# INSECT PEST POPULATION STUDIES IN MILLET/ GROUNDNUT CROPPING PATTERNS

BY

ABDULLAHI BABA UMARU.

B. Tech. Agriculture (Minna)

A thesis submitted to the post-graduate school,
Ahmadu Bello University, Zaria in partial
fulfilment of the requirements for the
degree of Master of Science in Crop Protection.

Department of Crop Protection

Faculty of Agriculture

Ahmadu Bello University

Zaria, Nigeria.

OCTOBER, 1997.

## DECLARATION

I hereby declare that this thesis has been written by me, being a record of my own research work. It has not been previously forwarded for the award of a higher degree.

Abdullahi Baba Umaru
Candidate

Date 26/5/98

The above declaration is confirmed by:

Dr. M.C. Dike.
Major Supervisor.

Date 26/5/98

## CERTIFICATION

This thesis meets the regulations governing the award of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

Dr. M.C. Dike
Chairman
Supervisory Committee.

Dr. I. Onu
Member
Supervisory Committee.

Dr. M.O. Ogunlana
Member
Supervisory Committee

Dr. I. Onu.
Head
Department of Crop Protection.

Prof. J. Y. Olayemi
Dean
Postgraduate School.
Date. 24/9/98

AHMADU BELLO UNIVERSITY

Z A R I A.

## DEDICATION

This work is dedicated to my father, mother, wife and daughter for their support, love and caring.

## ACKNOWLEDGEMENTS.

I wish to express my invaluable appreciation to Dr. M.C. Dike, the major Supervisor and Chairman of the Supervisory Committee who was an indispensable guide throughout the course of this study. His criticisms and contributions to this work will continue to be points of reference. Dr. I. Onu, the Head, Department of Crop Protection and member of Supervisory Committee deserves a profound gratitude for his highly valued contributions. Dr. M.O. Ogunlana, another member of Supevisory Committee is highly acknowledged for painstakingly going through the write-up and offering useful suggestions.

The accomplishment of this project and indeed other components of my entire M.Sc. Programme is not without financial, moral and administrative contributions of Dr. S.M. Misari (The Director) of National Cereals Research Institute (NCRI) Badeggi. I am particularly grateful to the Director and the entire Management of the Institute. Dr. E.D. Imolehin (The Assistant Director) and Dr. K.I. Nwosu will continue to be remembered for their immense contributions. The assistance and cooperation of colleagues such as A.A. Ndarubu, Usman Aliyu, Abdullahi Umaru (Baba Tetengi) and Rabiu Adamu are highly acknowledged. Mr. Mathew Chori of the insect museum of Crop protection Department also deserves a special mention for all his assistance especially in the area of insect identification. All the staff of Crop Protection Department are hereby highly acknowledged for their cooperation and friendliness throughout the period of the study.

Mr. G.O. Olaniyan, the Head of programme of Farming Systems Research of NCRI is highly acknowledged for his valuable contributions. Finally members of my entire family are remembered with gratitude for all their support. Praise be to Almighty Allah.

## ABSTRACT

Field experiments were conducted at Samaru in the Northern Guinea Savanna zone of Nigeria in 1995 and 1996 cropping seasons to evaluate the effect of five intercrop patterns and two monocrops on populations of insect pests of groundnut. The five intercrop patterns included millet/groundnut intercrops in the inter-row ratios of 1:1, 1:2, 1:3 and the intra-row ratios of 2:2 and 1:3. The monocrops were those of millet and groundnut.. *Aphis craccivora* Koch and *Ootheca* species were monitored on groundnut. For aphids, the highest pest populations were exhibited by the two intra-row arrangements of 2:2 and 1:3. Highest numbers of *Ootheca* species were recorded on monocrop groundnuts. However, for both aphids and *Ootheca* species, the lowest pest population were recorded in the 1:1 inter-row pattern.

There was significant difference ($P<0.05$) in populations of *Coryna hermaniae* Fab., *Agonoscellis vesicolor* F., *Melyris abdominalis* F., *Locris rubens* Erichson; *Mylabris* species, stem borers and shootflies monitored on millet between monocrop millet and the remaining inter-cropped arrangements. However within the remaining intercropped arrangements, there was no significant difference ($P > 0.05$) in populations of these insect pests monitored on millet.

Yields of both millet and groundnut were not affected by insect pests due to low insect population levels. For groundnut, intercropping with millet had significant ($P < 0.05$) effect on pod weight per plot and grain yield but had no significant ($P > 0.05$) effect on number of pods per plant and 100-grain weight. Similarly, for millet, intercropping with groundnut had significant ($P < 0.05$) effect on weight of millet head per plot and grain yield but had no significant effect on 1000-grain weight. The yields of both millet and groundnut put together demonstrated one of the advantages of intercropping as insuring against crop failures.

# TABLE OF CONTENTS.


| CONTENTS | | PAGE |
|---|---|---|
| Title ..... | | i |
| Declaration ..... | | ii |
| Certification ..... | | iii |
| Dedication ..... | | iv |
| Acknowledgements ..... | | v |
| Abstract ..... | | vi |
| Table of Contents ..... | | vii |
| List of Tables ..... | | xiii |
| List of Figures ..... | | xiv |
| List of Appendices ..... | | xv |
| CHAPTER ONE | | |
| **1.0** | **INTRODUCTION** ..... | 1 |
| CHAPTER TWO | | |
| **2.0** | **LITERATURE REVIEW** ..... | 4 |
| **2.1** | Pest Management in Intercrops..... | 4 |
| **2.2** | Stabilising Mechanisms in Intercrops ..... | 5 |
| 2.2.1 | Natural enemy action ..... | 6 |
| 2.2.2 | Visual Effects ..... | 6 |
| 2.2.3 | Chemical Effects ..... | 7 |
| 2.2.4 | Diversionary and Physical barrier Effect ..... | 7 |

CONTENTS CONT'D. PAGE


2.3 Insect pests of Groundnut..... 8

2.3.1 Aerial pests ..... 8

2.3.1.1 *Aphis craccivora* Koch. ..... 8

2.3.1.2 The Groundnut plant hopper ..... 11

2.3.1.3 Thrips ..... 12

2.3.2 Soil pests ..... 13

2.3.3 Pests associated with stored groundnut..... 15

2.4 Major Insect pests of Millet ..... 16

2.4.1 The millet headminer ..... 16

2.4.2 The millet shootfly..... 16

2.4.3 Head Beetles..... 17

2.4.4 The millet midge..... 17

2.4.5 The millet stemborer ..... 18

2.5 Interaction between pests and diseases of groundnut ..... 18

2.6 Disease management in Intercrops..... 19

2.7 Strategies for pest management ..... 20

2.8 Hazards of pesticide use..... 20

CHAPTER THREE

3.0 MATERIALS AND METHODS ..... 22

3.1 Experimental site ..... 22

3.2 Land preparation..... 22

CONTENTS CONT'D. PAGE


3.3 Experimental design and layout ..... 22

3.4 Seed Materials and Sowing ..... 25

3.5 Weeding ..... 25

3.6 Fertilizer application ..... 25

3.7 Data collection ..... 25

3.7.1 Groundnut insects sampling ..... 25

3.7.1.1 *Aphis craccivora* ..... 26

3.7.1.2 Rosette count score ..... 26

3.7.1.3 *Ootheca* species ..... 26

3.7.2 Millet Insects sampling..... 26

3.7.2.1 Millet shootfly..... 27

3.7.2.2 Millet stemborer..... 27

3.7.2.3 Population of Other insects on millet ..... 27

3.8 Yield data collection ..... 27

3.8.1 Groundnut yield data ..... 27

3.8.1.1 Number of pods per plant ..... 28

3.8.1.2 Weight of pods per plot ..... 28

3.8.1.3 Grain yield of groundnut ..... 28

3.8.1.4 100-grain weight of groundnut ..... 28

3.8.2 Millet yield data ..... 28

3.8.2.1 Weight of heads per plot..... 28

CONTENTS CONT'D. PAGE


3.8.2.2 Grain yield of millet ..... 29

3.8.2.3 1000-grain weight ..... 29

3.9 Data analysis ..... 29

CHAPTER FOUR

**4.0** **RESULTS** ..... 30

**4.1** Pests associated with millet/groundnut intercrop..... 30

**4.2** Effect of millet/groundnut cropping patterns on aphid population 33

**4.3** Rosette count score on groundnut. ..... 33

**4.4** Effect of millet/groundnut cropping patterns on population of *Ootheca* species ..... 34

**4.5** Effect of millet/groundnut cropping patterns on cummulative mean number of aphids and Ootheca species. ..... 37

**4.6** Effect of millet/groundnut cropping patterns on some insect pests of millet ..... 43

**4.7** Effect of millet/groundnut cropping patterns on yield and some yield components of groundnut..... 46

4.7.1 Mean number of pods per plant..... 46

4.7.2 Weight of pods per plant ..... 46

4.7.3 Grain yield of groundnut..... 46

4.7.4 100-grain weight of groundnut..... 48

4.8 Effect of millet/groundnut cropping patterns on yield and some yield components of millet..... 48

4.8.1 Weight of millet head per plot..... 48

4.8.2 Grain yield of millet..... 48

CONTENTS CONT'D. PAGE

4.8.3 1000-grain weight..... 48

CHAPTER FIVE

5.0 DISCUSSIONS ..... 50

5.1 Insect pests associated with millet/groundnut cropping patterns 50

5.2 Effect of millet/groundnut cropping patterns on population of aphids ..... 50

5.3 Rosette count score..... 52

5.4 Effect of millet/groundnut cropping patterns on population of *Ootheca* species ..... 53

5.5 Effect of millet/groundnut cropping patterns on some insect pests of millet..... 54

5.6 Insect populations and yield of millet and groundnut..... 55

5.7 Effect of millet/groundnut cropping patterns on yield and some yield components of groundnut 56

5.7.1 Weight of pods in kg/ha..... 56

5.7.2 Number of pods per plant ..... 57

5.7.3 Grain yield of groundnut in kg/ha..... 57

5.8 Effect of millet/groundnut cropping patterns on yield and some yield components of millet..... 57

5.8.1 Weight of millet head per plot in kg/ha ..... 57

5.8.2 Grain yield of millet in kg/ha..... 58

CONTENTS CONT'D. PAGE

5.8.3 1000-grain weight for millet and 100-grain weight for groundnut ..... 58

CHAPTER SIX

SUMMARY AND CONCLUSIONS..... 59

REFERENCES..... 61

APPENDICES..... 77

## LIST OF TABLES


| TABLES | | PAGE |
|---|---|---|
| 1 | List of insect pests found to be associated with millet/ groundnut intercrop..... | 31 |
| 2 | Aphid population at 3, 6, 9 and 12 WAP in 1995 ..... | 35 |
| 3. | Aphid population at 2, 4, 6 and 8 WAP in 1996..... | 35 |
| 4. | Rosette count score..... | 36 |
| 5. | Population of *Ootheca* species at 2, 4 and 6 WAP in 1995..... | 38 |
| 6. | Population of *Ootheca* species at 2, 4 and 6 WAP in 1996..... | 38 |
| 7. | Cummulative mean number of aphids in the cropping patterns in 1995 and 1996..... | 39 |
| 8. | Cummulative mean number of *Ootheca* species in the cropping patterns in 1995 and 1996..... | 41 |
| 9. | Effect of millet/groundnut cropping patterns on some insect pests of millet in 1995..... | 44 |
| 10. | Effect of millet/groundnut cropping patterns on some insect pests of millet in 1996..... | 45 |
| 11. | Effect of millet/groundnut cropping patterns on yield and some yield components of groundnut..... | 47 |
| 12. | Effect of millet/groundnut cropping patterns on yield and some components of millet..... | 49 |

## LIST OF FIGURES


| FIGURES | | PAGE |
|---|---|---|
| 1. | Experimental layout in 1995 ..... | 23 |
| 2. | Experimental layout in 1996..... | 24 |
| 3. | Cummulative mean number of aphids in the different cropping patterns in 1995 and 1996 ..... | 40 |
| 4. | Cummulative mean number of *Ootheca* species in different cropping patterns in 1995 and 1996 ..... | 42 |

## *LIST OF APPENDICES*


| | | PAGE |
|---|---|---|
| 1. | Rainfall distribution at 10 days interval at Samaru in 1995 and 1996 Cropping seasons (mm)..... | 77 |
| 2. | Records of mean Temperature and Relative humidity at 10-days interval at Samaru during 1995 and 1996 cropping seasons..... | 77 |
| 3. | Physico-chemical properties of soil samples collected to a depth of 230cm from the experimental site at Samaru in 1995 and 1996 cropping seasons..... | 78 |

CHAPTER 1

## 1.0 INTRODUCTION

Groundnut, *Arachis hypogea* L. (Papillionaceae) is an important annual leguminous crop cultivated in many warm tropical and sub-tropical countries and also in some temperate countries. It is grown on about 19 million hectares annually, mainly in India, Nigeria, United States, Senegal and Brazil (FAO, 1967).

