa; and their importance has been extensively studied in Senegal. Here, millipedes were found to be a serious pest on groundnut especially in the southern parts between the region covered by 70-100 cm rainfall Isolyet (Rossion, 1976). Whereas Peridontopyge spinossissima (Silvestri) is said to be the dominant millipede pest of groundnut in Nigeria (Raheja, 1975, Misari, 1975). Peridontopyge rubescence and Peridontopyge cenani are the dominant species in Senegal (Rossion, 1976). Other very common species of millipedes in the Senegal are Haplothysamus chapellai (Demange), Synodesmogenus spp.; Graphidostreptus spp. and Peridontopyge spinossissima.

In the Sudan several species of millipedes are found on groundnut but the species of millipedes belonging to the family Julidae locally known as "Surfa" are most common (Ahmad and Amin 1976).

1.7 Mode of attack

Observation has been made that millipede attack on groundnut are much more pronounced during two distinct developmental phases of the crop, germination and pod formation (Rossion, 1976). This agrees with the observation made in Nigeria by Raheja (1975) and Johnson (1978) that major millipede attack is confined to the period of pod formation. Millipedes have been observed attacking the cotyledon, radicle and more frequently the hypocotyl axis. Observation made in Gambia, Sudan and Senegal reveal that millipedes erode the cortical tissues of the plant. The openings left by the millipede damage, predisposes the plant to the entry of fungal pathogens. Investigations have shown that the number of plant stands could be reduced by 5 to 10% as a direct or indirect result of millipede attack (Rossion, 1976). After the gynophore formation the immature stages of millipedes (Peridontopyge spp.) penetrates the shell, leaving a small round hole 1 to 4 mm in diameter (Johnson et al. 1981). They feed on the inner linning of

the shell and the developing kernels. The size of the entrance hole often distinguished millipede attack from that of Microtermes spp. Losses resulting from this early attack by millipedes have not been quantified. Losses due to millipede attack are estimated to be between 10-20% of the total harvest in Senegal (Rossion, 1976) and from Nigeria, Raheja (1975) estimated that as much as 10% pods were lost due to millipede attack. Studies by Misari (1981) showed that the percentage pod damage by millipedes ranged from 1 to 39% and varied from place to place, from year to year and even among varieties.

Africa Groundnut Council report (Anon. 1976) suggested the incorporation of repellents such as napthaline flakes in the top 6 inches (22.5 cm) of the soil to control millipedes.

In Senegal a mixture of 88.9% Heptachlor 40 and 11.1% Lindane 90% is added to 50 Kg of wet millet flour and whole mixture spread at the time of sowing. Attack by millipedes was said to have been controlled through this method by about 50% (Rossion, 1976).

1.8 Scarabaeids

Other important groups of soil pests of groundnut belong to the family Scarabaeidae. In countries like Sudan, Senegal and Gambia where extensive work has been done, the following scarabaeid genera are found to be of economic importance: Trochalus spp. and Schizony cha africana (Lap.) (Hill, 1975, Magar, 1976). The damage is done by the larval stage of the insects. The larvae are soil dwellers and damage the pods of groundnut. Freshly turned soil, high in organic matter, is reputed to be attractive to the adult beetles. Eggs are laid in the soil, the larvae that emerge are white, fleshy, with a curved C-shaped body. The larval stage lasts for about six months (Hill, 1975). The larvae girdles the collar and excavates the plant leaving it partially severed. This provides an avenue for the entry of secondary organisms. The damage done by scarabaeids has not been quantified.

1.9 Nematodes

In Nigeria the most important genera of Nematode infesting groundnut is the testa nematodes Aphelenchoides arachidis (Bos). The testa Nematode was first found in groundnut seeds at Samaru, (Bos, 1977).

The Nematodes attack roots, hypocotyl, and pods from an early stage in plant development but they have not been found in cotyledon or embryo of seeds. As much as 25% of groundnut seeds were infested with the testa nematode (McDonald et al. 1979). Over 11 nematode species have been found associated with groundnut in Nigeria (Misari et al. 1980). A detailed discussion on the damage caused by nematode is outside the scope of this study, in any case, general observation suggest that they may not be a serious problem on groundnut (Johnson et al. 1981).

SECTION II

2.1 SURVEY OF SOIL PESTS IN THE MAJOR GROUNDNUT GROWING AREAS OF THE NORTHERN STATES

The purpose of the surveys was three fold:

(a) To delineate areas within the groundnut growing zones where soil pests are of importance in groundnut production.

(b) To identify the soil pests involved and nature of their damage.

(c) To identify the stages in the growth and development of the crop when it is most vulnerable to attack.

2.2 Survey Locations

A brief survey of the groundnut growing areas was made soon after planting and at harvest during the 1980 cropping season. Three types of farms were surveyed, namely: large partially mechanised farms belonging to the Institute for Agricultural Research, farms owned by the Ministry of Agriculture (Farm Centres) and farmers field. The survey covered all the major groundnut producing areas of the northern states, namely: Kano, Sokoto, Borno, Bauchi, Gongola, Kaduna, Plateau, Benue and Niger States.

The various locations within each state visited are shown in Fig. 2.

Out of the total of 20 locations surveyed 50% of them were located in the Sudan Savannah, 15% in the northern Guinea Savanna and 5% in the southern Guinea Savanna zones. More areas were surveyed within the Sudan Savanna because of the importance of the crop in this zone.

2.3 Materials and Methods

Small kits containing hand trowels, plastic bags, specimen tubes and alcohol were used for the surveys. Fields were inspected and observations on plant spacing, crop variety and plant growth stages were recorded. Visual estimates of wilted or wilting plants within each field were recorded. Farmers were interviewed and information obtained on the time of planting, source and variety of seeds, use of improved inputs like fertilizer and chemicals, types of soil pests causing damage to their crops.

Pre-harvest samples were taken from each of the farms visited. Five to ten plants were removed at random together with the soil covered by the plant's canopy. The entire plant and soil samples were bagged, labelled, and brought back to the laboratory. The samples were hand-sorted for arthropod pests, millipedes, termites and scarabaeids.

Damage assessment was made at harvest by taking five to ten plants per field and determining total numbers of pods, number of pods damaged by termites, millipedes, scarabaeids or by a combination of these pests. Damage done by termites on groundnut pods were categorised on the basis of the intensity of pod scarification into light, moderate and severe. Damage to the root system and attack on haulms was recorded. Termites associated with the attacked plants were collected for identification. Damage done to groundnut pods by millipedes was assessed by the characteristic small rounded holes 1-4mm in diameter on the pods. The size of the entrance holes often distinguished millipede damage from those of termites. The intensity of wilting in any field was categorised as follows:-

Very severe - over 50% wilting

Severe - 30% - 50% wilting

Moderate - 20 - 30% wilting

Light - 10 - 20% wilting

2.4 Results and Discussions

Interviews with Local Farmers

A majority of the farmers interviewed acknowledged aphids, termites and millipedes as the three most important

pests attacking groundnuts in their fields, while a few farmers were only aware of aphids. The timing of attack, especially by millipedes and termites seemed to be fairly well known by a majority of the farmers. The farmers were also aware that severe damage to groundnut by millipedes did not occur every year; and that termite damage to groundnut increased as the crop matured. Other factors affecting groundnut yields besides arthropod pests were also identified. These included lack of labour, fertilizers and chemicals, low yielding local varieties and non adoption of extension information. It was observed that most farmers were less willing to adopt the Agricultural Extension Research Liason Services (AERLS) groundnut spacing recommendation of 23 cm apart. Farmers in places like Potiskum, Kila, Yana, Bama maintained a wide spacing of about a metre. The non-adoption of the spacing recommendation which for instance predisposes groundnut to green rosette disease causes considerable loss in yield. A farmer interviewed at Guma (Bauchi State) confirmed that most of the groundnut farmers in the village were unable to increase groundnut production because of lack of farm labour and chemicals. Moreover, when such improved inputs like fertilizers and chemicals were made available, they normally came very

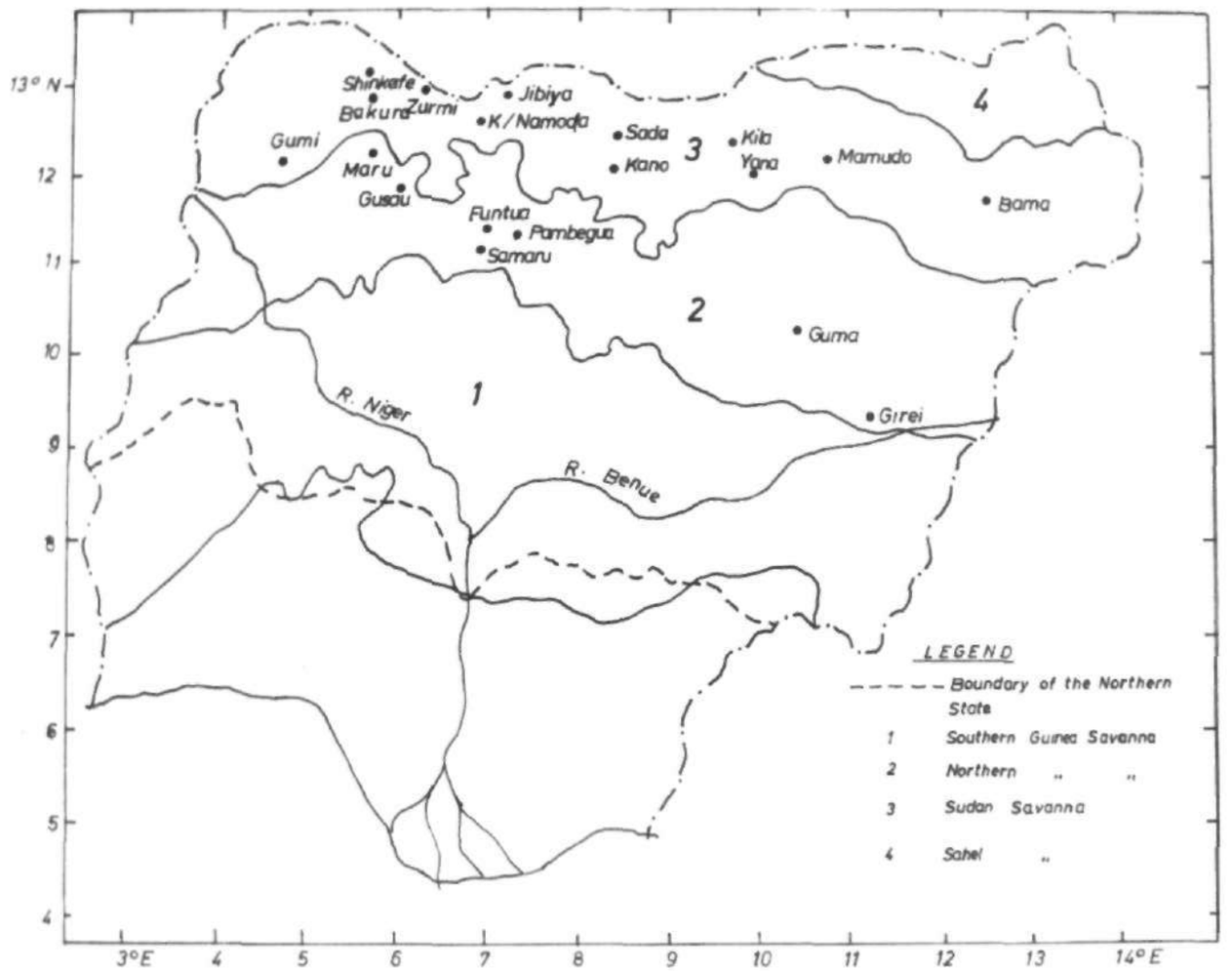


Fig 2 GROUNDNUT SOIL PEST SURVEY LOCATION 1980

late when their application would not make significant increases in yield.