The crop was introduced into Nigeria from South America by the early Portuguese and Spanish explorers in the 16th century (Hammons, 1973). Groundnut is rich in oil (35-54%) and proteins (21-36%) and has high energy value of 236 KJ/100g. Seeds are used for oil extraction, as food and as important ingredient in confectionary products. After extraction, the residual cake is processed largely for use as animal feed and also for human consumption. The haulms are valuable as fodder.

In Nigeria, about 0.8-1.2 million hectares of groundnut are grown annually by the peasant farmers (Harkness, *et al.*, 1976). The bulk of the crop is grown in the northern states mainly in Bauchi, Gombe, Adamawa, Taraba, Kaduna, Kano, Jigawa and Sokoto. The southern states produce only one percent of the total output (Agboola, 1979).

Millets (*Pennisetum* species) include a number of cereals of the grass family, Graminae (Rachie, 1975). It is an important food crop and is widely cultivated. It is also a common food grain and forage crop in the tropics especially in the semi-arid tropical regions and certain parts of the warm temperate regions of the world (Rachie, 1975; Vogel and Graham, 1978). The most important producing countries are China, India, Nigeria, Chad, Mali, Tanzania, Niger and Burkina Faso.

In Nigeria, about 5 million hectares of millet are cultivated annually in the savanna zones and an average yield of 561kg/ha has been estimated (Thakare, 1980). Millet is second to sorghum in importance in the savanna zones of Nigeria but more important than sorghum in the Sahel zones. It can adapt well to conditions of lighter soils and has low water requirement for growth, hence its predominance in the drier Sahel zone (Rachie, 1975; Kassam and Kowal, 1976).

Millet exists in about six to seven distinct types out of which the most widely cultivated speices in Nigeria is the pearl millet (*Pennisetum typhoides*). Three varieties of *P. typhoides* are grown in Nigeria, namely, *gero, maiwa* and *dauro* millets. Gero millets are the most popular and widely grown types due to their early maturing ability. They are non-photoperiod sensitive, short-seasoned, sown early in May at the beginning of the rainy season and matures between 80-90 days. Their cultivation stretches from Southern Guinea Savanna to Sahel Savanna zones. Gero millet accounts for over 80% of the millet grown in Nigeria (Ogunlela and Egharevba, 1981). *Maiwa* and *dauro* millets are grown mostly in the Southern Guinea Savanna zones and in Jos Plateau. Both are photoperiod sensitive and matures between 100-150 days. Millets generally are grown mostly in mixtures with sorghum and legumes such as groundnuts and cowpea except in the Sahel zones where they are grown as sole crops.

African farming systems are extremely complex from the combination of root crops, tree crops, cereals, vegetables and other crops that are grown in combination on a normal subsistence farm. Multiple cropping is defined as the growing of two or more crops on the same field in a year (Andrews and Kassam, 1976). Multiple cropping is a major component of the traditional farming systems in Africa and its most widesperead form on the continent is mixed intercropping

followed by relay intercropping. Judged by its profitability as compared with sole cropping, multiple cropping is an established means of intensifying production per unit area. It also performs soil protective functions and on the whole contributes to a more stable agroecosystem.

Furthermore, multiple cropping is an appropriate and efficient cropping systems for low-input technology traditional farming systems under which the use of agro-chemicals (e.g. Fertilizers, herbicides and pesticides) and farm machinery is nil or minimal. There are limited data on the entomology of most crops involved in specific intercrop systems especially as it relates to the small-scale farmer. This is because researchers have tended generally to give low priority to these crops of specific intercrop systems and to concentrate most research efforts on the monocrops involved in these intercrop systems (Ajayi, 1986; Adesiyun and Ajayi, 1980).

Acquiring quantitative information about the intercrops, with equal emphasis being given to all components, is pre-requisite of either basic or applied work in insect-plant interactions within intercrops. Such kind of informations could form a basis for the development of effective pest management strategies in intercropping systems thereby combating one of the major constraints to food production.

Millet and Groundnut form a common intercrop combination among farmers and there is need to study the ecology of their insect pests. The objectives of this study therefore were to:-

1. Identify insect pests likely to be associated with millet groundnut/intercrop.
2. Study the abundance and distribution of insect pests identified to be associated with millet/groundnut intercrop.

CHAPTER 2.

# 2.0 LITERATURE REVIEW

## 2.1 Pest management in intercrops.

Crop intensification in space and time dimensions causes changes in pests and their populations and calls for changes in the technology used in dealing with them. In intensive cropping, the pests should be studied over the entire cropping period because the pest of one crop might be influenced by the previous crops as well as the companion crops.

The objective of pest management is to reduce pest problems by actions selected after the life systems of the pests are understood and the ecologies as well as the economic consequences of these actions have been predicted as accurately as possible to be in the best interest of mankind (Rabb, 1970). It is the considered view of entomologists that modelling approach to pest management adopted for sole crop is not practicable for intercropping systems and emperical method based on experience is more sound (Van Emden, 1977).

Pest outbreaks are believed to be less common in mixed stands due to crop diversity than in sole stands. This regulation of pests in intercropping systems occurs by physical means (protection from wind, hiding, shading, alteration of colour or shape if the stand) and biological interference (production of adverse chemical stimuli, presence of predators, parasitoids etc). (Litsinger and Moody, 1976; Van Emden and Williams, 1974).

One reason cited for wide scale adoption of mixed cropping in marginal farming is low incidence of insect pests (Nickel, 1973). Factors such as increased parasitoid and predator populations, availability of alternate prey, decreased colonisation and reproduction in pests, chemical repellancy, masking, feeding inhibnition by odours from non-host plants, prevention

of immigration and optimum synchrony in relation between pests and their natural enemies are likely to be involved in pest regulation in intercropping (Bhatnagar and Davies, 1981). For example unsprayed cowpea was less subject to insect damage when intercropped with sorghum than sole cropped cowpea (Raheja, 1977). Similarly okra appears to be a useful diversionary crop for the flea beetles, *Podagrica* species attacking cotton in Nigeria (Usenbo, 1976).

In intercropping, the taller components may act as physical barrier to pests attacking shorter components (Burleigh, 1973). In sorghum/cowpea intercropping in Tanzania, the taller sorghum prevented chrysomellid (*Ootheca* species) pests damaging the shorter cowpea. In Nigeria, the webworm (*Antigostra* species) causes less damage to sesamum when it was intercropped with sorghum (Litsinger and Moody, 1976).

Management of pests in multiple cropping involves a diversity of control measures. Although pesticides have to be used, their use should be based on need and economised. Residual toxicity on succeeding crops especially with persistent chemicals and in vegetable crops should be borne in mind. A combination of chemical, biological and cultural methods is likely to succeed in the long run.

**2.2.0 Stabilising mechanisms in intercrops**

Many authors have suggested mechanisms that lower abundance of insects in mixed crop systems (Way, 1953; Smith, 1969; Altieri *et al*, 1977 and Uvah, 1978). Such mechanisms can be grouped into natural enemy action, Visual effects, chemical effects and diversionary and physical barrier effects.

### 2.2.1 Natural enemy action.

In the more diverse environment created by intercropping, the number and diversity of natural enemies may be increased. Apparently, mixed crop systems offer a greater variety of prey and hosts for active natural enemy stages. In Solomon Island, and Tanzania, O'conor (1950) found that coconut was attacked by coconut bug *Pseudotheraptus* species. A predaceous ant, *Oecophylla smaragdina* Fabricius could control the bug. However, where the coconuts were under clean culture, the colonies of *Oecophylla* were eliminated by another ant, *Pheidole* species. Only undergrowth provides a favourable habitat for *Oecophylla* as well as a means for it to avoid *Pheidole* while moving from tree to tree. Therefore cover crop was recommended and this permitted effective control of the coconut bug.

Entomogenous fungi generally benefit from high relative humidity beneath dense foliar canopies and this probably explains reduced mite abundance on areca nut grown beneath banana in India (Khader and Anatoly, 1968).

### 2.2.2 Visual effects.

The colour and contrast of the host with its background influence host finding by some insect pest species. A mixture of crop types may affect the visual stimuli which attracts insect pests to their suitable host plants and in extreme cases, one crop becomes totally camouflaged by another to flying insects. This is particularly so for young plants in relay systems. Smith (1969) found that growing Brussels sprout sparsely, so that the plant were strikingly silhouetted against bare soil, attracted host-seeking aphids.

Host finding by certain species may also be influenced by attraction to particular colours. For example maize in a maize/groundnut intercrop is less attacked by maize borer, *Ostrinia*

*furnacalis* Guenee because the moth prefers a background with a brownish colour to solid green background (Raros, 1973). Yellow colour is also attractive to many species of aphids (Moericke, 1950) and certain species of Diptera. Aphid numbers were reduced when ground cover was increased by growing groundnuts (A'Brook, 1964; 1968), field beans (Way and Heathcote, 1966) and sugarbeet (Heathcote, 1970) at higher densities.

### 2.2.3 Chemical Effects

Many phytophagous insects locate their host plants using olfactory mechanisms (Kennedy and Moorhouse, 1969). Thorsteinson (1960) also stated that odours are significant in food plant recognition in final host-finding stages. For example the odour of apple was reported to attract the appale maggot flies *Rhagoletis pomonella* Walsh (Prokopy *et al*, 1973).

Hills (1972) found that carrots intercropped with onions were protected from damage by *Psila rosae* because the onions "Jammed carrot scent". Many other insects of vegetable crops have been found to be repelled by a host of aromatic herbs (Cox, 1974). Altieri *et al*, (1977) suggest that adverse effects of confusing chemical stimuli are responsible for lowered herbivore abundance in some tropical multiple cropping systems.

### 2.2.4 Diversionary and physical barrier effect.

Diversion occurs in two forms, one of which is trap cropping where a crop prefered by the insect is used to protect a valuable one, for examaple strip cropping with alfalfa has been used to protect cotton from lygus bug (Stern *et al,* 1969). The other form of diversion is avoidance reaction whereby the pest on landing on non-host intercropped with host is caused to leave the vicinity of the mixture. The dispersal of both adult and larval stages of insect pests may be impeded where hosts and non-hosts are grown together. The non-host plant may offer

a barrier to dispersal of insects into and within the host habitat. For example thrips attack on cowpea is reduced by interplanted maize (Rosingh, 1980).

Taylor (1977) also observed that *Maruca vitrata* Fab. attacked cowpea flowers less when cowpea was intra-row mixed with maize. At Zaria, northern Nigeria, Uvah (1978) intercropped sorghum with relay crops of millet and cowpea and found that the abundance of *Aphis craccivora*, Koch, *Maruca vitrata* Fab., *Megalurothrips sjostedti* Trybom and pod-sucking bugs was lowered by 92%, 45%, 35% and 90% respectively compared to their numbers on monocropped cowpea. He suggested that the sorghum afforded partial protection to the cowpea by acting as a non-host physical barrier which confused landing potential insect invaders of cowpea at canopy level and also created an unsuitable microclimate about the cowpea below.

**2.3.0 Insect pests of groundnut.**

**2.3.1.0 Aerial pests**

**2.3.1.1 *Aphis craccivora* Koch (Homoptera: Aphididae)**

The most important of the aerial pests of groundnut is the Aphid, *Aphis craccivora* (A'Brook, 1968 and Akinfenwa, 1978). The groundnut crop is subject to attack mainly by invertebrate pests at all stages of its development and also during storage (Misari, 1975; Misari and Raheja, 1976). *Aphis craccivora* is considered to be the most important aerial pest of the crop because it is a vector of the groundnut rosette virus disease. In addition to sucking sap which leads to loss in plant vigour, the most important damage done by these aphids is the transmission of groundnut rosette virus (Storey, 1925; Misari and Raheja, 1976). Crop damage resulting from aphid activity has been estimated at 80% (Johnson *et al*, 1978). In 1975, more than half 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 lead to economic loss is the first four weeks of the crop growth (Robisson, 1976).

The groundnut aphid causes damage primarily as a vector of viruses, but it can injure plants by its feeding acvtivity alone. It concentrates on the upper stems, in the flowers and on the leaves. Plants that are heavily attacked early in the cropping season become twisted, stunted and become covered in honey dew which results in sooty moulds. Plants that are thus damaged are likely to be covered by their more robust neighbours. Feeding damage has been cited as the cause of yield loss in India and West Africa (Mayeux, 1984).

The control of aphids can be achieved by such methods as use of insecticides, host-plant resistance and cultural methods. Conclusion from David *et al*, (1965) has shown that aphids are susceptible to most insecticides. However, their susceptibility does not mean that they are simple to control by chemical methods. They reproduce faster than their natural enemies which tend to be susceptible to the same insecticides. The result is flare-ups by the aphids and the need for repeated applications at frequent intervals, unless selective aphicides such as menazon and pirimicarb are applied (Cameron *et al*, 1983).

Several incidents of host plant resistance to groundnut rosette virus disease has been reported. Screen house tests at ICRISAT centre indicated that *Arachis chacoense, A. villosa, A. correntina* and *A. glabrata* exhibited high levels of resistance to *A. craccivora.* Progenies of interspecific hybrids of *A. hypogea* with *A. chacoense* and *A. villosa* also showed high levels of resistance (Amin, 1985).

However, of many genotypes tested, EC 368C (ICG 5240) has been the most consistently resistant in southern India and Malawi. It is thus the most promising source of resistance for

breeding (Pagham *et al.*, 1989). The groundnut rosette virus in EC 3682 remained low even under abnormally heavy infestation by viruliferous aphids in a screening nursery up to about 40 days after emergence, by which time the virus has a reduced effect on crop yield.

There is no systematic study on the effectiveness of natural enemies of *A. craccivora* as natural control agents. Farrel (1976), writing of Malawian conditions in the mid 1960's presented the most complete investigations. He concluded that the natural enemies reduced population densities only after aphid population started to decline towards the end of season as a result of the deterioration of the host. Coccinellid and Syrphid larvae were the most numerous predators. Entomogenous fungi also appeared late in the season. *A. craccivora* does not tolerate high densities (Farrel, 1976) but few plots with more than 50 aphids/plant were found in heterogenous environement on the farmers field. On the other hand, coccinellids, syrphids and other potential predators were present on plants in relatively high densities, e.g one coccinellid or syrphid larva per aphid colony of about 20 individuals at the time of expected population build-up.

Under cultural control means, there are two ways in which farmers can escape infestations by groundnut rosette virus-carrying aphids. These are close-spacing and early sowing demonstrated in Nigeria by A'Brook (1964) and Booker (1963), in Malawi by Farrel (1976). Farrel (1976) showed that the aphids reproduced less repidly on closely spaced plants, suggesting a form of Pseudoresistance included by the physiologic state of the host.

Close spacing should be possible at all stages of the season. However, early sowing may not always be possible because of other activities that compete for farmers time, such as the sowing and weeding of the more important staple cash crops.

**2.3.1.2 The groundnut plant hopper *Hilda partruelis* Stall (Homoptera: Tettigometridae)**

*Hilda patruelis* is well known to groundnut growers in much of Africa. Signs of *H. patruelis* are often easy to see, although because of its cryptic colouring and motility, the insect is not always easy to find. It lives on the roots of groundnut plants just below the crown and moves from one plant to another usually along a row. Infestations can be detected by rapid wilting and death of plants around the periphery of fields and by presence of small black ants e.g *Pheidole megacephala* Fabricius that tend *H. patruelis*.

Weaving's (1980) literature review indicate that *Hilda* sp is found south of a line extending from Sudan in the east to Nigeria in the West. The presence of crops such as groundnut, sunflower and cashew as well as of certain common weeds may be the factor determining its distribution. *H. patruelis* is believed to inject toxin into host plants when it feeds (ICRISAT 1985). The vascular tissues of the roots turn brown soon after attack, the leaves turn yellow and stems droop until they become prostrate. Outbreaks of *H. patruelis* are highly sporadic.

Control of *Hilda* sp can be achieved through the use of insecticides such as monocrotophos, aldrin or dieldrin worked into soil before sowing. Diaznon, fenithron or fenithrothion can also be sprayed on the basis of plants.

The use of host plant resistance and systematic research on cultural control on this pest have not been reported. However, it has been reported that eggs of *H. patruelis* are parasitised by *Psyllechthrus* species. Weaving (1980) found that 56 percent of all eggs were parasitised and only 14 percent of the egg batches contained no parasites during 15 months testing.

### 2.3.1.3 Thrips (Thysonoptera)

Thrips seem to feed on groundnut plants throughout the geographical range of the crop. They include *Megalurothrips, Caliothrips, Frankliniella, Scirtothrips* and *Taeniothrips* and none of these is limited to anyone continent.

*Frankliniella schultzei* Trybom is mainly a flower dweller and has been implicated as a vector of the tomato wilt virus with *F. occidentalis* Pergande and *F. fusca* Hinds. *Thrips palmi* Karny is probably the main vector of the tomato spotted wilt virus, with *Thrips tabaci* Lind both of which live mainly in the folded leaflets. *Caliothrips* sp cause mottling on the leaf surface but there is no information available about their economic importance.

Thrips can be controlled by use of insecticides but relatively high dosages are required to eliminate these tiny insects (Reddy and Wightman, 1988). It has been reported that following insecticides use, population explosions have occured (Reddy and Wightman, 1988).

Phytophagous thrips are preyed upon by a number of general predators such as mites and anthocorid bugs, as well as by predatory thrips. Many genotypes and hybrids with resistance to jassids are also resistant to thrips e.g Robut 33-1 (Kadiri 3).

One method of reducing the risk of an outbreak of tomato spotted wilt virus is to phase the sowing of the crop in such a way that the seedling (i.e the stage that is most vulnerable to the virus) will not be exposed to an invasion of thrips. Research at ICRISAT has shown that the prevalence of the virus increases as the planting date is delayed - both in the rainy and post-rainy season. Furthermore, a densely sown crop is likely to have lower losses attributable to the virus than a widely spaced crop (Wightman and Amin, 1988).

Physical barriers across the prevailing wind also influence thrips density. This can mean

an intercrop that is not a host, such as sorghum, maize and millet or a row of trees.

Other very important aerial pests of groundnut include the phytophagous *Empoasca dolichi* Paoli, and the flower beetles of the family Meloidae (Misari, 1975). Of minor importance are *Monolepta* species, *Luperodes* species, *Ootheca mutabilis* Sahlb., red spider mites and grass hoppers (Misari, 1975).

**2.3.2 Soil pests.**

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

About 2,000 species of termites are known and about 10% of these are damaging to crops (Sands, 1962). Termites are mainly tropical pests and in Nigeria, they are abundant in the relatively drier savanna 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, 1962). Economically important genera include *Microtermes, Odontotermes, Macroterms* and *Trinerustermes* together with soldierless termites that were consistently found 10-20cm below the soil surface under groundnut plants in the moister parts of southern Africa.

Like most soil insects, termites are influenced by soil moisture. It has been shown that those areas of Nigeria where the annual rainfall is more than 800mm, less than 10% of stands are attacked (Johnson and Gumel, 1981). Wheatley *et al*, (1989) showed that the number of termites (*Microtermes obesi* Alc.) attacking wooden pegs were in soil with moisture of 10-13

percent where the field capacity of this Alfisol was 18.3 percent and wilting point 12.0 percent.

Yield losses by termites can be reduced by routine application of cyclodiene insecticides to the soil of a groundnut field at 1-2kg a.i./ha before sowing. Dust or grannular formulations are the most effective. However these insecticides find their way into the kernel oil at contamination levels that are not acceptable. Many other insecticides will kill termites but the conventional formulations of other insecticides do not persist long enough in tropical soils to protect the crop to the end of the growing season. It has already been shown that termites are mainly an end of season problem (Wood *et al*, 1977). The few termites present in a field early in the season may be controlled by an organophosphate or carbamate insecticide but as soon as conditions are suitable later, the termites will invade the crop. Side dressings with such insecticides may be beneficial but can only be effective if rain falls at the right time and in the correct quantity to allow the insecticide to penetrate the soil without getting washed away.

Termites in the soil are natural preys of ants, and in any case, ants dominate the invertebrate predators in many groundnut fields and reduce the levels of termites attack. This can serve as a biological control measure by the natural enemy. The relationship between late season and termite attack suggests that crops harvested before drought are less vulnerable than those harvested later. This implies that farmers should sow a variety with a short growing season. This approach is also sound from the perspective of disease avoidance and general agronomy of the crop.

A variety of Nigerian farmers methods are available in the control of termites. Malaka (1972) made a survey of farmers practices in groundnut growing regions of Nigeria and he asked the farmers how they controlled termites other than the use of insecticides. Farmers responses

included, hiring of drummers to drive the termites away, burning dead goats or fish viscera in the fields. Other methods include sprinkling alum solution, kerosene, liquid left after boiling locust bean seed, or contents of expired cell batteries around the crop. The use of disinfectant into nests, putting soldier ants into nests, removing the "royal couple" from nest, burrying cassava meal (fufu) and planting termites grass (*Vetivenria nigrotana*) around Ornamentals and *Digitaria* species etc. around farms are also a variety of cultural measures.

**2.3.3 Pests associated with stored groundnuts.**

Storage pests infestation of groundnut is mostly by insects although some mites have also been found associated with stored products. The common ones identified are *Ephestia cautella* Walk, *Oryzaephilus mercator* Fauv, *O. surinamensis* L., *Tribolium castaneum* herb and *T. confusum* du val (Protocor and Ashman, 1972).

Pointel *et al* (1979) found that the beetles *Caryedon serratus* Oliv. were associated with staked groundnut in Senegal. Joint investigations by Nigerian Stored Product Research Institute (NSPRI) and Pest Infestation laboratory, Slough (U.K) showed that *Tribolium* species were widespread in groundnut producing areas around Kano. The red flower beetle, *Tribolium castaneum* and *Ephestia cautella* have been reported as main storage pest of groundnut in Malawi.(Mercer, 1978). Conway (1976) found that staked groundnut in Gambia showed 84% pod infestation at peripheral layers by *Elasmolomus sordidus*. The most serious insect pests of groundnut in shell are *Caryedon serratus* and *Trogoderma grenarium* Everts, where about 30% infestation of undecorticated groundnut was reported (Magar, 1973).

**2.4.0 Major insect pests of millet.**

**2.4.1 The millet headminer *Heiliocheilus albipunctella* dejoannis (Lepidoptera: Noctuidae).**

In Nigeria, it was first noticed or recorded at Azare in 1926 (Deeming, 1978). Since then surveys have been carried out all over millet-growing areas of Nigeria and this has shown that the insect is restricted to areas between 11° and 13°N within Bauchi, Borno, Kano, Sokoto and Adamawa states in the Sudan and Sahel savanna zones (Ajayi, 1984).

Young carterpillars make holes into the flower and eat out the contents. Larger carterpillars eat away the bases of flowers including the ovaries thereby reducing seed setting and grain yield. The worthless flowers may remain attached to the head but often blown away by the wind with only the central rachis remaining (Ajayi, 1981).

Trials conducted by Ajayi (1984) at Institute for Agricultural Research, Samaru have shown that the late planted millet suffers higher infestations, because the emergence of ovipositing female insect coincides with the flowering and heading periods in millet. Early planting and deep ploughing are valuable cultural control methods.

Ajayi (1984) identified one hymenopteran parasite, *Bracon hebetor* Say. Cymbush e.c at the rate of 100g a.i/ha applied three times at weekly intervals starting from heading gave best control. Decis e.c at the rate of 30g a.i/ha, Malathion e.c at 1kg a.i./ha and carbaryl 85 wp at 1.68kg a.i./ha also gave effective control (Ajayi 1986).

**2.4.2 The millet shootfly, *Delia arambourgi* Seguy (Diptera: Antomyiidae)**

This pest attacks millet at early stages of their growth. Attack is generally on the shoot of the plant and the growing point resulting in deadhearts (Ajayi, 1980). The deadheart can easily be pulled out and emits a pungent smell. Attacked plants that survive come out deformed

and growth is very much retarded with a subsequent decrease in grain yield (Egharevha, 1978). One larva may destroy three to four shoots (Hill, 1975).

So far the most effective method of control is early planting. Seed dressing using dieldrin and heptachlor can equally give successful control (Hill, 1975).

**2.4.3 Head Beetles *Meligethes heteropus* Gerstaeoker (Coleoptera: Nitidulidae).**

Perhaps the most important of the several beetles that infest the millet head in Nigeria is *M. heteropus* (Ajayi, 1980). The beetle enters the millet spikelet between adjacent paleae of the twinned inflorescence and chews a hole through the paleae near the base and consumes several parts, both pistils and stamens.

Other beetles, *Monolepta goldingi* Bry., *Mylabris vestita* Reich., *M. bifasciata* Oliv *M. abdominalis* F., four species of *Psalydolylta, Coryna hermaniae* F., *Rhyniptia infuscata* Burm and three species of *Anomala* occasionally feed as adults in large numbers on millet pollen, but their effects on pollination and subsequent grain yield have not been quantified (Ajayi, 1986).

**2.4.4 The millet midge, *Geromyia penniseti* Felt. (Diptera: Cecidomyiidae).**

It is believed that this pest has been present on millet in Africa and India for a long time and has only been discovered as interest in the crop has increased (Coutin and Harris, 1969).

The larvae feed on the ovary and cause it to shrivel up without setting seed. An effective cultural control measure is the destruction of all infested heads, before the start of the rains to reduce the carry over of diapausing larvae.

Chemical control is difficult and expensive because several sprays and a complete coverage will be necessary. Many beneficial insects for example, pollinating beetles and natural

enemies could also be harmed. Furthermore residual chemicals in harvested heads could be dangerous (Ajayi, 1985).

**2.4.5 Millet stem borer *Coniesta ignefusalis* Hampson (Lepidoptera: Pyralidae)**

This pest is found wherever millet is grown. It is widely distributed in Northern Nigeria, where it is abundant in millet-growing areas. Harris (1962) recorded a grain yield loss of 15% due to attack by *C. ignefusalis* on early maturing (*gero*) millet in Kano. Late maturing (*Maiwa*) millet suffers higher levels of attack whilst the "*dauro*" millet may sometimes be totally destroyed in Samaru, Zaria (Ajayi, 1980).

Control methods include early planting, low rates of Nitrogen, mixed cropping, the development of stem borer resistant varieties of millet, the use of good systemic insecticide, for example carbofuran and the action of natural enemies (Ajayi, 1985).