Use of local low yielding varieties

Agricultural Extension and Research Liason Services recommends the following groundnut varieties for different locations in the northern states (AERLS recommended practices for Groundnut Production in Northern States).

State	Varieties Recommended
Sokoto	MK374, Samaru 61
Niger	MK374, Spanish 205
Kano	Samaru 61, DS569
Benue	MK374, T28-240
Plateau	Samaru 38, MK374
Gongola	MK374
Bauchi	G.153
Borno	G.153, Samaru 61, DS5418
Kaduna	Samaru 38, Samaru 61, DS569

Despite the above recommendations, majority of farmers use local groundnut varieties that are relatively low yielding. Harkness *et al.* (1976), observed that only 6% of the whole land area is grown with improved and recommended varieties of groundnut. Low-yielding local varieties do not readily respond to the application of improved farm inputs.



Plate 1. Damage caused by soil pests on groundnut pods by termites and millipedes.

2.5 Damage by termites

Damage by termites observed during the survey can be categorised into the following:

(a) attack on tap root,

(b) attack on pegs and pods, and

(c) attack on foliage.

Attack on tap root: It was observed in most of the areas visi ted that the most common termite spp. attacking the root system of groundnut was Microtermes spp. They penetrate and hollow out the tap root and this results in wilting and premature death of the plant. From visual estimate made on some farms percentage wilting due to termite attack on growing plants varied from 1% at Makera (Gongola State) to 20% at Biu (Borno State).

Attack on pegs and pods: Microtermes spp. was observed attacking the pegs and subsequently the pods of groundnut. The attack on the pegs resulted in increased gleanings at harvest. Also Microtermes spp. was observed scarifying the more matured pods, occasionally Microtermes spp. was observed penetrating the pods and feeding on the pod linnings and the kernels, (Plate 1).

Attack on foliage: Odontotermes spp. and Macrotermes subhyalinus (Rambur) were observed attacking foliage of already wilted and dead stands. This attack resulted in



Plate 2. Millipede feeding on groundnut pod.

the reduction in the quantity of haulms obtained at harvest. Table 1 shows the result of damage assessment made in 1980. Damage by termites on pods ranged from 0.0 at Anka to 45% at Bakura. There appears to be a linear relationship between level of wilting and damage to pods as demonstrated at Mamudo, Sada and Gumi where wilting was severe (50% or above) and the amount of damage to pods was 7.8%, and 13.1% respectively. Low percentage damage of 1.7%, 4.6%, 1.5% were obtained from Samaru, Wudil and Guma respectively, where wilting was light (10-20%).

2.6 Millipedes

Damage to seedlings: Millipedes belonging to the genus Peridontopyge spp. damage groundnut seedling after germination. During the preharvest survey, 2 to 3 millipedes/plant were recorded in some of the location like Mamudo and Bakura.

Damage to pods: During podding, immature stages of millipedes penetrate the shell of groundnut. Damage done to groundnut pods by millipedes are recognised by the characteristic small holes on groundnut pods, (Plates 2 and 3). The size of the entrance hole (1-4 mm diameter) often distinguishes millipedes damage from that of termites. Johnson et al. (1981) indicated that attack



Plate 3. Groundnut plant with pods showing damage by soil pests.

Table 1 : Summary of Damage Assessment at Harvest by Termites and Millipedes

Date	Location	Wilting (Visual Estimates)	Total No. of Pods Sampled	% Damage to Pods by Milli-pedes	Termi-tes
Sept. 1980	SAMARU	Light	295	17.6	1.7
" "	NGURORE	Light	1048	27.2	1.0
" "	GIREI	Moderate	326	16.9	4.9
Oct. 1980	NAMUDO	Severe	371	5.9	7.8
" "	SADA	Severe	59	10.2	4.1
" "	WUDIL	Light	717	3.3	4.0
" "	YANA	Light	438	3.0	3.9
" "	BAMA	Moderate	274	11.7	5.2
" "	GUMA	Light	343	11.1	1.5
" "	BAKURA (MOA)	Fields Harvested	260	9.2	41.5
" "	BAKURA (IRS)	Fields Harvested	1020	1.7	5.9
" "	T/MAFARA	Fields Harvested	250	6.8	12.0
" "	SHINKAFE	Fields Harvested	110	4.3	13.9
" "	ANKA	Moderate	251	13.1	4.8
" "	GUMI	Severe	122	5.7	13.1
" "	K/NAMODA	Fields Harvested	439	10.3	14.1
" "	GUSAU	Severe	56	3.6	23.2

IRS = Irrigation Research Station

MOA = Ministry of Agriculture

by millipedes at podding was largely restricted to immature pods when the length of the pods varied from 15-20 mm. Penetration of pods allow the millipedes to feed on the inner linning of the shell and the developing kernels.

Damage by millipedes was mostly marked in the following locations, Ngurore 27.2%, Girei 16.9%, Samaru 17.6%, Bama 11.7%, Anka 13.1%, and Guma 11.1%. Other areas that suffered substantial damage to the pods through millipede attack included Sada 10.2%, Bakura 9.2% and Kaura Namoda 10.3% (Table 1).

2.7 Scarabaeids

The major scarabaeid pests of groundnut, Schyzonycha africana (Lap.) was almost absent in all the area surveyed except at Guma and Ngurore, where substantial population was found on the groundnut crop. In these areas the soils were moist and quite high in organic matter content.

SECTION III

BIOLOGICAL STUDIES

Laboratory culture and study of the biology of *Macrotermes subhyalinus* (Rambur) (Isoptera, Termitidae).

3.1 Materials and Methods

Macrotermes subhyalinus colonies were reared by two methods. The first was the aluminium foil cup method (Plate 4). Aluminium foil was made into cups, 10.8 cm high and 7.4 cm in diameter. Each cup was filled with sifted sterilized subsoil to a depth of 5.4 cm and with similarly treated top soil to a depth of a further 5.0 cm. Thirty such cups were constructed. A glass rod was used to make a depression on each of the cups so as to provide an entry point for the reproductives.

The second method was the glass plate method (Plate 5). This is similar in construction to that described by Luscher (1949) and Williams (1959). These plates consist of two sheets of glass 20.5 cm separated by 0.25 cm wide glass strips on three sides and filled with sifted subsoil to a depth of 5 cm and top soil to a further depth of 5 cm. Ten such glass plates were constructed.



Plate 4. Aluminium foil cups used in culturing M.subhyalinus (Rambur)



Plate 5. Glassplate used in culturing M.subhyalinus.

De-alate reproductives formed tandem pairs after flight and were collected under light between 9.00-9.30 pm on the 28th of May, 1980. Collection was done by allowing the tandem pairs to crawl into 3 cm x 1 cm tubes placed on their path. The tubes were inverted into the aluminium foil cups and the tandems quickly burrowed, within 20 minutes, into the soil. The entry hole was later plugged with soil. Similarly, de-alate tandems were introduced into the glass plates. The glass plate cultures were initially kept vertical to allow the reproductives to burrow sufficiently down. Thereafter, they were laid horizontally. Both cultures were kept moist at room temperature which fluctuated between 25-32^{o}C. The progress of the incipient colonies was monitored at weekly intervals.

3.2 Results and Discussion

Out of the 10 glass plate cultures set up, only 2 survived the first 2 weeks. This high mortality was attributed to inadequate development space to accommodate the fairly large introduced reproductives. A few observations, especially on foraging, were made on the two surviving cultures. Twenty-nine of the 30 aluminium foil cup cultures survived and the bulk of the weekly samples were taken from this set of cultures.

In both containers, the reproductives burrowed to depths of 6.0 to 7.0 cm. At the end of burrowing, the copularium, a rounded chamber of repacked soil, neatly polished with saliva was formed. This had a mean volume of 1.76 cub.cm. Copulation and extensive gromming of the female by the male took place within this chamber (Plate 6). A summary of the major events in colony development of M. subhyalinus is given in Table 5.

Oviposition: This commenced 7-10 days after the introduction of the tandem pair. The eggs, sausage shaped, transluscent, with a mean length of 0.79m±0.0010 were laid in batches of about 4-6 eggs per batch. An average of 26 eggs with a range of 8-52 eggs per colony were laid. The low egg numbers observed was attributed to intensive oophagy which was observed in some of the cultures.

Brood development: Grooming and rearrangement of the eggs continued and the first batch of larvae appeared in the colony between 35-38 days. This first batch of larvae were uniform in size and morphology and belonged to the worker castes as shown through the examination of their mouth parts. As the colonies progressed, four larval instars were discerned, on the basis of some morphological features, such as instar straight length, mouth part



Plate 6. Grooming of the female by the male within the copularium

development and number of antennal segments, (Table 2). The first larval instar had a straight length of 1.75 ± 0.0004 mm, as compared with 2nd instar (2.17 ± 0.0006 mm), 3rd and 4th instars of lengths 3.17 ± 0.0002 mm and 3.98 ± 0.0002 mm respectively. Mouth parts were rudimentary in 1st and 2nd instars, but became fully formed and terminally sclerotized in the 3rd instar. At the 4th instar there was full sclerotization of the mouthparts. Differences were also noticed in the number of antennal segments in the different instars. The 4th instar larvae had 17 antennal segments as compared with 14, 14 and 16 segments in the 1st, 2nd and 3rd instars respectively.