Other pests of millet are *Marasmia trapezalis* Cin. The larvae of this pest bind the two edges of a leaf together with silk and form a funnel inside which they feed on the leaves. Keeping the surrounding weed free is a good control measure. *Janomina mescundulata* Strand (gizaka in Hausa) may completely defoliate plants. Removal of tree host plants within the vicinity of the millet plant effectively controls the pest (Ajayi, 1980).

**2.5.0 Interaction between pests and diseases of groundnuts.**

Apart from vector/virus relationship between *Aphis craccivora* and rosette virus there are quite a lot of important interactions between pests and diseases of groundnuts. Soil pests which attack seeds and seedlings facilitate fungal invasion and those which damage pods notably termites and millepedes make it easy for soil fungi to attack seeds and this is especially important in relation to aflatoxin contamination.

Work by Mac Donald, Bos and Gumel (unpublished) has shown that infection of pods and seed testa by *Aphelenchoides arachidis* can lead to increased fungal infection of seeds with adverse effects upon subsequent germination and seedling emergence. Where attack by soil pests is followed by rotting of pods and seeds, the damage may not be apparent at harvest. This is particularly the case with pods penetration by termites and millipedes.

**2.6.0 Disease management in intercrops.**

Unlike in weed and insect pest management, the management of diseases in an intercrop may not be totally advantageous as would be desired. In inter-cropping, complete canopy cover over the land have been reported to have negative effects as the micro climate becomes more humid and is favourable for proliferation of fungal diseases (Trenbath, 1974).

Intercropping by combining susceptible and resistant crops may lead to reduced disease incidence. Control of potato blight (*Phytophthora infestans*) in Ireland and southern maize leaf blight (*Helminthosporium maydis*) in U.S.A. has been obtained by adopting this approach (Adams *et al.*, 1974).

Plant density affects disease incidence. With wind or soil borne diseases and spores, the wider the separation between individual host plants, the less likely it becomes that the organism infect new plants (Chivers and Brittain, 1972). However the spread of wind borne diseases depends more on the number of dispersals than on the distance between the host. Virus diseases spread more easily to adjacent plants. Thus intercropping where plants of the same species are separated by plants of other species, a slower rate of dissemination will be expected (Litsinger and Moody, 1976).

**2.7.0 Strategies for pest management.**

Pest management in intensive cropping systems involves a diversity of methods. A strategy suitable for tropical small farmers has been outlined by Van Emden (1977). This consists of three ways (a) pest suppression, this is the prevention of pest populations from increasing (b) pest regulation, preventing the pest population from exceeding the point of control of natural enemies and (c) resource limitation - making the pest population to fall from its peak density.

The breakthrough in developing a pest management strategy for intensive cropping systems may lie in an approach where crop management rather than pest control possibilities and crop characteristics rather than pest populations are given importance. This needs a screening programme to select those components contributing to the cropping systems. The pest problems of existing and proposed systems should be studied critically. The ones where pest build up occur should be discarded and others retained for further evaluations. This is a continuous process and the strategy will change with crops, varieties, cultural methods and pest behaviour.

**2.8.0 Hazards of pesticide usage.**

The immense value of pesticides in crop production cannot be over-emphasized. However, it is noted that at manufacturing, packaging, transporting, marketing, storage and use, they constitute potential hazards to man and the environment. Weeks (1979) had noted that wherever pesticides are being produced, transported, stored and used, they constitute a potential risk and the task is to forsee and prevent incidents rather than finding solutions after events.

Thus with the present status of agriculture and increase in pesticide use, national governments have to enforce strictly the laws or introduce new legislation to deal specifically

with control of their use. However, legislation on the control of pesticides is inevitably complex. This according to WHO (1970) is the consequence of the multiplicity of ways in which pesticides can affect human health and well being which in turn results in pesticide control being the responsibility not only of a single but a number of authorities.

The need to restrict residual quantities of pesticides in food to safe levels has been recognised for a long time. England initiated legal safe levels in 1900 while Carlifornia enacted legislation over 40 years ago restricting the levels of arsenicals in food (Rudd, 1964).

In the light of the forgoing argument and given the peasant farmer situation in Nigeria, it would be obvious that while farmers await concrete legislation on pesticide use to control some notorious pests, there is need to try other methods of pest control or regulation. Cultural practices adopted by farmers in their farming systems is one way of controlling pests, of these cultural practices, intercropping is one way by which pests population can be controlled.

CHAPTER 3

# 3.0 MATERIALS AND METHODS

## 3.1 Experimental site.

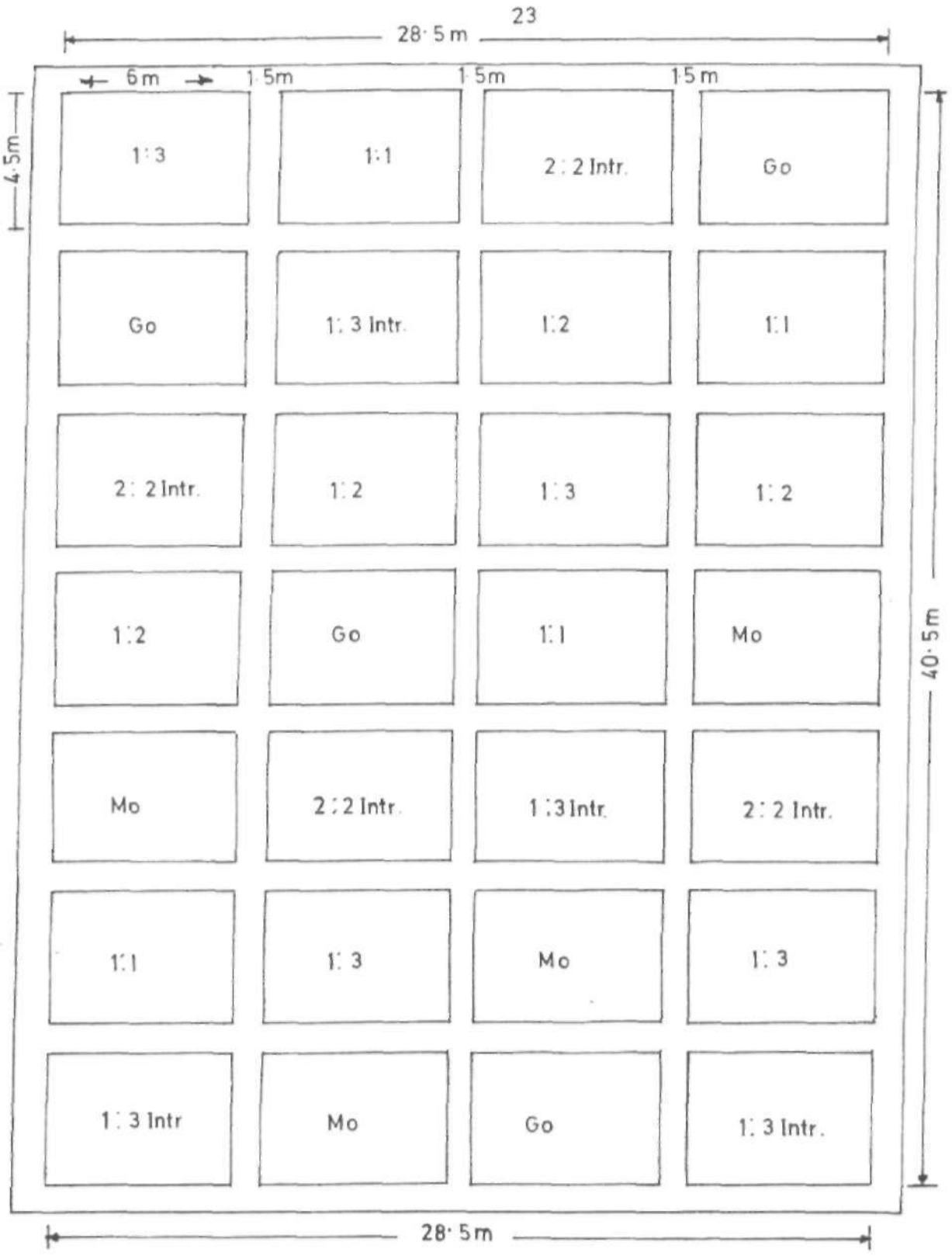
Two field experiments were carried out during the 1995 and 1996 cropping seasons at the research farm of the Institute for Agricultural Research, Samaru, Zaria (Lat. 11° 11'N, Long. 07° 38'E, 686m) in the Northern Guinea savanna ecological zone of Nigeria. Meteorological and soil data during the periods of the two experiments are available in appendices 1 and 2 respectively.

## 3.2 Land preparation.

The fields were ploughed for each year, using a plough. This was followed by harrowing to further pulverise the soil into finer particles. Finally, ridging was done with rows 0.75m apart to give suitable beds for seed germination and to provide proper drainage.

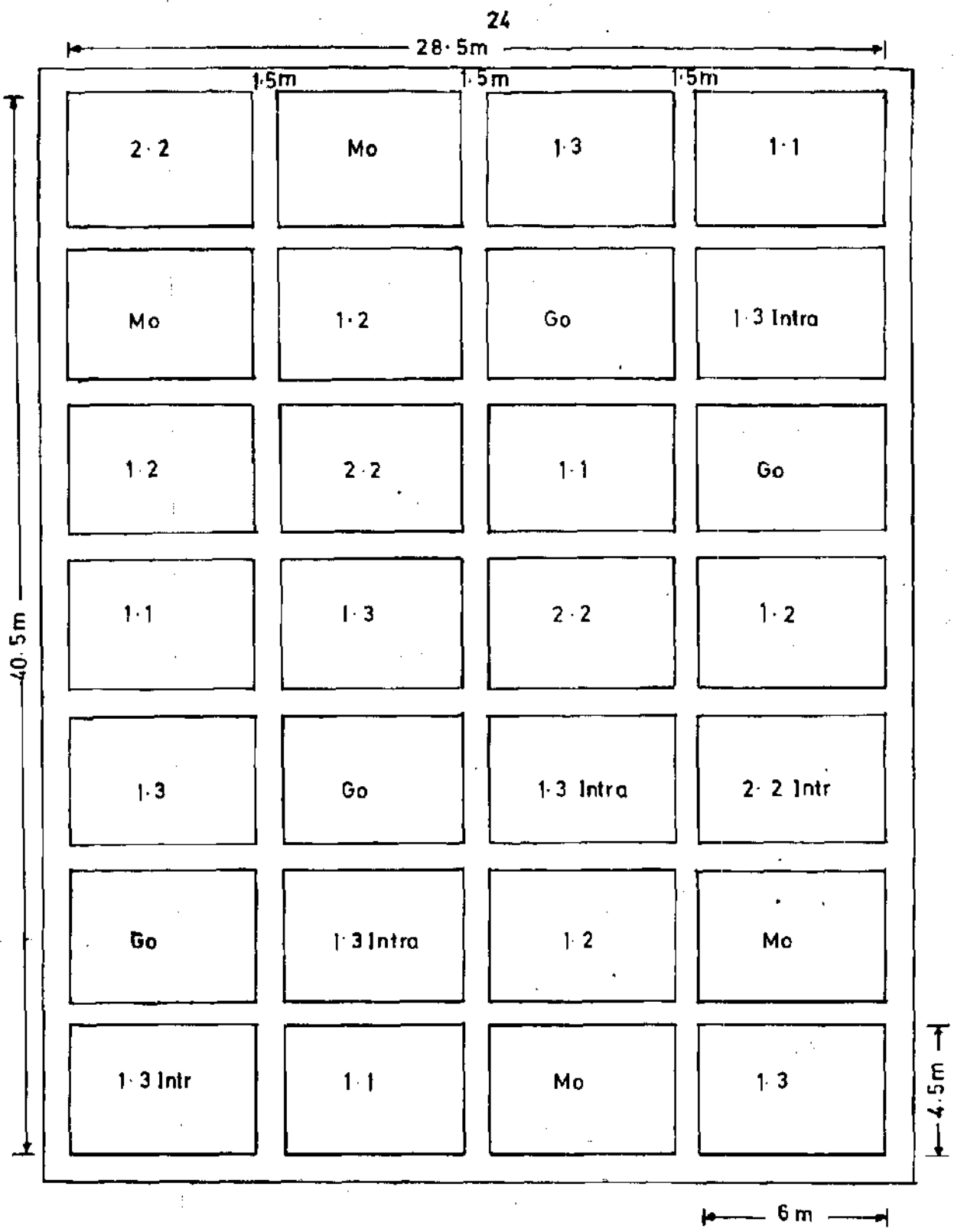
## 3.3 Experimental design and layout.

In each of the experiments for the two years, an area measuring 40.5m x 28.5m was marked out and 28 smaller plots each measuring 6m x 4.5m (i.e 6 metres x 6 ridges) were marked out. Each smaller plot was separated from the adjacent one by 1.5m gap path. Each experiment was then laid out in a randomised complete block design containing seven treatments replicated four times. The layout and the details of the seven treatments for both 1995 and 1996 cropping seasons are shown in figures 1 and 2, respectively.




1. 1:1 Millet/Groundnut inter-row (M/G 1:1) 2. 1:2 Millet/Groundnut inter-row (M/G 1:2)
3. 1:3 Millet/Groundnut inter-row (M/G 1:3) 4. 2:2 Millet/Groundnut intra-row (M/G 2:2)
5. 1:3 Millet/Groundnut intra-row (M/G 1:3) 6. Monocrop Millet (Mo)
7. Monocrop Groundnut (Go)

FIGURE 1: LAYOUT OF 1995 EXPERIMENT




1. 1·1 Millet/Groundnut inter-row (M/G 1·1)
2. 1·2 Millet/Groundnut inter-row (M/G 1·2)
3. 1·3 Millet/Groundnut inter- row (M/G 1·3)
4. 2·2 Millet/Groundnut intra-row (M/G 2·2)
5. 1·3 Millet/Groundnut intra-row (M/G 1·3)
6. Monocrop Millet (Mo)
7. Monocrop Groundnut (Go)

FIGURE 2: LAYOUT OF 1986 EXPERIMENT

### 3.4 Seed materials and sowing.

An early maturing "*gero*" millet (Ex-Borno) variety was intercropped with groundnut (Rmp 12) variety. About four to seven seeds of millet were sown at a spacing of 25cm apart. These were later thinned down to an average of two plants per stand. Two seeds of groundnut were sown per hole also at 25cm apart. Thinning of millet was done at two weeks after planting (WAP). Sowing was done simultaneously on 3rd July in 1995 and 10th July in 1996.

### 3.5 Weeding

Hoe-weeding was carried out throughout the growing season whenever it was found to be necessary especially at critical periods of weed interference.

### 3.6 Fertilizer application

Compound fertilizer containing Nitrogen, Phosphorus and Potassium was applied at the recommended rate of 60KgN/ha, 30KgP/ha and 30KgK/ha. $54KgP_2O_5$/ha as a single superphosphate was also applied to groundnut. Benlate was sprayed at the rate of 30 grammes in 20 litres of water to shield off any effect of fungal attack.

### 3.7.0 Data Collection

### 3.7.1 Groundnut insects sampling

Using the crops developmental stage, insects were sampled using the techniques of handpicking and direct physical count. Plants were chosen randomly in each plot and no plant was sampled twice for a single pest. Adults were identified at the insect museum of Institute of Agricultural Research, Ahmadu Bello University, Zaria.

#### 3.7.1.1 *Aphis craccivora*

Aphids were sampled by counting or recording their populations on five randomly selected plants from each plot for up to 12 WAP in 1995. In 1996, sampling of aphids was terminated at 10WAP. Sampling was always done weekly either in early mornings or late evenings by direct physical count.

#### 3.7.1.2 Rosette count score.

Rosette score was taken in the case of groundnut using a scale of 1-5 as described by Khun and Smith (1977) as follows:

1 = No rosette symptoms.

2 = Discernible rosette leaf symptoms (no stunt).

3 = Rosette leaf symptoms plus stunt ranging from barely discernible to about 15%

4 = Rosette leaf symptoms plus stunt ranging from 15-50%

5 = Rosette leaf symptoms plus stunt greater than 50%.

#### 3.7.1.3 *Ootheca* species

Populations of Ootheca species comprising both *Ootheca bifrons* and *O. mutabilis* Salhberg were recorded weekly for six weeks in 1995 while in 1996 populations were recorded for five weeks. In all cases of *Ootheca*, sampling by direct handpicking was employed.

### 3.7.2 Millet insect sampling

Sampling of insects on millet was done by randomly selecting five plants with the associated tillers from each plot. Depending on the type of insect involved, sampling was done either by direct physical count or by the use of damage indices as in the cases of shootflies and stem borers. No plant was selected twice for the same insect.

### 3.7.2.1 Millet shootfly. *Delia aramburgi*

In each plot, shoots having deadheart was noticed at 6, 7 and 8 WAP in 1995. Deadheart was not noticed in 1996. It was identified by gently pulling the growing point which pulled off easily and emited a pungent smell.

### 3.7.2.2 The millet stem borer *Coniesta ignefusalis*

Stem borer record was taken at 40 and 50 days after planting (DAP) in 1995 and in 1996, the record was taken at 40, 50 and 60DAP. In both years five stalks were taken per plot and the stalks were then dissected and larval numbers were recorded.

### 3.7.2.3 Population of other insects on millet.

At 7 and 8 WAP, record of some other insects were taken in both 1995 and 1996. These included *Agonoscellis vesicolor, Melyris abdominalis, Coryna hermaniae* and *Mylabris* species. In most of these cases five plant stands with associated tillers per plot were usually selected and record of these insects on them were taken by holding each tiller and directly counting. With the exception of *Melyris abdominalis* where record was taken for 6, 7 and 8 WAP, all others had their records taken at 7 and 8 WAP.

In 1996 population of *Locris rubens* Erichson was observed to be appreciable and record on it was taken at 6, 7 and 8 WAP by directly counting their number on the tillers of five randomly selected plant stands per plot.

## 3.8.0 Yield data collection

### 3.8.1 Groundnut yield data

The data collected with respect to groundnut yield included number of pods per plant, total weight of pods per plot, grain yield of groundnut and 100-grain weight.

**3.8.1.1 Number of pods per plant.**

At maturity, five plant samples were harvested from each plot. The number of pods on each plot and the number of pods on each plant were recorded and the average number of pods was calculated.

**3.8.1.2 Weight of pods per plot.**

The total weight of pods from each plot was recorded. After working out the means for the four replications, the figures were then converted to give weight of pods per hectare.

**3.8.1.3 Grain yield of groundnut.**

Shelled groundnut grains obtained from each plot were weighed and the means for the four replications were obtained. These were then converted to give grain yield of each plot in kg per hectare.

**3.8.1.4 100-grain weight of groundnut.**

One hundred grains selected randomly from the shelled groundnut of each plot was counted. They were weighed using a sensitive analytical balance (Mettler Scale) and the 100-grain weight of groundnut obtained in grammes.

**3.8.2 Millet yield data.**

Yield data collected for millet included total weight of millet head per plot in kg/ha, Grain yield of millet per plot and 1000-grain weight.

**3.8.2.1 Weight of millet heads per plot.**

From each plot the total millet heads harvested were weighed on a scale. The means of the four replications were calculated out and this was later converted to kg per hectare.

**3.8.2.2 Grain yield of millet.**

Threshed grains from each plot were weighed and mean yield per unit area was obtained in each plot to enable conversion to kilogramme per hectare.

**3.8.2.3 1000-grain weight.**

One thousand grains were counted from each plot and weighed out using a sensitive Mettler scale to give 1000-grain weight.

**3.8.2.4 *Data analysis.***

All data collected were subjected to analysis of variance (ANOVA) and the means were separated using Duncan Multiple Range Test (DMRT) at 5% level of significance.

CHAPTER 4

# 4.0 RESULTS.

## 4.1 Pests associated with groundnut/millet intercrop

Table 1 shows a list of insects found to be associated with millet/groundnut intercrop in 1995 and 1996 cropping seasons in Samaru. *Aphis craccivora* and *Ootheca* species were the major insect pests found on groundnut in the two years and special attention was paid to their population and distribution in the cropping patterns. This can be seen in the subsequent tables that follow later.

On millet the major pests found were stemborers, the millet shootflies and some panicle insects such as *Coryna hermaniae, Melyris abdominalis, Mylabris* species and *Agonoscellis versicolor.* Particular attention was paid to their population trend in the different cropping arrangements and this can be seen in the subsequent tables that follow later.

Many other insects were observed apart from those mentioned above but did not show any particular distribution pattern with regards to crop arrangements (Table 1). Some were observed on both millet and groundnut such as earwigs, cotton stainer and a host of others.

**Table 1: List of insects found associated with millet/groundnut intercrop at Samaru in 1995 and 1996 cropping seasons.**

| Types of insect | 1995 | 1996 |
|---|---|---|
| *Agonoscellis versicolor* (F) Hemiptera: Pentatomidae | ++ | ++ |
| *Aphis craccivora* Koch Homoptera: Aphididae | + | + |
| *Anoplocnemis curvipes* Fab. Heteropteria: Coreidae | - | + |
| *Chilomenes sulphurea* Oliva Coleoptera: Coccinellidae. | - | + |
| *Chilomenes vicinia* Muls Coleoptera: Coccinellidae | + | - |
| *Chondororhina abbrevita* (F). Coleoptera: Scarabidae. | - | + |
| *Coniesta ignefusalis* Hampson. Lepidoptera: Pyralidae. | + | + |
| *Coryna hermaniae* (F). Coleoptera: Meloidae. | - | + |
| *Delia arambourgi* Seguy. Diptera: Antomyiidae. | + | + |
| *Diplognatha gagates* Forst. Coleoptera: Scarabaeidae. | - | + |
| *Dysdercus volker* F. Heteroptera: Pyrrhochoridae. | - | ++ |
| *Ellidius apiralis* Waterb Coleoptera: Cantharidae. | - | + |
| *Forficula senegalensis* Service Dermaptera: Forficulidae. | - | ++ |
| *Locris rubens* Erichson Homoptera: Cercopidae | + | ++ |
| *Lygaeus rivularis* Germ. Heteroptera: Lygaedae | - | + |
| *Mylyris abdominalis* (F.) Coleoptera: Melyridae | - | + |

Table 1: Contd.

| | 1995 | 1996 |
|---|---|---|
| *Mylabris* spp<br>Coleoptera: Meloidae. | + | + |
| *Ootheca* species<br>Coleoptera: Chrysomelidae | + | + |
| *Peploptera aracuta* Clav.<br>Coleoptera: Chrysomelidae | + | - |
| *Podagrica uniforma* Jac.<br>Coleoptera: Chrysomelidae | + | - |
| *Poophilus costalis* Wlk.<br>Homoptera: Aphorphoridae | - | + |
| *Sphaerocoris annulus* F.<br>Heteroptera: Pentatomidae. | + | + |
| *Sphaenocarpa* species<br>Hymenoptera: Braconidae | + | - |

+ low population ++ high population.

**4.2 Effect of millet/groundnut cropping patterns on aphid population.**

In 1995, there was no significant difference ($P<0.05$) in aphid population among the different crop arrangements at 3 WAP (Table 2). At 6 WAP there seem to be no statistical significant difference ($P>0.05$) in aphid population between the various crop arrangements but the mean number of aphid population between the two extreme treatments of 1:1 inter-row arrangement and sole cropped groundnut differed tremendously (Table 2). Almost the same trend was observed at 9 and 12 WAP except that at 9 WAP, it was clear that the three inter-row arrangements showed significant differences ($P<0.05$) in aphid population between the two intra-row arrangements and the sole cropped groundnut (Table 2).

There was no statistically significant difference ($P>0.05$) in aphid population among all the different crop arrangement in 1996 at 2 and 4 WAP (Table 3). However at 6 WAP, there was significant difference ($P>0.05$) between 1:1 inter-row arrangement and sole cropped groundnut in aphid population. The two intra-row arrangements were significantly different ($P<0.05$) from all other treatments (Table 3).

At 8 WAP there was significant difference ($P<0.05$) among all the crop arrangements in aphid population in 1996. Generally in both 1995 and 1996 cropping seasons, the two intra-row treatments recorded higher aphid numbers even in cases where they were not statistically significant (Tables 2 and 3).

**4.3 Rosette count score on groundnut**

There was statistically significant difference ($P<0.05$) between the two extreme treatments of 1:1 inter-row arrangement and monocropped groundnut in rosette count score in 1995 and the same trend was observed in 1996 (Table 4). However, within the various inter-row

and intra-row arrangements there was no statistically significant difference ($P > 0.05$) in rosette count score. This trend was observed for both the 1995 and 1996 cropping seasons.

**4.4 Effect of millet/groundnut cropping patterns on populations of *Ootheca* species.**

There was no significant difference ($P > 0.05$) in the population of *Ootheca* species at 2 WAP in 1995 (Table 5). However, at 4 WAP there was significant difference between the two extreme treatments of 1:1 inter-row and sole cropped groundnut. Within the remaining crop arrangements at 4 WAP, there was no statistical significant difference ($P > 0.05$) (Table 5). At 6 WAP there was significant difference ($P < 0.05$) among the 1:1 inter-row arrangement and sole cropped groundnut.

**Table 2: Aphid population at 3, 6, 9 and 12 WAP in 1995.**

| Treatments | Weeks After Planting (WAP) | | | |
|---|---|---|---|---|
| | 3 WAP | 6WAP | 9 WAP | 12 WAP |
| M/G - 1:1 inter-row | 10.0a | 8.8b | 8.8b | 13.3a |
| M/G - 1:2 inter-row | 9.8a | 11.3ab | 10.3b | 12.5a |
| M/G - 1:3 inter-row | 11.3a | 13.5ab | 11.3b | 12.8a |
| M/G - 2:2 intra-row | 12.5a | 18.5ab | 18.3a | 20.3b |
| M/G - 1:3 intra-row | 10.8a | 18.0ab | 21.3a | 14.8ab |
| Sole G'nut | 11.8a | 17.8ab | 17.8a | 16.8ab |
| SE ± | 2.5 | 5.6 | 3.8 | 7.1 |

Means followed by the same letters in the same column are not significantly differently at 5% level of significance using DMRT.