The mean number of individual castes within the cultures is summarised in Table 3. Generally number of individuals was low in the laboratory cultures as against what obtains in the field. It does appear that incipient colonies had limited reproductive capacity in the laboratory. However, the major workers out-numbered other castes. Ratio of major:minor workers was estimated at 2 : 1. Major workers were distinguished from minor workers through head width measurements (Table 4). Minor soldiers emerged between the 55 - 59 days after introduction. They had an average body length of 6.65 mm and head width of 2.20 ± 0.002 mm. Sclerotization of the mouthparts occurred two

Table 2: Development of Larval Instars in M. subhyalinus (Rambur)

Instars	Larval Length mm	Mouth Parts	Antennal Segments	Hairs and Bristles
Egg	0.77 ± 0.0010	-	-	-
1st	1.75 ± 0.0004	Rudimentary mouthparts	14	Bristles on Antennae
2nd	2.17 ± 0.0001	Maxillary palps fully formed and Labial palps formed.	14	Bristles on Abdomen
3rd	3.17 ± 0.0002	Well formed with two cutting edges	16	Reduction of bristles on abdomen
4th	3.98 ± 0.0002	Fully formed with three Sclerotized cutting edges. Labrum hyaline tipped	17	-

Table 3: Mean Number of Individuals in Laboratory Cultures of M.subhyalinus

Pre-adult stage				Workers				Soldiers	
Eggs		Larvae		Major		Minor		Minor	Major
Mean No.	Range	Mean No.	Range	Mean No.	Range	Mean No.	Range	Mean No.	Range	-
26	8-52	20	6-36	9	3-25	19	9-25	2	1-3	

Table 4: Head width and Head length measurements of the different castes (mm)

	MAJOR WORKERS	MINOR WORKERS	MINOR SOLDIERS
Head width	1.75 ± 0.0001	1.32 ± 0.0001	2.20 ± 0.002
Head length	2.52 ± 0.0002	1.67 ± 0.0001	2.81 ± 0.002

Table 5: Summary of colony development in M. subhyalinus

Days	Events
0	Introduction of the tandem pairs and burrowing.
1 - 6	Grooming and construction of the copularium.
7 - 10	Nest improvement and oviposition.
13 - 38	Hatching of eggs.
55 - 59	Emergence of soldier castes.
60 - 70	Sclerotization of workers.
73 - 80	Sclerotization of minor soldiers.
90 - 94	Foraging activities commenced.
113	Fungus - comb formation.

weeks later. Minor soldiers ranged from 1-3 per culture. No major soldiers were observed in any of the cultures. Ratio of workers to soldiers was estimated at 8 : 1.

Foraging and establishment of fungus combs:

Foraging commenced at about the 13th week (90-94 days). Foraging activity was clearly shown in the glass plate cultures. Foraging gallery began in the root of the copularium and proceeded in the direction of the soil surface. In the aluminium foil cultures, foraging was indicated by galleries constructed with subsoil brought to the surface.

The construction of the primordial fungus comb started in the aluminium foil cultures at about the 16th week (3 weeks after commencement of foraging). This structure was first seen as a short pillar of tiny balls of soil attached to the wall of the copularium. Cultures examined 2-3 weeks later after the appearance of the fungus comb showed some fungal mycelia on the combs. Since the cultures were raised on sterile soil, it is possible that the fungus comb may have been innoculated by fungal spores on the body of the founding reproductive pair. This observation agrees with that made by Wood et al. (1979) on Microtermes spp. in the southern Guinea savanna of Nigeria.

SECTION IV

FIELD EXPERIMENTS

Four locations were selected for field experiments, Bakura, Sada, Mamudo and Samaru. The aim of the experiments was to test the efficacy of three levels of Furadan 3G, a soil insecticide, in controlling soil pests attacking groundnuts. In the Samaru experimental site systematic sampling was done to ascertain damage to the various stages of the crop's growth. The Bakura, Mamudo, Sada experimental sites were selected on the basis of the relatively high mean number of millipede population, (2 millipedes/plant) as indicated in the field surveys (Section 2).

4.1 Sites

Samaru is located in the Northern Guinea Savanna Zone with a mean annual rainfall of 1125 mm. The field was located at the Institute for Agricultural Research Farm. Groundnut was planted there in the previous cropping season (1980). Bakura has a mean annual rainfall of about 591.5mm. The field belongs to the Sokoto State Ministry of Agriculture. Millet was planted at the site in the previous season.

Sada has a mean annual rainfall of 560mm and the field belong to the Kano State Farm Training Centre. Millet was planted on it the previous season. Mamudo has a mean annual

rainfall of 425 mm and the field belongs to the Borno State Farm Training Centre. Sorghum and cowpea were grown on it in the previous season. All the fields have a long history of cultivation.

4.2 Materials and Methods

The layout of the experiment was a randomized complete block design with three treatments and a control, replicated four times.

Each plot measured 10m x 10m with a metre wide buffer area between each plot. The variety 'Samaru 38' was used at the recommended spacing of 23 cm on ridges. All other recommended agronomic practices with respect to fertilizer application and weeding were followed.

Three different levels of carbofuran (Furadan 3G, F.M.C.; U.S.A.) corresponding to 2 kg a.i/ha, 1.5kg a.i/ha and 1.0 kg a.i/ha were applied at planting into grooves made at the sides of each row. Index of termite population was determined through attack on soft wooden baits each measuring 15.2 cm x 2.5 cm. These were placed in a grid system one week after sowing. Ten baits were used per plot. The baits were checked at weekly intervals for termite attack. The intensity of termite foraging was measured by the rate of discovery of baits (i.e. percentage attack on baits).

At Samaru, millipede surface counts were also made at weekly intervals on treated and untreated plots between the hours of 0600-0700 hours soon after planting. Counts of both living and dead millipedes were taken during each weekly observation.

Counts of dead, wilting plants were taken at weekly intervals in all the locations.

4.3 Damage Assessment

At harvest, damage assessment was carried out to determine the following parameters (a) damage by termite and millipedes and (b) yield.

Percentage gleanings of pods per plant was estimated, by sampling ten healthy and ten wilting or dying plants at random from each plot. The soil area from where the plant was removed was searched in order to determine the number of gleaned pods. Counts of each category of pods (gleaned and attached) were made and percentage gleanings per plant calculated.

4.4 Results and Discussion

Samaru Experiments:

Termite foraging activity measured by the Baiting Technique

Termite attack on soft wooden baits gives an estimate of the foraging activity of wood feeding termites. This

was shown at Mokwa to be closely related with estimates of absolute population density obtained by coring (Wood and Johnson, 1978). The index of efficiency of the applied insecticide can therefore be measured through this technique. The results are shown in Table 6. In the 1980 experiment percentage attack on baits was generally low in all the treatments. However, lower percentage attack (15.6% and 15.1% respectively) were recorded in treatments 2 and 3 representing 1.0kg a.i/ha and 1.5kg a.i/ha of Furadan 3G. Highest attack on baits (28.5%) was recorded in the 2.0kg a.i/ha plots. The most dominant species observed on the baits was Microtermes lepidus (sjostedt), a species which is responsible for the damage on groundnuts.

Table 6. Summary of Percentage Attack by Termites on Wooden Baits in Furadan 3G Treated Plots in 1980 and 1981 at Samaru

Furadan 3G (kg.a.i/ha)	% attack on wooden baits 1980	1981	Mean % attack
0 (control	22.7	17.3	20.0
1	15.6	20.3	17.9
1.5	15.1	21.3	18.2
2.0	28.5	24.0	26.2

Other termite species occasionally isolated from the baits included Ancistrotermes spp. and Odontotermes spp. No quantitative data on the amount of damage done by these later species was obtained.

Generally attack on baits was low in all the plots indicating a low termite population in the plots. The mean percentage attack on baits for the two years indicated a lower percentage attack of 17.9 and 18.2 on 1.0-1.5kg a.i/ha plots respectively. However plots with the highest dosage rate of 2.0kg a.i/ha gave the highest percentage attack on the baits. Reasons for this high percentage attack on these plots are not clear.

4.5 Surface Millipede Counts

Table 7 shows the summary of the counts of both dead and living surface millipedes at the experimental site in Samaru over a period of two years.

Surface Millipedes Live (SML): In 1980, highest mean numbers of (SML) was recorded in all treatments including control in the first five weeks of planting, ranging from 1.0 to 7.4 millipedes/plot. From the ninth week, mean number of (SML) decreased in all the treatments, and were not statistically significant (P = 0.05) from the control plots. However from the 6th week the mean numbers of SML

Table 7: RESULTS OF SURFACE MILLIPEDE COUNTS 1980 AND 1981

	Furadan 3G Treatments (kg a.i/ha)								Statistics							
	0		1.0		1.5		2.0		G.M		S.E		L.S.D		SIG.	
WEEKS	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981
SML.																
1	7.8	0.3	7.0	0.5	8.0	0.3	6.8	1.8	7.4	0.7	-	0.6		2.4	n.s	n.s
2	3.6	0.5	4.8	0.8	5.2	2.8	6.0	1.3	4.9	1.3	-	0.4		1.6	n.s	n.s
3	2.4	0.3	3.2	0.5	3.8	0.5	3.4	0.3	3.2	0.4	-	0.3		1.5	n.s	n.s
4	1.2	0.0	3.4	0.0	2.0	0.3	2.4	0.3	2.2	0.1	-	0.2		0.8	n.s	n.s
5	0.6	0.0	1.0	0.3	0.6	0.0	2.0	0.0	1.0	0.1	-	0.0		0.0	n.s	n.s
6	0.0[a]	0.0	0.6[a]	0.0	0.4[a]	0.3	1.6[b]	0.3	0.6	0.1	-	0.0		0.0	*	n.s
7	0.6	0.3	0.4	0.0	0.2	0.0	1.4	0.3	0.6	0.1	-	0.0		0.0	n.s	n.s
8	0.4	0.0	1.6	0.0	0.2	0.0	1.2	0.0	0.8	0.0	-	-		-	n.s	n.s
9	0.6	0.0	1.8	0.0	0.6	0.0	1.0	0.0	1.0	0.0	-	-		-	n.s	n.s
SMD.																
1	0.2	0.0	0.0	0.0	0.2	0.0	0.2	1.5	0.2	0.4	-	0.04		0.17	n.s	n.s
2	1.8	0.0	8.6	0.5	8.0	0.5	0.0	0.0	4.6	0.3	-	0.1		0.36	*	n.s
3	0.8[a]	0.3	8.0[b]	0.0	17.4[b]	0.0	0.0	0.0	6.6	0.3	-	0.01		0.02	*	n.s
4	0.0	0.0	0.4	0.0	0.2	0.0	0.0	0.0	0.2	0.0	-	-		-	n.s	n.s
5	0.6	0.0	1.0	0.0	1.2	0.0	0.0	0.0	0.7	0.0	-	-		-	n.s	n.s
6	0.6	0.0	0.4	0.3	0.6	0.0	0.0	0.0	0.4	0.1	-	-		-	n.s	n.s
7	0.4	0.0	0.2	0.0	0.6	0.0	0.0	0.0	0.3	0.0	-	-		-	n.s	n.s
8	0.2	0.0	0.0	0.0	0.6	0.0	0.4	0.0	0.3	0.0	-	-		-	n.s	n.s
9	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.0	-	-		-	n.s	n.s

SML - Surface millipede live. SMD = Surface millipede dead.
* - Significant (P=0.05) n.s = No signifant

recorded in the 2.0 kg a.i/ha plots were higher than other treatments and control. A similar trend was observed in 1981. However more SML was recorded in the treated plots but the differences observed between treated and control plot were not statistically significant. There seem to be no relationship between the populations of live millipedes and Furadan 3G treatments. Millipedes by nature are very migratory. It is therefore suggested that soil applied insecticides would not bring about any significant differences in the SML population on treated and control treatment, probably because of immigration from outside the experimental area.