M/G = Millet/groundnut intercrop.

**Table 3: Aphid population at 2, 4, 6 and 8 WAP in 1995.**

| Treatments | Weeks After Planting (WAP) | | | |
|---|---|---|---|---|
| | 2 WAP | 4WAP | 6 WAP | 8 WAP |
| M/G - 1:1 inter-row | 6.5a | 9.8a | 8.3d | 6.8f |
| M/G - 1:2 inter-row | 7.8a | 9.8a | 11.3c | 9.8c |
| M/G - 1:3 inter-row | 7.5a | 9.0a | 12.3bc | 12.8d |
| M/G - 2:2 intra-row | 9.0a | 10.3a | 17.0a | 20.8a |
| M/G - 1:3 intra-row | 7.8a | 9.8b | 16.8a | 18.5b |
| Sole G'nut | 7.0a | 9.8a | 14.3b | 15.0c |
| SE ± | 1.9 | 1.9 | 1.3 | 1.4 |

Means followed by the same letters in the same column are not significantly differently at 5% level of significance using DMRT.

M/G = Millet/groundnut intercrop.

**Table 4:** Rosette count score on Groundnut

| Treatments | 1995 | 1996 |
|---|---|---|
| M/G - 1:1 inter-row | 1.0c | 1.0b |
| M/G - 1:2 inter-row | 1.5bc | 1.5ab |
| M/G - 1:3 inter-row | 1.8abc | 1.5ab |
| M/G - 2:2 intra-row | 2.3ab | 2.0ab |
| M/G - 1:3 intra-row | 2.3ab | 2.5a |
| Sole G'nut | 2.5a | 2.5a |
| SE ± | 0.5 | 0.6 |

*Means followed by the same letters in the same column are not significantly differently at 5%* level of significance using DMRT.

M/G = Millet/groundnut intercrop.

The 1:1 and 1:2 inter-row arrangements were not statistically significant ($P>0.05$) in *Ootheca* species population. The two intra-row arrangements were not statistically different ($P>0.05$) from the 1:3 inter-row arrangement but differed significantly ($P<0.05$) from the 1:1 and 1:2 inter-row arrangements in *Ootheca* species population (Table 5).

In 1996, there was no significant difference ($P>0.05$) among all the treatments at 2, 3 and 4 WAP (Table 6). However, at 5 WAP there was significant difference ($P<0.05$) between the 1:1 inter-row crop arrangement and sole cropped groundnut. However, within the remaining crop arrangements, there was no significant difference ($P>0.05$) among them (Table 6). It was observed generally that the sole cropped groundnut recorded highest number of *Ootheca* species among all the treatments in both 1995 and 1996 (Tables 5 and 6).

### 4.5 Effect of millet/groundnut cropping patterns on cummulative mean number of aphids and *Ootheca* species

The cummulative mean distribution of aphids in the different cropping patterns in both 1995 and 1996 shows that in both cases, the two intra-row crop arrangements had significantly higher pest populations ($P < 0.05$) than other crop arrangements (Table 7) with the sole cropped groundnut following closely (Fig. 3). The 1:1 inter-row arrangement recorded significantly lowest pest population ($P < 0.05$) when compared with other crop arrangements (Fig. 3). The 1:2 and 1:3 inter-row arrangements were not significantly different ($P < 0.05$) in their aphid population in both years (Table 7).

Almost the same trend was observed in the case of *Ootheca* species population in both years except that the highest pest population were recorded on sole cropped plots (Table 8). The 1:1 inter-row crop arrangement recorded lowest pest population even though they were not statistically significantly different ($P > 0.05$) from the pest population recorded on 1:2 and 1:3 inter-row crop arrangements (Table 8).

Fig. 4 shows clearly that the sole cropped groundnut in both years recorded highest pest populations and 1:1 inter-row crop treatments recorded lowest pest populations of *Ootheca* species.

**Table 5: Population of *Ootheca* species at 2, 4 and 6 WAP in 1995.**

| Treatments | Weeks After Planting (WAP) | | |
|---|---|---|---|
| | 2 WAP | 4WAP | 6 WAP |
| M/G - 1:1 | 13.0a | 13.0c | 4.0c |
| M/G - 1:2 | 14.5a | 19.3bc | 7.3c |
| M/G - 1:3 | 13.5a | 22.8ab | 19.8ab |
| M/G - 2:2 intra | 13.0a | 21.5ab | 17.3b |
| M/G - 1:3 intra | 11.8a | 17.8bc | 13.8b |
| Sole Groundnut | 15.5a | 27.8a | 24.8a |
| SE ± | 2.8 | 4.4 | 4.1 |

Means followed by the same letters in the same column are not significantly differently at 5% level of significance using DMRT.

**Table 6: Population of *Ootheca* species at 2, 3, 4 and 5 WAP in 1995.**

| Treatments | Weeks After Planting (WAP) | | | |
|---|---|---|---|---|
| | 2 WAP | 3WAP | 4 WAP | 5 WAP |
| M/G - 1:1 | 3.3a | 3.0a | 6.0a | 3.8c |
| M/G - 1:2 | 3.0a | 4.0ab | 6.0a | 5.5bc |
| M/G - 1:3 | 3.5a | 5.0a | 6.8a | 7.5b |
| M/G - 2:2 intra | 3.0a | 5.0a | 6.3a | 6.0b |
| M/G - 1:3 intra | 3.0a | 5.0a | 7.0a | 6.0b |
| Sole Groundnut | 2.5a | 5.0a | 7.8a | 10.3a |
| SE ± | 0.9 | 0.7 | 1.3 | 1.3 |

Means followed by the same letters in the same column are not significantly differently at 5% level of significance using DMRT.

M/G = milleg/groundnut intercrop

Table 7: Cummulative mean number of aphids in different cropping patterns in 1995 and 1996.

| Treatments | Cummulative Mean numbers | |
|---|---|---|
| | 1995 | 1996 |
| M/G - 1:1 inter-row | 40.9c | 31.4a |
| M/G - 1:2 inter-row | 43.9c | 38.7ab |
| M/G - 1:3 inter-row | 48.9c | 41.6bc |
| M/G - 2:2 intra-row | 69.6a | 56.9c |
| M/G - 1:3 intra-row | 64.9ab | 52.1c |
| Sole Groundnut | 64.2ab | 46.1bc |
| SE ± | 9.8 | 3.2 |

Means followed by the same letters in the same column are not significantly differently at 5% level of significance using DMRT.

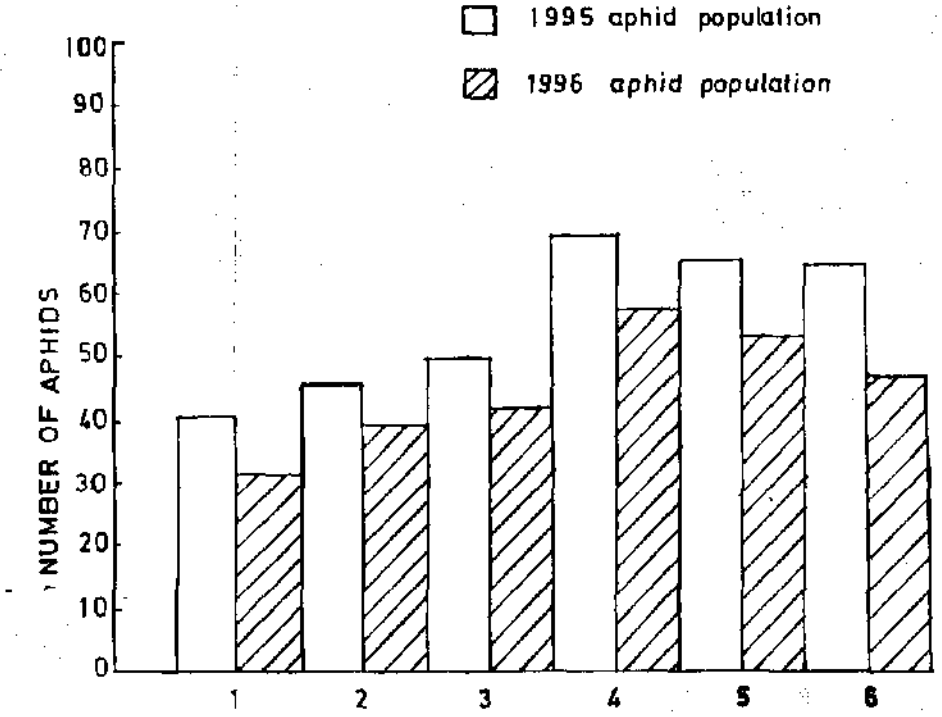



Figure 3: Cummulative mean number of aphids in the cropping patterns in 1995 and 1996.

Table 8: Cummulative mean number of *Ootheca* species in different cropping patterns in 1995 and 1996.

| Treatments | Cummulative Mean numbers | |
|---|---|---|
| | 1995 | 1996 |
| M/G - 1:1 inter-row | 30a | 31.4a |
| M/G - 1:2 inter-row | 41.1ab | 38.7ab |
| M/G - 1:3 inter-row | 56.1b | 41.6bc |
| M/G - 2:2 intra-row | 51.1bc | 56.3c |
| M/G - 1:3 intra-row | 43.4b | 52.9c |
| Sole Groundnut | 68.1c | 46.1bc |
| SE ± | 10.6 | 1.8 |

Means followed by the same letters in the same column are not significantly differently at 5% level of significance using DMRT.

M/G = Millet/groundnut intercrop.

LEGEND

1. M/G - 1:1
2. M/G - 1:2
3. M/G - 1:3
4. M/G - 2:2 Intr
5. M/G - 1:3 Intr
6. Monocrop groundnut (Go)

1995 Ootheca population

1996 Ootheca population

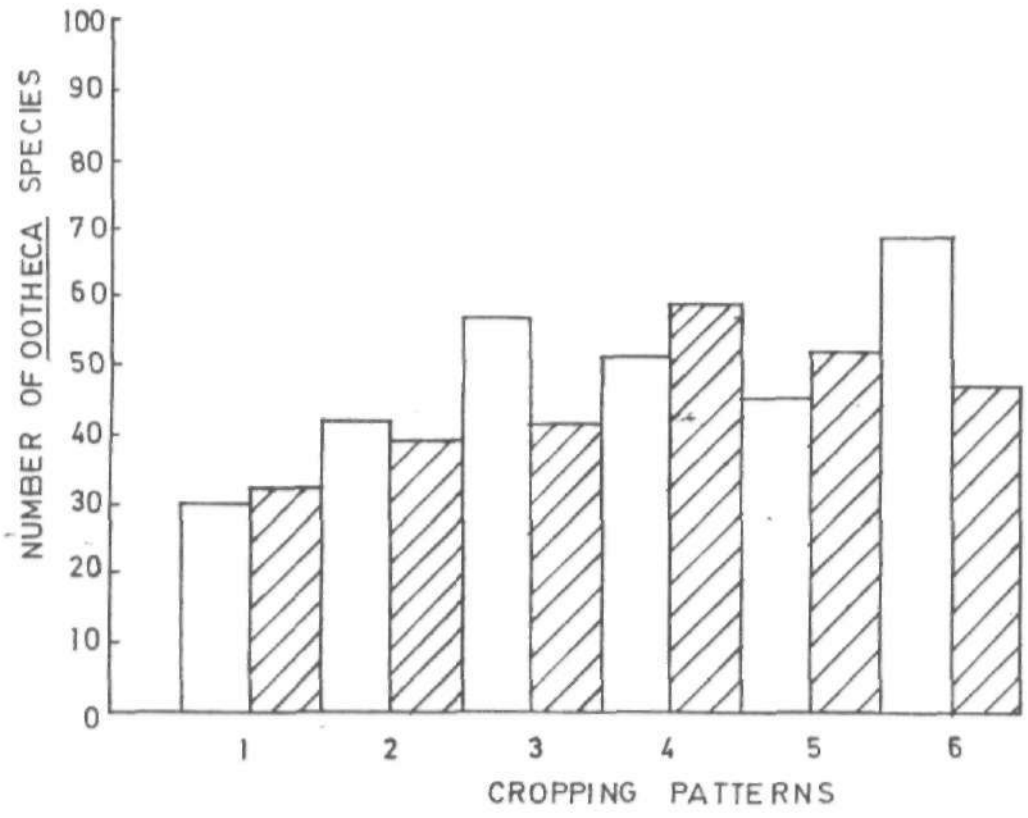



Figure 4: Cummulative mean number of Ootheca species in the cropping patterns in 1995 and 1996

**4.6 Effect of millet/groundnut cropping patterns on some insect pests of millet.**

In both 1995 and 1996, it was observed that insects monitored on millet showed a general trend when sole cropped millet was compared with the rest of the intercropped arrangements. Generally, monocropped treatments had significantly higher pest population ($P<0.05$) than the intercropped arrangements for 1995 and 1996 respectively (Tables 9 and 10). It was also observed that when the different cropping patterns were compared with one another, there was no significant difference ($P>0.05$) among them in most cases for both years with the exception of some few cases especially in 1995 (Tables 9 and 10).