Surface Millipedes Dead (SMD): In 1980, there was no difference between the mean number of dead millipedes in treated and control plot (Table 7) in the first week. However during the second and third weeks significant differences in the number of dead millipedes were recorded in the different treatments. The mean numbers of dead millipedes in 1.0kg a.i/ha and 1.5kg a.i/ha treatment was significantly higher than in the 2.0kg a.i/ha and control treatments in week 2 and 3 respectively. 1.5kg a.i/ha seemed to give the highest mortality of surface millipede in 1980. In 1981, more dead millipedes were recorded in

both treated and untreated plots. This period corresponds with the downward movement of millipedes into the soil. Similarly 1.5kg a.i/ha treatment seemed to give a better kill of millipedes.

4.6 Relationship between surface millipedes and time

The results of the surface millipede counts for 1980 did not indicate positive correlation between populations of surface millipede and time intervals in weeks. The practical implication of this relationship is that control can be timed to correspond with periods of high millipede populations. The correlation coefficient for the overall surface millipedes live (SML) was positive (R = 0.43) (Fig. 3). There was however a negative correlation (R = ¯0.26) between SMD and time (Fig. 4). This means that with time as the crop matures, there seems to be a sharp decrease in SMD indicating a reduction in the efficiency of the applied Furadan 3G to bring about a kill of the millipedes. Figure 3 indicates that the population of surface millipedes decreased with crop development. There is a slow rate of population decline from the 5th week and this continued until the 8th week when no more surface millipedes were observed. This period corresponds with the time when millipedes move into the soil to mate and feed on the developing groundnut pods. Figure 4 shows the

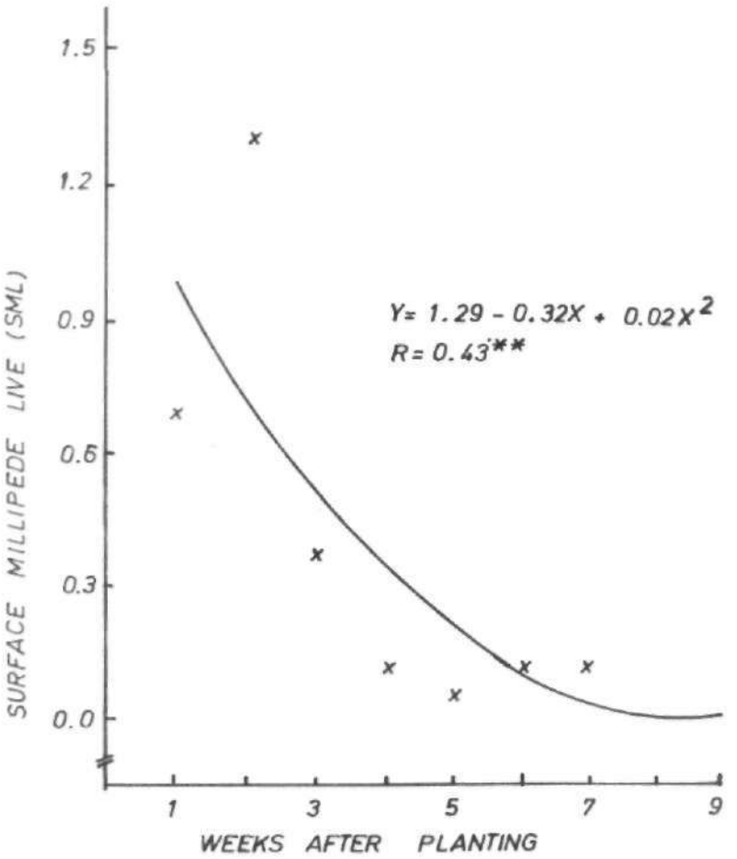


Fig 3 LINEAR REGRESSION OF OVERALL POPULATION SML AGAINST TIME INTERVAL IN WEEKS AFTER PLANTING

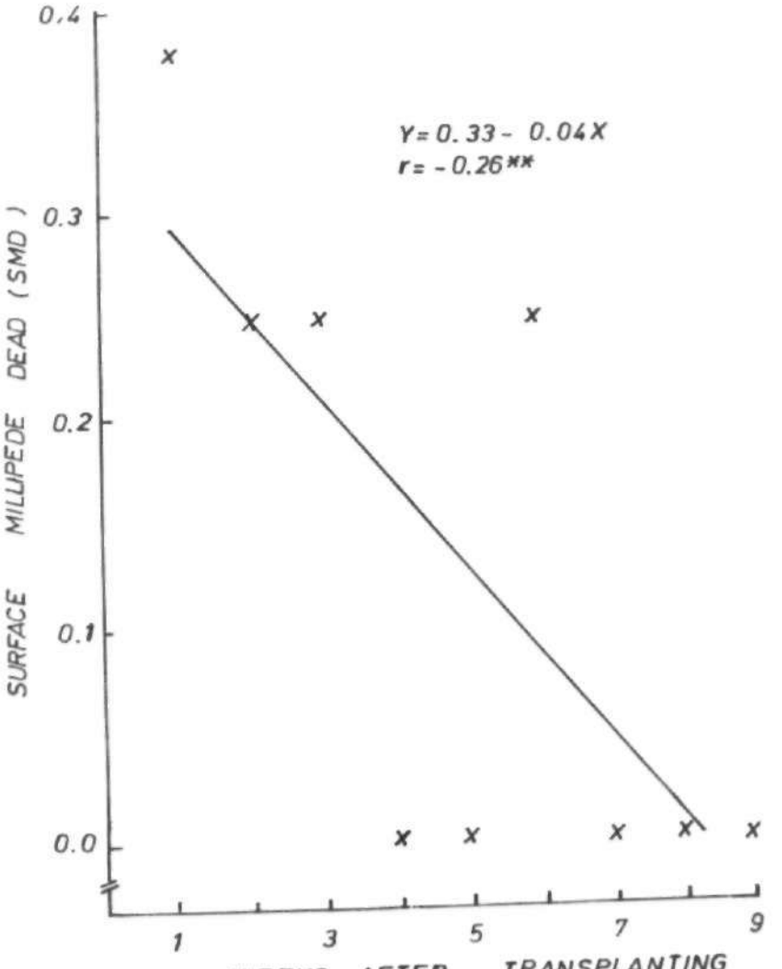


Fig 4 LINEAR REGRESSION OF OVERALL SMD AGAINST TIME INTERVAL IN WEEKS AFTER TRANSPLANTING

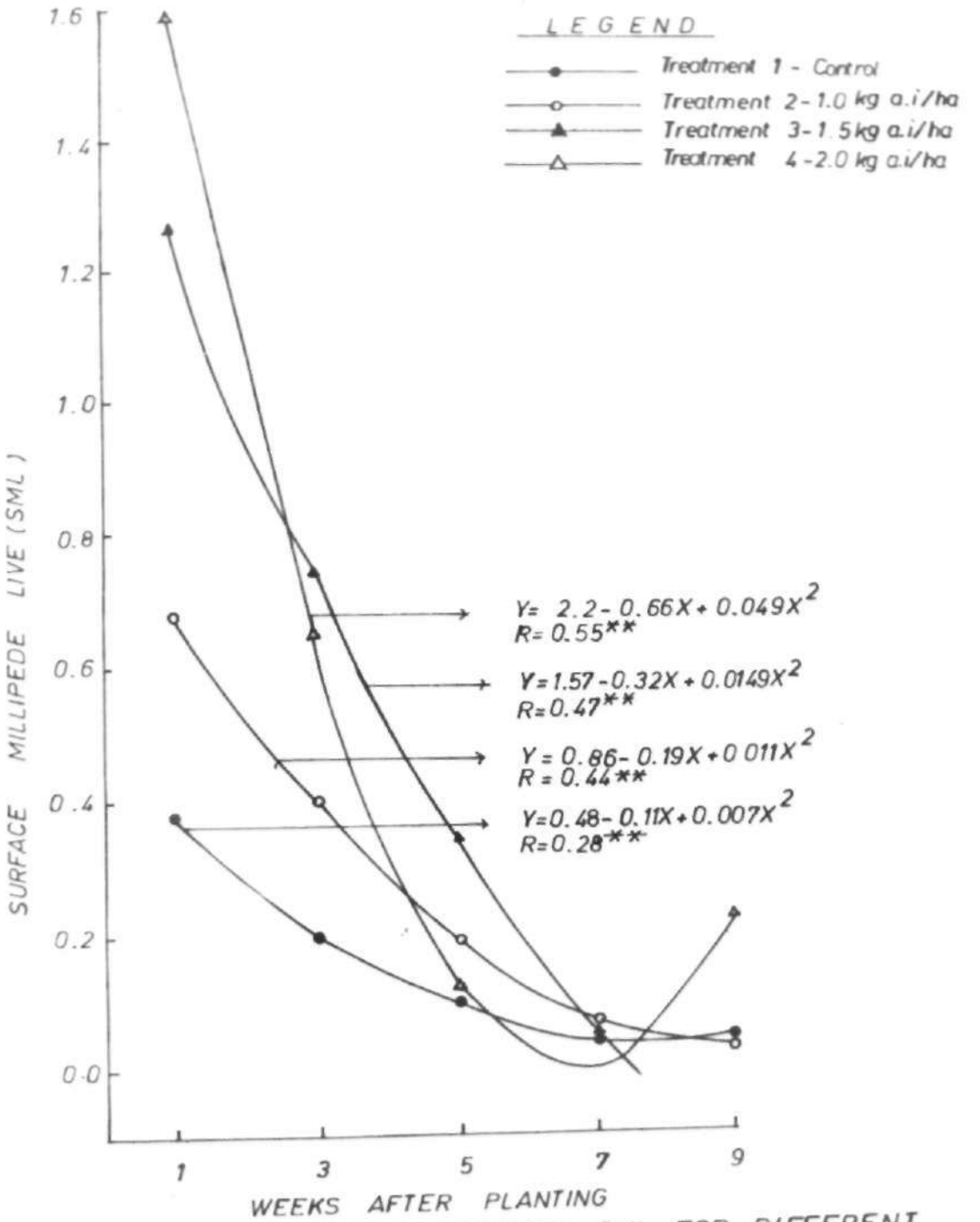


Fig 5 LINEAR REGRESSION OF SML FOR DIFFERENT TREATMENTS AND CONTROL AGAINST TIME INTERVAL IN WEEKS AFTER PLANTING

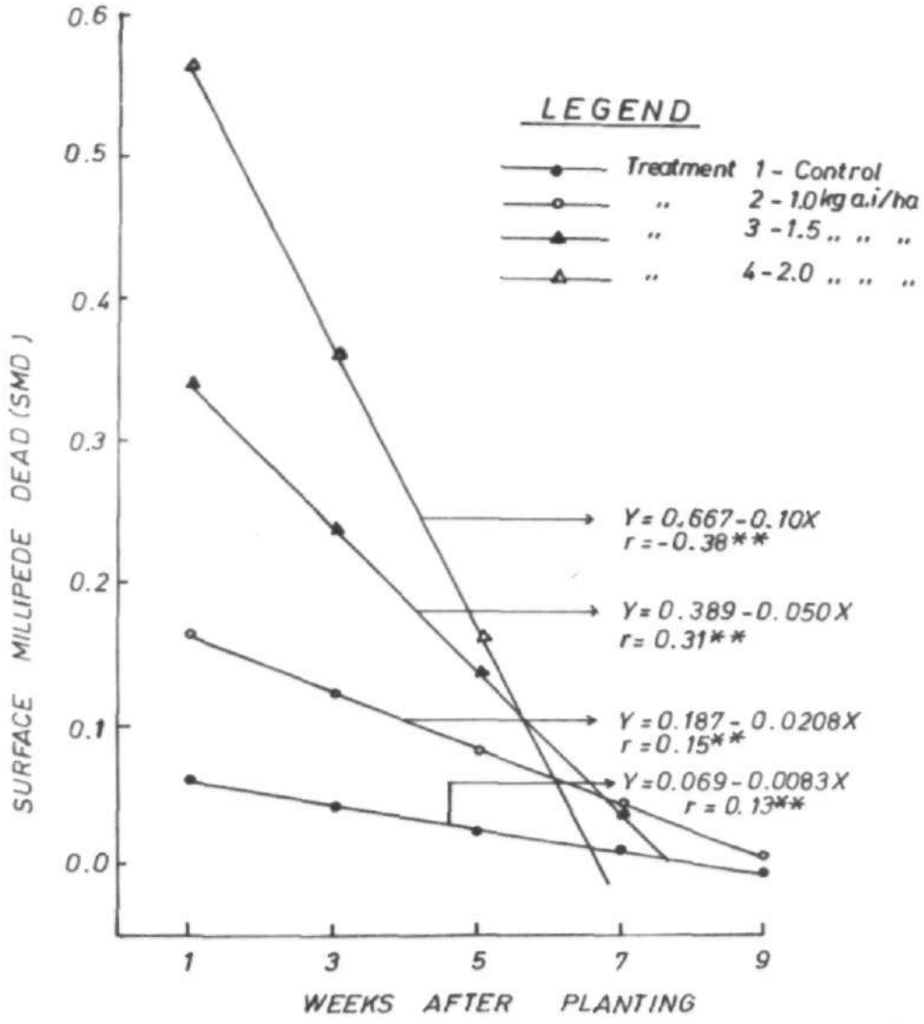


Fig 6 LINEAR REGRESSION OF SMD FOR DIFFERENT TREATMENTS AND CONTROL AGAINST TIME IN WEEKS AFTER PLANTING

regression curve of SMD plotted against time in weeks. There is an overall sharp decline in the number of dead millipedes as crop development progressed. After the 8th week no more SMD were recorded due to their probable movement into the soil.

Figure 5 shows the regression curves of SML for each level of Furadan 3G treatment and control treatment plotted against time. Treatments 1,2,3,4 have correlation coefficients of R = 0.28, R = 0.44, R = 0.47 and R = 0.55 respectively. These figures indicate that the rate of decrease in SML population per unit time increased as Furadan 3G treatment increased. Rate of decline in SML population in control treatment was gradual.

Figure 6 shows regression curves of SMD for each treatment plotted against time. Correlation coefficients for treatments 1,2,3,4, were R = ⁻0.13, R = ⁻0.15, R = ⁻0.2[illegible] respectively. There was an increase in the number of dead millipedes with increased doses of Furadan 3G. The control treatment had the lowest number of dead millipedes per unit time.

On the average, groundnuts are planted from the first week in June when rainfall are fully established in most parts of northern Guinea Savanna. Figures 3 to 6 indicate

that the populations of surface millipede is highest at the onset of rains, this period of numerical abundance in surface millipedes coincides with the time millipedes move out of their hidding places as observed by Misari (per. comm.).

Table 8 ANALYSIS OF VARIOUS PARAMETERS USED IN ASSESSING DAMAGE ASSESSMENT

(SAMARU 1980)

Variable	Furadan Treatments (kg a.i/ha				Statistics		
	0	1	1.5	2.0	Gm	SE	LSD
Total Plant	211.0	214.6	218.0	209.8	213.1	2.59	7.7
Wilted Plants	23.8	10.6	22.2	14.6	17.8	n.s	
Unwilted Plants	187.2	204.0	195.8	195.2	195.6	n.s	
Total Pods	249.0	281.0	232.4	296.0	264.8		
Damaged Pods	39.8	41.8	30.4	64.0	44.0	n.s	
Undamaged Pods	209.4	240.0	202.0	232.0	220.8	n.s	
Pods damaged by Termites	3.2	2.6	3.0	6.8	3.9	n.s	
Pods damaged by Millipede	35.6	37.6	26.4	54.8	38.6	n.s	
Pods damaged by Termite and Millipede	0.8	1.6	1.0	2.2	1.4	n.s	

4.7 Damage Assessment

Damage assessment was done in different locations using the following parameters: Wilted plants (WPL), Unwilted plant (UNWPL), Damaged Pods (DPD), Undamaged pods (UNDPD), Pod damaged by Termites (PDT), Pods damaged by Millipedes (PDM), Pods damaged by Millipedes and Termites (PDTM) (Tables 8 to 11).

Analysis of damage assessment for Samaru 1980 is shown in Table 8. The highest mean number of WPL was obtained in the control treatments. However among the treated plots 1.0kg a.i/ha treatment gave the lowest mean number of WPL. Amongst the treatments, the lowest number (30.4) of DPD was recorded in the 1.5kg a.i/ha treatment. However, differences between treatments and control were not significant. 1.5 kg a.i/ha treatment gave the best control against pods damaged by millipedes (PDM).

An analysis of the data obtained for the combined effect of termites and millipedes on pods (PDTM) showed no significant differences between the different levels of Furadan 3G treatments and control.

Yield results (kg/ha) (Table13) obtained from 1980 trial show that highest kernel yields/ha were obtained from 1.0kg a.i/ha (881kg/ha) and 1.5kg a.i/ha,(802kg/ha)

Table 9 : ANALYSIS OF VARIOUS PARAMETERS USED IN ASSESSING DAMAGE ASSESSMENT (SAMARU 1981)

Variable	Furadan 3G Treatments (kg a.i/ha)				Statistics		
	0	1.0	1.5	2.0	GM	SE	LSD
Total Plants	238^{b}	232^{b}	241^{b}	200^{a}	228	8.6	24*
Wilted Plants	22	29	32	17	25	6.06	19 n.s
Unwilted Plants	216	204	210	184	203	7.19	23 n.s
Total Pods	135^{a}	210^{ab}	257^{b}	356^{c}	240	23.61	76**
Damaged Pods	30^{a}	49^{ab}	62^{b}	62^{b}	50	6.02	19**
Undamaged Pods	106	162	196	294	189	16.0	51 n.s
Pods damaged by Termite	9	34	47	32	30	6.0	19 n.s
Pods damaged by Millipede	20	15	14	28	19	3.5	11 n.s
Pods damaged by Termite and Millipede	1	-	2	2	2	0.75	2 n.s

* = Significant P.05

** = Significant P.01

n.s = Not significant

treatments. Yield from 2.0kg a.i/ha (703kg/ha) was the lowest. However, these differences were not statistically significant. Among the treated plots 1.0kg a.i/ha treatment seemed to have given the best control against damage by termites and millipedes in Samaru in 1980, although differences in figures recorded for treated and untreated plots were not statistically significant.

Samaru 1981 Experiment: Table 9 shows the results of analysis of various parameters used in damage assessment at Samaru in 1981. The Furadan 3G application rate of 2.0kg a.i/ha treatment gave the lowest mean number of WPL compared with other treatments. Pod damage (DPD) was significantly higher in all treatments than the control and there appeared to be an increase in mean number of DPD with increased dosage. However, among treatments of DPD were statistically similar (P = 0.01).

Pod damage by termites (PDT) seem to increase as treatment levels increases and the highest mean number of PDT was recorded in 1.5kg a.i/ha treatment. The different levels of Furadan 3G application did not significantly reduce the number of pods damaged by termites (PDT) as shown in Table 9. Similarly there was no significant difference between control and the various levels of treatments in terms of damage to pods by millipedes.

Table 10: ANALYSIS OF VARIOUS PARAMETERS USED IN ASSESSING DAMAGE ASSESSMENT (BAKURA 1981)

Variable	Furadan 3G Treatments (kg a.i/ha)				Statistics		
	0	1.0	1.5	2.0	GM	SE	LSD
Wilted Plant	35	45	42	46	42	6.7	21.4 n.s
Unwilted Plant	63	87	58	73	70	12.6	40.3 n.s
Total Pods	177[a]	200[ab]	364[c]	376[c]	279	39.8	127.3 *
Damaged Pods	48	53	84	83	67	12.7	40.6 n.s
Undamaged Pods	128[a]	147[ab]	280[c]	293[c]	212	30.8	98.5 **
Pods damaged by Termite	30	35	43	50	39	6.6	21.1 n.s
Pods damaged by Millipede	18	17	41	33	27	8.6	27.5 n.s

* = Significant (P.05)

** = Significant (P.01)

n.s = Not significant

Generally. yields were low in 1981 due to the drought which occurred in mid June in Samaru. However, yield figures from 1.5 kg a.i/ha treatment (289.2kg/ha) and 2.0 kg a.i/ha (311.2kg/ha) were statistically different from the yields from the control plots (112.3kg/ha). There was no significant difference between yields in 1.0kg ai/ha). (190.7kg/ha) and control.

No consistent trend was shown in the effect of the different levels of Furadan 3G treatments on the various parameters considered in the control of soil pests. However, better yield figures were obtained from highest dosages. This could be attributable to higher mean number of total pods (TPD) obtained from treated plots and the good pod fill observed in Furadan 3G treated plots.