However, in the case of stem borer populations in 1996, it was observed that even the monocropped millet showed no significant difference ($P>0.05$) with all the other cropping patterns. Therefore, essentially in 1996 there was no significant difference ($P>0.05$) in stemborer population amongst all the treatments (Table 10).

Of the many insect pest shown on table 1, only those that exhibited this pattern of monocropped treatment having higher pest build-up were shown on tables 9 and 10 for 1995 and 1996 respectively.

**Table 9: Effect of millet/groundnut cropping patterns on some insect pests of millet in 1995.**

| Treatment | Stemborers/ stalk at 40, 50 & 60 DAP | *Melyris*/head at 7 & 8 WAP | *Agonosceles*/ head at 7 & 8 WAP | *Coryna*/head at 7 & 8 WAP | *Mylabris*/head at 7 & 8 WAP | Deatheart at 6, 7 and 8 WAP |
|---|---|---|---|---|---|---|
| M/G - 1:1 inter-row | 4.4b | 6.1c | 5.9c | 4.3d | 1.1c | 2.0c |
| M/G - 1:2 inter-row | 6.0b | 6.5c | 6.4c | 4.6cd | 1.1c | 3.0bc |
| M/G - 1:3 inter-row | 5.8b | 7.6b | 7.7b | 5.4b | 2.1b | 3.5bc |
| M/G - 2:2 intra-row | 4.6c | 5.9c | 6.3c | 4.5cd | 0.9c | 3.0bc |
| M/G - 1:3 intra-row | 4.8c | 6.1c | 6.4c | 5.1bc | 1.3c | 4.5b |
| Sole Millet | 7.2a | 9.1c | 9.06a | 6.9a | 2.8a | 9.8a |
| SE $\pm$ | 0.44 | 0.46 | 0.66 | 0.48 | 0.36 | 1.4 |

Means followed by the same letters in the same column are not significantly differently at 5% level of significance using DMRT.

M/G = Millet/groundnut intercrop.

((0))



**Table 10: Effect of millet/groundnut cropping patterns on some insect pests of millet in 1996.**

| Treatment | Stemborers/ stalk at 40, 50 & 60 DAP | *Melyris*/head at 6 & 7 WAP | *Agonosceles*/ head at 7 & 8 WAP | *Coryna*/head at 7 & 8 WAP | *Locris rubens*/ head at 6, 7 & 8 WAP | *Mylabris*/head at 7 & 8 WAP |
|---|---|---|---|---|---|---|
| M/G - 1:1 inter-row | 2.8b | 4.4b | 3.5b | 3.4b | 5.8bc | 1.7c |
| M/G - 1:2 inter-row | 3.4ab | 5.0b | 3.9b | 3.1b | 5.1bc | 1.6c |
| M/G - 1:3 inter-row | 2.7b | 4.6b | 3.4b | 3.5b | 4.6bc | 2.5b |
| M/G - 2:2 intra-row | 3.4ab | 4.2b | 3.6b | 3.2b | 5.6b | 1.7c |
| M/G - 1:3 intra-row | 3.6a | 3.9b | 3.3b | 3.1b | 5.3bc | 1.7c |
| Sole Millet | 3.1ab | 6.3a | 5.9a | 5.6a | 8.4a | 3.7a |
| SE $\pm$ | 0.38 | 0.64 | 0.4 | 0.54 | 0.66 | 0.32 |

Means followed by the same letters in the same column are not significantly differently at 5% level of significance using DMRT.

M/G = Millet/groundnut intercrop.

### 4.7.0 Effect of millet/groundnut cropping patterns on yield and some yield components of groundnut

#### 4.7.1 Mean number of pods per plant.

There was no significant difference ($P > 0.05$) in the mean number of pods per plant in both 1995 and 1996 (Table 11). However, it can be clearly observed that even though there was no significant difference ($P > 0.05$) among all the treatments in 1995, the monocropped groundnut and 1:3 inter-row arrangement recorded lowest pod number per plot. In 1996 however, the monocropped groundnut and 2:2 inter-row arrangement recorded lowest pod number even though there was no significant difference ($P > 0.05$) among the rest of the treatments.

#### 4.7.2 Weight of pods per plant

The 1:3 inter-row arrangement exhibited the highest pod weight per plot and its pod weight was significantly higher ($P < 0.05$) than all those of the other treatments (Table 11). However, it can be generally seen that the intra-row arrangements had significantly lower pod yield than the inter-row arrangements (Table 11).

#### 4.7.3 Grain yield of groundnut

The highest grain yields in kilograms per hectare were recorded in the two treatments of 1:3 inter-row crop pattern and monocropped groundnut treatment. The grain yield in those two plots were significantly higher ($P < 0.05$) than those of the other treatments in both 1995 and 1996 (Table 11). The lowest grain yield was recorded by 2:2 intra-row cropping patterns in the two years. There was no significant difference ($P > 0.05$) in grain yield between 1:1 inter-row and 1:2 inter-row crop patterns (Table 11).

**Table 11: Effect of millet/groundnut cropping patterns on yield components of groundnut.**

| Treatments | Weight of pods kg/ha | | No. of pods/plant | | Grain yield kg/ha | | 100-grain weight(g) | |
|---|---|---|---|---|---|---|---|---|
| | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 |
| M/G - 1:1 inter-row | 8990.8b | 8230.8b | 50.4a | 47.4ab | 1300.8ab | 1310.8b | 44.6a | 43.1a |
| M/G - 1:2 inter-row | 8490.5b | 7680.8bc | 54.3a | 52.7ab | 1350.6b | 1416.7ab | 43.8a | 42.8a |
| M/G - 1:3 inter-row | 12000.0a | 10079a | 63.6a | 63.4a | 2411.9a | 2350.5a | 43.5a | 42.4a |
| M/G - 2:2 intra-row | 4810.8c | 4807.6a | 29.4a | 33.8ab | 1120.8b | 1112.2b | 42.5a | 42.4a |
| M/G - 1:3 intra-row | 5498.5c | 5371.5c | 48a | 44.7ab | 1950.4ab | 1901.1ab | 42.2a | 42.0a |
| Sole Groundnut | 6330.0c | 6160.3bc | 30.1a | 31.9b | 2469.0a | 2260.3a | 32.2a | 41.9a |
| SE ± | 128.8 | 92.5 | 23.4 | 16.3 | 57.8 | 56.4 | 7.8 | 0.99 |

Means followed by the same letters are not significantly different ($P < 0.05$) at 5% level of significance using DMRT.

M/G = Millet/groundnut intercrop.

### 4.7.4 100-grain weight for groundnut

In the two years of the experiment, there was no significant difference ($P > 0.05$) in 100-grain weight for all the treatments (Table 11). However, lowest grain weights were recorded from sole groundnut treatments in the two years.

### 4.8.0 Effect of millet/groundnut cropping patterns on yield and some yield components of millet.

### 4.8.1 Weight of Millet head per plot in kg/ha

The highest millet head weight in kilograms per hectare per plot were recorded in the two extreme treatments of 1:1 inter-row ratio and monocropped millet. They were recorded to be significantly heavier ($P < 0.05$) in millet head weight than all other treatments in both 1995 and 1996 (Table 12). In most other cases there was no significant difference ($P < 0.05$) among all other treatments.

### 4.8.2 Grain yield of millet

There was no significant difference ($P > 0.05$) in grain yield between the inter-row treatments of 1:1, 1:2, and 1:3 (Table 12) in both 1995 and 1996 and even between these three treatments and the rest of the treatments in 1996. However the monocropped millet treatment and 1:3 intra-row pattern recorded lowest grain yield (Table 12). In 1995 the highest grain yield was recorded by the 1:2 inter-row arrangements and in 1996, the highest grain yield was recorded by 1:1 in-row cropping pattern (Table 12).

### 4.8.3 1000 grain weight

In the two years of experimentation there was no significant difference ($P > 0.05$) in 1000-grain weight (Table 12).

**Table 12: Effect of millet/groundnut cropping patterns on yield and some yield components of millet.**

| Treatments | Weight of Millet head(kg/ha) | | Grain yield(kg/ha) | | 1000-grain weight(g) | |
|---|---|---|---|---|---|---|
| | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 |
| M/G - 1:1 inter-row | 1291.3a | 1485a | 630.0a | 872.5a | 10.5a | 10.3a |
| M/G - 1:2 inter-row | 916.5ab | 1107.5ab | 666.0ab | 587.3ab | 10.3a | 10.3a |
| M/G - 1:3 inter-row | 999.5ab | 1162.5ab | 608.0ab | 612.5ab | 10.3a | 10.1a |
| M/G - 2:2 intra-row | 1066.5a | 1207.5ab | 474.5bc | 681.3ab | 100.3a | 10.0a |
| M/G - 1:3 intra-row | 608b | 875.0b | 374.7c | 462.5b | 9.5a | 10.0a |
| Sole Millet | 1291a | 1377.5ab | 366.5c | 720.0ab | 9.3a | 9.8a |
| SE ± | 278.7 | 316.7 | 125.3 | 183.3 | 0.09 | 1.83 |

Means followed by the same letters are not significantly different ($P < 0.05$) at 5% level of significance using DMRT.

M/G = Millet/groundnut intercrop.

CHAPTER 5

# 5.0 DISCUSSIONS

## 5.1 Insect pests associated with millet/groundnut cropping patterns.

Several insects were found associated with millet/groundnut intercrop as shown on Table 1. This may be due to the fact that each of the crops in the mixture has an array of insects associated with it individually. For instance Ajayi (1987) had earlier on indicated that extensive surveys have identified up to 161 insect species that are associated with the millet crop in Nigeria. Similarly insect pests of groundnut were first extensively reviewed by Feaken (1973) and later Smith and Barfield (1982) listed 356 taxa known to be associated with groundnut crop.

However, the list found on table 1 may be location-specific because in some cases major insect species of the same crop could vary from country to country and also among different agroecological zones worldwide. This is why a major pest of a particular crop in a particular location or region may be a minor pest of the same crop in a different location. It could however be noted that the list in table 1 may not be exhaustive even for the same region. For example, table 1 shows that more insect pests were found associated with the crop mixture in 1996 than in 1995. This may be due to variation in weather conditions within the two years, presence or absence of predators and preys and other factors.

## 5.2 Effect of millet/groundnut cropping patterns on the population of aphids.

The lack of significant difference in aphid population at 3 and 6 WAP in table 2 could be due to the fact that the pest suppressing abilities of millet such as height that will create the barrier, tillering, modification of the micro-climatic condition of the crop mixture were not fully operational at the early stages of plant growth. However, as the season advanced, significant differences observed at 9 and 12 WAP could be as a result of full establishment of the factors

mentioned above.

The same reason could be advanced for lack of significant difference in aphid population at 2 and 4 WAP in 1996 (Table 3). However, at 6 and 8 WAP in 1996 (Table 3), the significant differences observed could also be due to the same reasons as in the case of 9 and 12 WAP in 1995 (Table 2).

For the two years, the highest aphid numbers recorded in the two intra-row arrangements could be due to non-continuous canopy formation by the groundnut plants due to millet plants arranged between the groundnut plant stands (Tables 2 and 3). This arrangement exposes the brown soil which is attractive to aphids and the consequence may be high aphid numbers in those plots. A'Brook (1964) had earlier shown that more aphid numbers were trapped over groundnut crops that were widely spaced than in those crops that were closely spaced due to brown background of the soil.

However, with the exception of the two intra-row arrangement which recorded highest aphid numbers probably due to reasons given above, all other intercrop arrangements had lower aphid numbers compared to the monocropped groundnut plots. This is expected because there is more free movement of aphids in monocropped treatments than in intercropped plots, hence more aphid numbers on monocropped groundnut than in intercropped plots.

In a similar study with cowpea, Uvah (1978) had indicated that intercropping sorghum with a relay crop of cowpea reduces the abundance of cowpea herbivore *Aphis craccivora*, *Maruca vitrata*, *Megalurotrips sjostedti* and pod-sucking bugs by 92% 45%, 35% and 90% respectively compared to their numbers on monocropped cowpea. The lack of significant difference in aphid numbers between 1:1 inter-row and 1:2 inter-row crop arrangement could

be due to the fact that the two treatments were very similar to one another.

Generally aphid numbers recorded on tables 2 and 3 were low regardless of the treatments. This could be due to several reasons, one of which could be due to activities of natural enemies such as Coccinellids and syrphids which are known to parasitise on aphids. Dike (1992) reported a good number of predators of aphids namely, adults and larvae of *Chilomenes sulphurea* Oliv., *C. vicina* Muls., *Exochomus flavipes* Thunb and the larvae of *Chrysopa antica* Walk and *Ischiodon aegyptium* Wied.

Farrel, (1976) had earlier on indicated that *Aphis craccivora* does not tolerate high densities. It is also known that at high aphid numbers in air, there could be attrition whereby individuals collide with each other leading to death of some of them and consequent reduction in their population. Aphid population and biology also varies with weather conditions, soil fertility, soil moisture and host plant.

The same reasons advanced above for the trend of result obtained in tables 2 and 3 could also be given in the case of table 7 in cummulative manner. Table 7 shows the effectiveness of each cropping pattern in regulating aphid population throughout the growing period with 1:1 inter-row arrangement having lowest aphid numbers.