Bakura: 1981 Experiment: Table 10 shows damage assessment results from Bakura. As a result of the poor plant establishment in this experimental site, inconclusive results were obtained for the different parameters measured. Except for 1.5kg a.i/ha which gave considerably more undamaged pods (UNDPD) than other treatments there were no significant difference between treatments and control in the other parameters considered.

Mamudo: 1981 Experiment: Table 11 shows the results of the damage assessment carried out at Mamudo. Wilting of the plants was quite low in all the treatments although a greater number of unwilted plants was recorded in the treated plots than the control. 1.0kg a.i/ha and 1.5kg a.i/ha treatments recorded lower mean number of DPD than the control treatment, but mean number of DPD recorded from 2.0kg a.i/ha treatment was higher than that from control treatments. Higher mean number of UNDPD was recorded from Furadan 3G treated plots, although among the treated plots 2.0kg a.i/ha treatment gave the highest mean number of UNDPD. However, these differences were not statistically different from the control. Termite and millipede damage in all the treatments was quite low. Lowest figures of PDT and PDM were recorded in the 1.5kg a.i/ha treated plots, indicating that this level of treatment would probably give a better control of both termite and millipede damage in this location. Yield figures for this experimental site are given in Table 9. Lowest yield was obtained from control treatment while 1.0kg a.i/ha treatment gave the highest pod yield (418 kg/ha). Pod yield in the various treatments seemed to be better than other location in 1981 (Table 13). However, differences in pod yield in the different treatments were not statistically significant.

Table 11: ANALYSIS OF VARIOUS PARAMETERS USED IN ASSESSING DAMAGE ASSESSMENT (MAMUDO 1981)

Variable	Furadan 3G Treatments (kg a.i/ha)				Statistics		
	0	1.0	1.5	2.0	GM	SE	LSD
Total Plant	129	167	156	144	149	10.7	$34^{n.}$
Wilted Plants	18	22	18	19	19	2.7	$8.6^{n\ s}$
Unwilted Plants	111	144	137	125	129	8.6	$2.7^{n\ s}$
Total Pods	491	643	479	680	573	7.3	$235^{n\ s}$
Damaged Pods	44	37	25	53	40	6.8	$21.9^{n\ s}$
Undamaged Pods	447	605	454	626	533	68.7	$21.1^{n\ s}$
Pods damaged by Termite	17	19	11	35	20	6.6	$21.1^{n\ s}$
Pods damaged by Millipede	27	18	13	17	19	3.6	$11^{n.}$
Pods damaged by Termite and Millipede	-	-	-	-	-	-	-

n.s = Not significant

Sada: 1981 Experiment: The data for Sada experimental side are shown in Table 12 No record of wilting of plants was made. Other parameters measured showed that more pods were damaged in the treatments than the control although these differences were not significant. More undamaged pods (UNDPD) were recorded in the treated than untreated plots. No significant differences were recorded between treatments and control in both pods damaged by termites (PDT) and millipedes (PDM). The Sada experimental site did not give consistent results. This is attributable to the poor supervision of the experiment.

Also very poor yield was recorded in this site. This could be attributable to late and insufficient rainfall, resulting in poor stand development. However, very significant difference (P = 0.01) in yield was shown between control and treated plots. 2.0kg a.i/ha treatment yielded significantly higher (78 kg/ha) than 1.0 kg/ha and 1.5 kg a.i/ha with yield figures of 43 kg/ha and 40 kg/ha respectively.

4.8 Percentage Gleanings per Stand

Gleaning of pods is due to termite attack on groundnut pegs towards harvest. Estimates made at Samaru showed no difference in the amount of gleanings in the control and

Table 12: ANALYSIS OF VARIOUS PARAMETERS USED IN ASSESSING DAMAGE ASSESSMENT (SADA 1981)

Variable	Furadan 3G Treatments (kg a.i/ha)				Statistics		
	0	1.0	1.5	2.0	GM	SE	LSD
Total Pods	195[a]	232[ab]	283[b]	321[b]	258	21.7	69*
Damaged Pods	30	49	61	73	53	11	35n.s
Undamaged Pods	165	183	222	248	204	20	64n.s
Pods damaged by Termite	20	36	46	51	40	6.8	22n.s
Pods damaged by Millipede	14	12	14	22	15	5	16n.s
Pods damaged by Termite and Millipede	DNT	DNT	DNT	DNT	DNT	DNT	DNT

* = Significant (P 0.5)

n.s = No significant

DNT = Data Not Taken

Table 13: YIELD RESULTS (Kg/ha)

Year of Experiment	Location of Experiment	0	1.0	1.5	2.0	GM	SE	LSD	
1980	SAMARU	789	881	802	703	794	119	n.s	
1981	SAMARU	112.3[a]	190.7[ab]	289.2[b]	311.3[b]	225	32.7	104	*
1981	SADA	8[a]	43[b]	40[b]	78[c]	42	8.1	25	*
1981	MAMUDO	248	418	342	402	353	55.9	178.3	n.s
1981	BAKURA	DNT	DNT	DNT	DNT				

** = Highly significant (P=0.01)

n.s = Not significant

DNT = Data Not Taken

the various treatments. There was also no relationship between treatments levels and mean gleanings/stand. At Bakura, the situation was a bit different. Higher percentage gleanings/stand was obtained from samples in the control plots as compared with those receiving the different levels of treatment. The higher level of gleanings/stand at Bakura could be due to higher termite (Microtermes) population occasioned by the short wet season and light sandy soils at Bakura. Johnson, et al. (1981) noted higher termite (Microtermes spp.) damage in areas with well drained soil and short wet season. The overall trend in the damage assessment studies indicated that the different levels of Furadan treatment did not significantly control the damage to groundnuts by termites and millipedes probably due to low levels of population of the soil pests and the timing of the application of the insecticide.

SECTION V

GENERAL DISCUSSION

Soil pest survey carried out in the various locations indicated that farmers, even though aware of recommended practises for groundnuts were reluctant to adopt these measures, especially the spacing recommendation because of their interest in growing the crop as an intercrop. Furthermore, it was also obvious that greater results would be achieved in enhancing groundnut production if the necessary inputs like fertilizer is made available on time to farmers.

Arthropod pests especially termites and millipedes and their damage to groundnut are known by most groundnut farmers. Generally, damage by wilting on groundnut increases as the crop reaches maturity. Good cultural practises including early harvest of groundnuts is advocated to reduce damage by soil pests. This study confirms earlier reports by Rossion (1974) that millipedes cause substantial damage on groundnut at germination and podding. Control efforts should therefore be intensified during these periods.

Scarabaeids were almost absent in most of the areas surveyed except at Guma and Ngurore, the soil at these sites was high in organic matter content. This seems to be in line with the reports of Davidson and Robberts (1968) in

which organic matter was said to have increased the population of scarabaeids in soils. If population build up occurs in an area with high organic matter, application of soil insecticides and removal of crop residues may help to bring down the population of scarabaeids (Davidson and Roberts, 1968).

The biological studies confirm that M. subhyalinus (Rambur) can be cultured in the laboratory to a stage where the responsibility for colony maintenance and further development is transferred from the reproductives to the worker termites. These observations are similar to the preliminary investigation on Microtermes sp. by Johnson (1981). The knowledge of the period of production of workers, which do most of the damage is considered essential in planning management strategies for control of termites on groundnuts.

Appearance of fungal mycelia on the fungus combs in a culture raised on sterile soil is an indication that M. subhyalinus carried fungal spores either in its alimentary canal or on the body of the founding reproductives. This corroborates with observations made by Wood et al. (1979), Johnson (1981). Furthermore the successful culturing of termite pest species in the laboratory provides ready

specimens for the laboratory bioassay of candidate insecticides before field tests are carried out to determine their efficacy and suitability for use in control. In this study carbofuran (Furadan 3G) was chosen as the candidate insecticide because it acts as a systemic and contact insecticide. It also has some fumigant action. Even though its oral toxicity to mammal is high 8-14 mg/kg for rats, it has a low mammalian dermal toxicity.

The different levels of carbofuran treatment did not significantly control the damage to groundnut by termites and millipedes probably due to low population densities of these pests in the soil, and the timing of the application of the insecticides. It has also been noted by Johnson (1978), Johnson and Wood (1980) that soil pests rarely cause spectacular damage to groundnut in any particular year, especially at low population.

The applied carbofuran itself could have contributed to the type of results obtained. Carbofuran (Furadan 3G), half-life 4 weeks Hill, (1975), Kuhr and Dorough (1976) may not have persisted long enough to provide control against the soil pests especially termites. A fairly persistent insecticide may therefore be desirable for the control of termites whose damaging effect on groundnuts is mostly

pronounced at crop maturity. It is also possible that the dosage rates of carbofuran used in this trials may have been too low to effect control of the soil pests.

Other factors could have affected the efficiency of the applied insecticide in the soil, such as the behaviour of the soil pests themselves, soil type (Burkhardt and Fairchild, 1976), and soil temperature (Edwards, 1964). Temperature affects the biological activity of carbamates (Harris 1971).

Increases in yield as a result of carbofuran (Furadan 3G) treatment were not significant. It was possible that extent of damage was insufficient to affect the yield of groundnuts as was demonstrated in most of the locations. Moreover, lack of sufficient rainfall in some of the locations may have contributed to the low yields obtained.

5.1 Summary and Conclusion

1. This study was carried out between 1979 and 1981 to ascertain the importance of millipedes, termites and scarabaeids as soil pests of groundnut.

2. Extensive review of relevant literature was done to provide information about the past and present status of groundnut production in Nigeria. Reasons for the decline in yield were enunciated. Investigations made in Nigeria and elsewhere to control soil pests of groundnut were also highlighted in the review.

3. Surveys were made in the major groundnut producing zones during the 1980-81 growing season. Areas where these pests were considered as pests of economic importance were located, namely Mamudo, Sada, Girei, Bakura, Gusau, Anka. Interviews with local farmers revealed that farmers were aware of the problems created by termites and millipedes in their respective areas.

4. Laboratory studies on one termite species (Macroterme: subhyalinus (Rambur), commonly found in the groundnut producing areas were carried out. Two methods for culturing were adopted, namely the aluminium foil method and the glassplate method. Observations were made on colony development, foraging and formation of fungus-combs. Producti

capacity of incipient colonies in the laboratory was low compared with what obtains in the field. Lee and Wood (1971) suggest that some members of the Macrotermitinae such as Odontotermes spp and Macrotermes bellicosus lay eggs at the rate of 4,000 and 36,000 per day. However, the successful maintenance of laboratory culture of termite pest species, especially the non-mound-building species, is considered important, not only for obtaining further information on their biology, feeding habits and food preferences, but also for maintaining sufficient numbers of such termites for the bioassay of insecticides.

5. Field experiments were conducted between (1980-1981) at Samaru and other locations, to investigate the possibility of using a carbamate (Furadan 3G) to effect control of soil pests notably termites and millipedes. Different parameters namely, attack on wooden baits, wilting of groundnut plant, attack on pods, percentage gleanings/stand, root damage and yield were evaluated.

6. The different levels of Furadan 3G did not give significant control of soil pests damage on groundnut. However at Samaru in 1980, Bakura 1981 and Sada, 1981 1.0 kg a.i/ha seemed to have given a better control of

soil pests than other treatments; while at Mamudo in 1981, 1.5 kg a.i/ha gave the best control over other treatments. Indications are therefore that dosage rates of 1.0-1.5 kg a.i/ha could be adequate in the control of these soil pests in groundnut.

7. Timing of application of this insecticide appears to be very important. Millipedes cause damage at germination and later betweem the 5-7th week when they move into the soil to attack the developing pods. Termites on the other hand cause damage at crop maturity. Therefore for effective control, two split application, one at planting and later at podding would be desirable.

However, further research work in the timing and rates of application of Furadan 3G is therefore suggested before adequate recommendations are put out to farmers for the control of soil pests om groundnut in Nigeria.

LITERATURE CITED

ABDULLAH, A. (1979). African declining share of world peanut output. Peanut Journal and Nut world, 58 : 23 - 29.

A'BROOK, J. (1968). The effects of plant spacing on the number of aphids trapped over the groundnut crop. Annals of Applied Biology 61,: 289 - 294.

AHMED, K.M. and AMIN, E. (1976). Field pests of groundnuts (Arachis hypogaea) and Millet (Pennisetum typhoides) in the Sudan with special reference to Kordofan Province. In minutes of International symposium on field pests of groundnut and millet, Kaelack, Senegal, April, 21-23. p. 145-156.

AKINFENWA, S. (1978). Rosette virus disease and aphids. Aphid craccivera and rosette virus disease of groundnu in Nigeria. In Proceedings of the National Seminar on groundnut production, Bagauda Lake Hotel, Kano, February, 13-14.

ANONYMOUS, (1976d) . Facts on groundnut and the African groundnut council. A.G.C. Information Services, Trend lith limited, Norwich, p. 1-3.

ANONYMOUS, (1976b). Recommended practices for groundnut production in northern states. Extension recommended practices. No. 1 Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Zaria, Nigeria, 2p.

ASTRIDLOFS-HOLMIN, (1981). Influence in field experiments of benomyl and carbendazin on earth worm (Lumbricide) in relation to soil texture. Swedish Journal of Agricultural Research. 11: 141-147.

BOS, W. (1977). Aphelenchoides arachidis, an endoparasite of the testa of groundnut in Nigeria. Journal of Plan Disease and Protection, 84 : 95-99.

BURKHARD, T.C.C. and FAIRCHILD, M.L. (1967). Toxicity of insecticides to house crickets and bioassay of treated soils in the laboratory. Journal of Economic Entomology 6 : 1496-1503.

DEMANGE, J.M. (1975). Millipedes (Diplopoda) harmful to groundnuts in Senegal. Oleagineux, 30 : 19-24.

FEAKINS, S.D. (1973). Pest control in groundnuts. Pests Articles and News Summaries No. 2, Third Edition. Centre for Overseas Pest Research, Foreign and Commonwealth Office, Overseas Development Administration, London, 197p.

FAO, (1966). Agricultural development in Nigeria 1965-1980, pp.161-163. Food and Agricultural Organisation of the United Nation, Rome, William Clowes and Sons Limited, London.

GLEEN, R. (1954). Factors that affect insect abundance. Journal of Economic Entomology, 47: 398-405.

HAMMONS, R.O. (1973). Early history and origin of the peanut. In Peanut culture and uses. American Peanut Research and Education Association, pp.12-45.

HARKNESS, C. (1970). The trade in Nigerian groundnut. Samaru Agricultural Newsletters, 12 : 62-65.

HARKNESS, C., KRIESEL, H.C., and DAGG, M. (1971). National Agricultural Development Committee: Report of the study group on groundnuts, 73p. Federal Department of Agriculture, Lagos.

HARKNESS, C., KOLAWOLE, K.B., and YAYOCK, J.Y. (1976). Groundnut Research in Nigeria. Paper delivered at the Technical Workshop on Germplasm preservation and Genotype Evaluation in Peanut. University of Florida, U.S.A., July 11-15. Samaru conference paper, No. 7, 3p.

HARRIS, W.V. (1954). Termites and tropical Agriculture. Tropical Agriculture, 31 : 11-15.

HARRIS, W.S. (1969). Termites as pests of crops and trees. Commonwealth Institute of Entomology, London. 47p.

HARRIS, W.S. (1971). Termites, their recognition and control. Longmans, London. 186p.

HARRIS, C.R. and LICHTENSTEIN, E.P. (1961). Factors affecting the volatilization of insecticidal residues from soils. Journal of Economic Entomology, 54 : 1038-1045.

HARRIS, C.R. (1964). Influence of soil moisture on the toxicity of insecticides in soils to insects. Journal of Economic Entomology, 57 : 946-950.

HARRIS, C.R. and MAZURE, J.H. (1964). Comparison of the toxicity to insects of certain insecticides applied by contact and in the soil. Journal of Economic Entomology, 57 : 688-701.

HARRIS, C.R. (1971). Influence of temperature on the biological activity of insecticides in soils. Journal of Economic Entomology, 64 : 1044-1048.

HILL, D.S. (1975). Agricultural insect pests of the tropics and their control, 516p. Cambridge University Press.

JOHNSON, R.A. (1978). Soil pests of groundnut in Nigeria. Paper presented at the seminar on groundnut production, Kano, February, 13-14.

JOHNSON, R.A., AKINFENWA, S., and RAHEJA, A.K. (1978). Pre and post harvest crop protection. Pests of groundnut in Nigeria. Paper presented at the Third General Conference of Association for the Advancement of Agricultural Science in Africa, Ibadan, April, 9-15.

JOHNSON, R.A. and WOOD, T.G. (1980). Combating Termites. West African Farming and Food Processing, 55p. Alain Charles Publishers Limited.

JOHNSON, R.A., LAMB, R.W., and WOOD, T.G. (1981). Termite damage and crop loss studies in Nigeria. A survey of damage to groundnut. Tropical Pest Management, 27 : 325-342.

JOHNSON, R.A., and GUMEL, M.H. (1981). Termite damage and crop loss studies in Nigeria, the incidence of termite searified groundnut pods and resulting kernel contamination in field and market samples. Tropical Pest Management, 27 : 343-350.

KOWAL, J.M., and KNABE, D.T. (1972). An Agroclimatological Atlas of the Northern State of Nigeria. Ahmadu Bello University Press, Zaria.

KUHR, R.J. and DOROUGH, H.W. (1976). Carbamate Insecticides Chemistry, Biochemistry and Toxicology. CRC Press Inc. Florida, U.S.A. 301pp.

LEE, K.E., and WOOD, T.G. (1971). Termites and Soils. 251p. Academic Press, London and New York.

LUSCHER, M. (1949). Continuous observation of termites in laboratory cultures. Acta Tropica 6 : 161-165.

MAGAR, W.Y. (1976). Tabulated informations in field pests of groundnuts in members states of African Groundnut Council. In minutes of International Symposium on field pest of groundnut and millet, Kaolack, Senegal, April 21-23 p.160-175.

MILNE, A. (1962). On the theory of natural control of insect populations. Journal of theoretical biology 3 : 19-50.

MISARI, S.M. (1975). Insects and other arthropod pests of groundnu' n northern Nigeria. Samaru Agricultural Newslette.. 17 : 4-9

MISARI, S.M. (1981). Preliminary studies on soil pests of ground, Arachis hypogaea L. in Nigeria and their contro . A paper presented at the 11th Annual Conference of the Nigerian Society for Plant Protection, University of Nigeria, Nsukka, February, 15-18.

MISARI, S.M. and RAHEJA, A.K. (1976). Notes on field pest of groundnut in northern Nigeria. In minutes of International symposium on field pests of groundnut and millet. Kaolack, Senegal, April 22-23.

MISARI, S.M., HARKNESS, C. and FOWLER, A.M. (1980). Groundnut production, Utilisation, research problem and further research needs in Nigeria. In Proceeding of the International Workshop on groundnuts. October, 13-17, Patencheru, Andra Pradesh India, pp.164-273.

MOORE, N.W. (1967). A synopsis of the pesticide problem. Advances in Ecological Research, 4 : 75-126.

NICHOLSON, A.J. (1958). Dynamics of Insect population. Annual Review of Entomology, 3: 107-136.

OHIAGU, C.E. (1980). A review of grass and dead-wood feeding termites in Nigeria savanna. A paper presented at the "Man and Biosphere" Workshop on the state of knowledge on the Nigerian Savanna at the Kainji Lake Research Institute, New Bussa, Kwara-State, p.10.

ONU, I. and OHIAGU, C.E. (1980). Laboratory culturing and study of the biology of Macrotermes subhyalinus (Rambur). Paper presented at the 13th Annual Conference of the Entomological Society of Nigeria, December, 14-17. Moor Plantation, Ibadan.

PERRY, D.A. (1967). Premature death of groundnut plants in northern Nigeria. Experimental Agriculture, 3 : 211-214.

RACHIE, K.O. (1973). Importance of food legumes in tropical Africa. In proceedings of a symposium of Protein Advisory group of the United Nation. Ed. M. Milnet.

RAHEJA, A.K. (1975). Millipedes on groundnut, Arachis hypogaea, L. Nigerian Journal of Plant Protection, 1: 91-92.

RIBAH, I.S. (1975). The importance of groundnut haulms in the Kano Metropolitan area. Thesis submitted for Diploma in General Agriculture to College of Agriculture, Ahmadu Bello University, Zaria, 46 p.

RIPPERS, W.E. (1956). Effect of pesticides on the balance of arthropoda population. Annual Review of Entomology 1 : 403-438.

ROSSION, J. (1974). Chemical control of millipedes in groundnut growing. Synthesis of research carried out by I'institut de Recherches pour les Huiles et Oleagineux. Oleagineux, 29 : 365-370.

ROSSION, J. (1976). Millipedes, groundnut pests in general. In minutes of International symposium on field pests on groundnut and millet, Kaolack, Senegal, April 21-23; p.1026.

RULIE, J.E. (1970). A revision of the termites of the genus Macrotermes from the Ethiopean region (Isoptera, Termitidae). Bulletin British Museum of Natural History, (Entemology). 24 : 365-444.

SANDS, W.A. (1966). The evaluation of insecticide as soil and Mound poison against termites in Agriculture and Forestry in West Africa. Bulletin of Entomological Research, 53 : 179-192.

SANDS, W.A. (1973). Termites as pests of tropical food crops. Pest Articles and News Summaries (PANS). 19: 167-177.

SMITH, H.S. (1935). The role of biotic factors in the determination of population densities. Journal of Economic Entemology, 28: 873-895.

STOREY, H. (1925). Transmission of groundnut rosette virue. Nature: 116 : 97-98.

TAYLOR, A.T. (1967). Fifty years of Applied Entomology in Nigeria. In Proceedings of Entomological Society of Nigeria, pp. 20-21.

TOYE, S.A. (1966). The reaction of three species of Nigerian Millipedes to light humidity, and temperature, Entomological Experimentalis et Applicata, 9 : 468-484.

WILLIAMS, R.M.C. (1959). Colony development in cubitermes ugandensis (Fuller), (Isoptora, Termitidae) Insect Sociaux, 6 : 291-304.

WILSON, C. (1945). A Diplodia associated with concealed damage in peanuts. Phytopathology, 35: 480.

WOOD, T.G., and OHIAGU, C.E. (1976). A preliminary assessment of the significance of grass-eating termites (Isoptera) in pastures in northern Nigeria. Samaru Agricultural Newsletter, 18: 22-30.

WOOD, T.G., JOHNSON, R.A., and OHIAGU, C.E. (1977). Population of termites (Isoptera) in natural and Agricultural systems in Southern Guinea Savannah Mokwa, Nigeria. International Journal of Tropical Ecology and Geography, 1 : 139-148.

YAYOCK, J.Y. ROSSEL, H.W. and HARKNESS, C. (1976). A review of the 1975 groundnut rosette epidemic in Nigeria. In minutes of the International symposium on field pest of groundnut and millet, Kaolack, Senegal, April, 21-23. p. 129-137.

YAYOCK, J.K. (1978). Yield and yield characters of certain varieties of groundnut, as affected by plant population and fertilizer level in Nigeria. Ph.D. Thesis, Ahmadu Bello University, Zaria.

APPENDIX 1

DATE I SML

ANALYSIS OF VARIANCE TABLES

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	E RATIO	F PROB.
BETWEEN GROUPS	3	6.187	2.0625	1.62	0.236
WITHIN GROUPS	12	15.25	1.271		
TOTAL	15	21.438			

N.S. = 05%

DATE I SMD.

ANOVA

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	E RATIO	F PROB.
BETWEEN GROUPS	3	6.75	2.25	3.00	0.073
WITHIN GROUPS	12	9.00	0.75		
TOTAL	15	15.75			

N.S. at 05

APPENDIX 2

DATE 2. SML

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	E RATIO	F PROB.
BETWEEN GROUPS	3	12.187	4.063	2.826	0.084
WITHIN GROUPS	12	17.250	1.438		
TOTAL	15	29.437			

NS at 05

DATE 2. SMD

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	E RATIO	F PROB.
BETWEEN GROUPS	3	1.00	0.333	1.00	0.426
WITHIN GROUPS	12	4.00	0.333		
TOTAL	15	5.00			

N.S. at 05

APPENDIX 3

DATE 3. SML

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	E RATIO	F PROB.
BETWEEN GROUPS	3	1.25	0.0833	0.182	0.907
WITHIN GROUPS	12	5.50	0.4583		
TOTAL	15	5.75			

N.S at 05

DATE 3. SMD

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	E RATIO	F PROB.
BETWEEN GROUPS	3	1.50	0.50	1.71	0.22
WITHIN GROUPS	12	3.50	0.29		
TOTAL	15	5.00			

N.S at 05

APPENDIX 4

DATE 4. SML

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	E RATIO	F PROB.
BETWEEN GROUPS	3	0.25	0.0833	0.667	0.588
WITHIN GROUPS	12	1.5	0.125		
TOTAL	15	1.75			

N.S at 05

DATE 4. SMD

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	E RATIO	F PROB.
BETWEEN GROUPS	3	0.0	0.0	0.0	0.0
WITHIN GROUPS	12	0.0	0.0		
TOTAL	15	0.0			

N.S at 05

APPENDIX 5

DATE 5. SML

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	3	0.187	0.063	1.00	0.43
WITHIN GROUPS	12	0.750	0.063		
TOTAL	15	0.937			

N.S at 05

DATE 5. SMD

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	3	-	-	-	-
WITHIN GROUPS	12	-	-		
TOTAL	15	-			

N.S at 05

APPENDIX 6

DATE 6: SML

SOURCE	D.F	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB
BETWEEN GRCUPS	3	0.25	0.83	0.67	0.59
WITHIN GROUPS	12	1.50	0.13		
TOTAL	15	1.75			

N.S at 05

DATE 6: SMD

SOURCE	D.F	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	3	0.188	0.063	1.00	0.43
WITHIN GROUPS	12	0.75	0.063		
TOTAL	15	0.94			

N.S at 05

APPENDIX 7

DATE 7: SML

SOURCE	D.F	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB
BETWEEN GROUPS	3	0.25	0.083	0.67	0.59
WITHIN GROUPS	12	1.5	0.13		
TOTAL	15	1.75			

N.S at 05

APPENDIX 8

TPL. ANOVA TABLES LOCATION: MAMUDO 1981

SOURCES	D.F	SUM OF SQUARES	MEAN SQUARES	F	SIG.
BETWEEN GROUPS	3	3204.7	1068.22	2.13	0.149(
WITHIN GROUPS	12	6016.75	501.32		
TOTAL	15	9221.43			
WPL.					
BETWEEN GROUPS	3	65.3	21.8	0.892	0.4731
WITHIN GROUPS	12	292.5	24.4		
TOTAL	15	357.7			
TPD.					
BETWEEN GROUPS	3	126979.3	42326.4	1.71	0.2178
WITHIN GROUPS	12	.296E+06	2+744.0417		
TOTAL	15	.423E+06			
DPD.					
BETWEEN GROUPS	3	1726.2	575.4	3.7	0.0428
WITHIN GROUPS	12	1865.3	155.4		
TOTAL	15	3591.4			
UNDPD.					
BETWEEN GROUPS	3	0.110E+06	35688.729		
WITHIN GROUPS	12	.279E+06	23329.60	1.57	0.247
TOTAL	15	.390E+06			
PDT.					
BETWEEN GROUPS	3	1303.3	434.4		
WITHIN GROUPS	12	1708.5	142.38	3.1	0.069
TOTAL	15	3011.7			
PDM.					
BETWEEN GROUPS	3	386.8	128.9		
WITHIN GROUPS	12	491.0	40.9	3.15	0.0614
TOTAL	15				

APPENDIX 9

WPL. ANOVA TABLES LOCATION: BAKURA

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F.	SIG.
BETWEEN GROUPS	3	288.2	96.1	0.15	0.929
WITHIN GROUPS	12	7841.8	653.5		
TOTAL	15	8129.9			
UNWPL.					
BETWEEN GROUPS	3	2046.7	682.2		
WITHIN GROUPS	12	7178.8		1.14	0.372
TOTAL	15	2225.4			
TPD.					
BETWEEN GROUPS	3	.133E+06	4+395.333		
WITHIN GROUPS	12	69873.0	58228	7.62	0.004
TOTAL	15	.203E+06			
DPD.					
BETWEEN GROUPS	3	4222.7	1407.6		
WITHIN GROUPS	12	6514.8	542.9	2.59	0.101
TOTAL	15	10737.43			
UNDPD.					
BETWEEN GROUPS	3	90097.7	30032.56		
WITHIN GROUPS	12	47920.3	3993.4	7.52	0.004
TOTAL	15	.138E+06			
PDT.					
BETWEEN GROUPS	3	868.7	289.6		
WITHIN GROUPS	12	2621.8	218.5	1.325	0.3[illegible]
TOTAL	15	3490.4			
PDM.					
BETWEEN GROUPS	3	.1594.2	531.4		
WITHIN GROUPS	12	2965.8	238.8	2.3	0.13[illegible]
TOTAL	15	4459.93			

APPENDIX 10

TDP. ANOVA TABLE LOCATION: SADA

1981

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F.	SIG.
BETWEEN GROUPS	3	37206.5	12402.2		
WITHIN GROUPS	12	24732.5	2061.0	6.01	.0096
TOTAL	15	61939.0			
DPD.					
BETWEEN GROUPS	3	4128.7	1376.3		
WITHIN GROUPS	12	6763.0	563.6	2.4	0.144
TOTAL	15	10891.8			
UNDPD.					
BETWEEN GROUPS	3	16875.3	5625.42		
WITHIN GROUPS	12	18043.5	1503.63	3.74	0.04
TOTAL	15	34919.8			
PDT.					
BETWEEN GROUPS	3	1874.6	624.9		
WITHIN GROUPS	12	2783.2	253.01	2.5	0.116
TOTAL	15	4657.7			
PDM.					
BETWEEN GROUPS	3	207.3	69.1		
WITHIN GROUPS	12	1320.5	110.0	0.63	0.610
TOTAL	15	1527.8			

APPENDIX 11

TPL. LOCATION - SAMARU 1981

SOURCE	D.F	SUM OF SQUARES	MEAN SQUARES	F	SIG.
BETWEEN GROUPS	3	4208.2	1402.72		
WITHIN GROUPS	12	3862.8	321.9	4.3	0.027
TOTAL	15	8070.9			
WPL.					
BETWEEN GROUPS	3	530.2	176.7		
WITHIN GROUPS	12	1406.8	117.2	1.5	0.26
TOTAL	15	1936.9			
UNWPL.					
BETWEEN GROUPS	3	2290.2	763.4		
WITHIN GROUPS	12	2949.5	245.8	2.10	0.067
TOTAL	15	5239.8			
TPD.					
BETWEEN GROUPS	3	0.101E+06	33973.4167		
WITHIN GROUPS	12	50933.5	4244.5	8.0	.003
TOTAL	15	0.152E+06			
DPD.					
BETWEEN GROUPS	3	2724.68	908.2		
WITHIN GROUPS	12	4305.3	358.8	2.5	0.10
TOTAL	15	7029.9			
UNDPD.					
BETWEEN GROUPS	3	75127.7	25042.5		
WITHIN GROUPS	12	36832.7	3069.4	8.15	.003
TOTAL	15	.111E+06			

APPENDIX 11 (Contd.)

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F.	SIG.
PDM					
BETWEEN GROUPS	3	539.2	179.7		
WITHIN GROUPS	12	1250.7	104.22	1.7	0.21
TOTAL	15	1789.9			
PDT.					
BETWEEN GROUPS	3	2966.5	988.8		
WITHIN GROUPS	12	4993.5	416.12	2.3	0.12
TOTAL	15	7960.00			
PDTM.					
BETWEEN GROUPS	2	0.700	0.35		
WITHIN GROUPS	2	2.5	1.25	0.28	0.781
TOTAL	4	3.2			