**5.3. Rosette count score.**

*The significant difference exhibited by the 1:1 inter-row arrangement and sole cropped* groundnut in rosette count score could be due to the fact that millet in 1:1 inter-row arrangement reduced aphid number by acting as barrier for aphid invasion of the field while in the sole cropped groundnut, there could be more free movement of the aphids hence more aphid numbers. Since aphids serve as the vector for rosette transmission, it could be expected that

rosette transmission should be proportional to the number of aphids invading the field. Tables 2 and 3 indicate more aphid numbers in monocropped groundnut than in 1:1 inter-row arrangement for both 1995 and 1996. This further explains the significant difference in rosette count score on Table 4.

The lack of significant difference among the two intra-row arrangements (Table 4) in rosette score could be due to the fact that the two treatments are similar and there is possibility of the same number of aphids invading the field. Another possible reason could be that when a barrier crop is used against aphids, because they are air-borne, when flying, they knock against the barrier crop and against themselves. During this process some of them may die and some may loose the virus because with the groundnut rosette virus, the relationship between the virus and the aphid is semi-persistent. This incidence is more pronounced with millet as barrier crop as compared to sorghum or maize (Alegbejo, personal communication). This is what is generally responsible for low aphid number and low rosette score when millet is used as a barrier crop. This reason is also attributable to the rosette score of 1:2 and 1:3 inter-row arrangements for the two years of 1995 and 1996.

**5.4. Effect of millet-groundnut cropping patterns on population of *Ootheca* species**

The highest population of *Ootheca* species exhibited in most cases by the monocropped groundnut treatment could be explained by the absence of millet barrier in monocropped treatment as opposed to the presence of millet barrier in the other cropping patterns. The lowest *Ootheca* population observed in 1:1 inter-row arrangement is probably due to the fact that it had the very high number of millet barriers and as a result, an environment that is not easy to penetrate by the insects is created when compared with monocropped treatments or other

cropping patterns that are more widely intercropped.

Earlier investigations have indicated that as the density of the host plant increases, they become less attractive to colonising insects in colour and also the colonising insects may penetrate dense crops less readily (Way and Heathcote, 1966). Burleigh, (1973) had also reported that in intercropping, the taller components may act as physical barrier to pests attacking shorter components.

The reason for lack of significance in *Ootheca* population at 2 and 4 WAP in 1995 and at 2, 3 and 4 WAP in 1996 (Tables 5 and 6) could be the same as explained in section 5:3 for lack of significance at 3 and 6 WAP and 2 and 4 WAP with respect to aphid population in 1995 and 1996. Generally the population of *Ootheca* species recorded during the two years of study were very low. The reason for this is not clear but Akingbohungbe (1978) had indicated that very high numbers of *Ootheca* are required per plant before they can cause economic damage and that this high number is normally not always attained under field practical conditions.

Table 8 shows the efficacy of each cropping pattern in regulating *Ootheca* population with 1:1 inter-row arrangement having lowest *Ootheca* number and monocropped groundnut having highest number of *Ootheca* species.

**5.5 Effect of millet/groundnut cropping patterns on some insect pests of millet.**

The reason for lack of significant difference in millet pests population among all the intercropped arrangements in both 1995 and 1996 is not very clear. This may suggest that intercropping will not be effective in reducing millet pests population. However the highest pest populations recorded on all the monocropped millet treatment could probably be due to preference of the monocrop background by millet pests. The monocrop treatments also had the

highest density of millet plants and so the relative abundance of the host plants could have attracted more millet pests.

In an earlier study, Ajayi and Tabo (1995) had shown that depending on the cultivar used, intercropping sorghum with soyabean decreased headbug incidence on sorghum by up to 22% in 1989 and by 8-49% 1991. They discovered that both 1:1 and 1:2 sorghum: soyabean row arrangements had fewer headbugs than sole sorghum. This is related to the result obtained on tables 9 and 10. The high pest numbers recorded on monocrop millet treatments could further be explained by the fact that on monocropped plots, there is only one host-millet, but in intercropped treatments, groundnut is another host and some insects may not prefer to see the groundnut background. This is because colour and contrast of the host with its background influence host-finding in insects (Smith, 1969; Raros, 1973).

Though there was no significant difference in millet pests population among all the intercrop arrangements, the significant difference observed between the monocrop treatments and the intercropped treatments suggests to the farmer that pest out-breaks are less common in intercropped farming systems than in monoculture.

**5.6 Insect populations and yield of millet and groundnut.**

The major insects monitored on groundnuts, aphids and *Ootheca* species, could not have affected the yield of groundnut primarily due to their low population which did not allow them to cause economic damage. In the case of groundnut, tables 2 and 3 show the low aphid population recorded and table 4 shows the low rosette score recorded. It is the high incidence of these (i.e. rosette score and aphid population) that will have caused economic damage which will then haved serious effect on yield. In the case of *Ootheca* species, the population was too

low to cause any economic damage. Akingbohungbe (1978) had earlier on indicated that very high numbers of *Ootheca* species is not normally attained under field practical conditions. Therefore the *Ootheca* population recorded on tables 5 and 6 could not have had any serious effect on yield.

Most of the damages caused by both aphids and *Ootheca* species on groundnut were foliar damages during growth stages and the plants were able to recover from these minor damages within few days. In the case of millet yield, most of the insects recorded on it are minor pests of millet with the exception of stem borers and shootflies. Ajayi (1986) had shown that beetles such as *Monolepta goldingi, Mylabris vestita, M. bifasciata, M. abdominalis,* four species of *Psalydolylta,* three of *Mylabris, Coryna hermaniae, Rhinyptia infuscata* and three species of *Annomala* occasionally feed as adults in large numbers on millet pollen, but their effects on pollination and subsequent grain yield have not been quantified. The population of stemborers and shootfiles were also too low to cause any economic damage.

### 5.7.0 Effect of millet/groundnut cropping patterns on yield and some yield components of groundnut.

### 5.7.1 Weight of pods in kg/ha.

The significant differences found among the various treatments in pod yield in both 1995 and 1996 could be due to differences in the number of pods that are actually filled with grains because not all the pods formed that were actually filled with grains. The differences could also come as a result of competition between the millet and groundnut in the mixture for space, light and nutrient especially in those plots where intra-row arrangements occur. The sizes of the pods could also be responsible for significant differences in pod yield among various treatments. This is because the number of grains in a pod varies from 1-4 depending on the variety and size of

the pods.

**5.7.2 Number of pods per plant.**

The lack of significant difference in number of pods per plant in 1995 and 1996 could be due to uniformity within a variety. This is because each variety has characteristics peculiar to itself and in the case of number of pods per plant, it will not vary much within a variety.

**5.7.3. Grain yield of groundnut in kg/ha.**

The significant difference shown in grain yield between the two extreme treatments of 1:1 inter-row and monocropped groundnut could be due to the fact that the monocrop was more exposed to envionmental conditions of light, temperature, space and nutrition because of absence of barrier as millet. The monocrop treatment in the two years gave the highest grain yield. within the remaining intercrop arrangements, there was no significant difference probably because all the treatments were subjected to nearly the same condition of mixed cropping.

**5.8.0 Effect of millet-groundnut cropping patterns on yield and some yield components of millet.**

**5.8.1 Weight of millet head per plot in kg/ha**

A combination of factors could either bring about significant difference or lack of significant difference in the weight of millet head. Such factors could be due to differences in panicle length, number of tillers per plants, activities of panicle insect pests and also damage as a reslt of attak by birds. Depending on the intensity of each of these factors, millet head weight could vary considerably from treatment to treatment. These factors and others combine to give haphazard differential head weight per plot.

### *5.8.2 Grain yield of millet in kg/ha.*

The same explanation given for the trend obtained in the case of millet head/ha in section 5.8.1 could also be given in the case of grain yield in kg/ha. However in the case of grain yield, the percentage of grains left on the panicle after agents of removal such as insects, birds etc. have done their damage could be responsible for either significant difference or lack of significant difference in grain yield among the treatments. As a result of this, grain yield obtained could vary considerably. For instance in 1995, yield ranged between 366.5 kg/ha - 666kg/ha and in 1996, it ranged from 462kg/ha - 872 kg/ha. This wide margin is due to differential panicle length, number of tillers, panicle insect pests, damage by birds and other factors.

### 5.8.3 1000-grain weight for millet and 100-grain weight for groundnut.

There was no significant difference in 1000-grain weight for millet and 100-grain weight for groundnut regardless of the treatment being considered principally due to little or no variation in the sizes of individual grains selected for weighing. This trend was observed for both 1995 and 1996 for the two crops. Olugbemi (1985) had earlier shown that nitrogen and varieties had no effect on 1000 seed weight for wheat because of little variation in sizes of the seeds.

In the case of millet, the sizes of the individual grains are even more uniform and this further explains why there is no significant difference among all the treatment in 1000-grain weight.

# CHAPTER 6

## SUMMARY AND CONCLUSIONS

It can be deduced from this study that given the peasant farmers' situation in a developing country where the fartmers have few pest control options than in more advanced countries because they often lack the technology, money and expertise to exercise the most cost effective control strategies, farmers faced with insect pest problems should intensify effort in the practice of mixed cropping. This is evident from the result obtained whereby the 1:1 millet/groundnut inter-row crop arrangements in most cases exhibited the lowest pest population levels of *Aphis craccivora* and *Ootheca* species. It was also shown that in the case of groundnut, the monocrop treatments had the highest pest populations of aphids and *Ootheca* species except the two intra-row arrangement in the case of aphids.

It is also evident from this study that decreasing or increasing row-ratios of the components of the mixture either decreases or increases pest distribution and abundance in a crop mixture. The principle that species diversity can be important in the control of pest populations outbreaks (Way, 1977) has been further highlighted in this studies. The idea that intercrop systems can promote mutual protection of their component crops from pests (Adesiyun 1983; Uvah and Raheja, 1984) has also been supported.

The advantage of pest reduction in intercrop systems may accrue to all the crop components in the mixture. This was observed from this studies when it was observed that even the millet monocrop treatments had more pests than the various intercrop patterns. However the lack of significant difference in pest populations among the different intercrop patterns suggests that intercropping millet with legumes can reduce infestation of some millet pests but

not in all cases. Therefore intercropping may be used in combination with other measures such as early sowing, early maturity and resistant cultivars to give a more effective control measure.

The yield obtained from this studies also point to the fact that the farmer is more assured of better returns by the practice of inter-cropping systems. This is particularly so because the individual yields of millet and groundnut obtained from this studies may not be different from what the farmer will have obtained under monocropping of each of these crops under peasant farming situation. For instance Thakare (1980) had reported yield estimates of 561kg/ha for millet in northern Nigeria. With the practice of intercropping, this yield of 562kg/ha by a farmer can be added to whatever yield that is obtained from the other crop in the mixture to give more harvest.

It is therefore being concluded from this studies that intercropping millet and groundnut in inter-row ratio of 1:1 is capable of lowering groundnut pest population and some millet pests too and also as the row-ratios are being increased or decreased, the pest population may either increase or decrease. The advantage of double yield components of millet and groundnut is also indicated in this study.

Although pest reductions in intercropping systems may be influencial on crop production in capital-scarce, low-input agriculture, it may not satisfy the high level control required in capital intensive agriculture.

The practice of growing crops in mixture will continue in African agriculture and indeed in Nigeria. It is acknowledged that changes in climate, cropping systems (including the adoption of new cultivars) and human populations often lead to changes in insect populations and their distribution. Adequate knowledge of the incidence, distribution, economic importance and farmers' perception of an insect is pivotal in determining a research agenda targetted to appropriate management options.

## REFERENCES

A'Brook, J. (1964).

The effect of planting date and spacing on the incidence of groundnut rosette disease and the vector, *Aphis craccivora* Koch at Mokwa, northern Nigeria. *Annals of Applied Biology 64*:199-208.

A'Brook, J. (1968).

The effect of plant spacing on the number of aphids trapped over the groundnut crop. *Annals of Applied Biology. 61*:289-294.

Adams, M.W., Ellingbow, A.H. and Rossman, E.C. (1974)

Biological uniformity and disease epidemics. *Australlian Journal of Biological Science, 21*:1067-1070.

Adesiyun, A.A. (1983).

Some effects of intercropping of sorghum, millet and maize on infestation by lepidopterus stalk borers, particularly *Busseola fusca* Fuller. *Insect Science and its Application 4(1-2)*:387-391.

Adesiyun, A.A. and Ajayi, O. (1980).

Control of sorghum stem borers, *Busseola Fusca* by partial burning of stalks. *Tropical Pest management, 26*(2):113-117.

Agboola, S.A. (1975).

Insect and other arthropod pests of groundnut in northern Nigeria. *Samaru Agricultural Newsletter.* 1760.

Agboola, S.A. (1979).

*An agricultural atlas of Nigeria* Oxford University Press, 248pp.

Ajayi, O. (1980).

Insect pests of millet in Nigeria. *Samaru Miscellaneous Paper 97*:10pp.

Ajayi, O. (1981).

Millet headworm *NOMA 3(1)*:11-13.

Ajayi, O. (1984).

The distribution of the millet head carterpillar, *Rhaguva* spp. in northern Nigeria. *Samaru Journal of Agricultural Research. 2(1 and 2)*: 125-126.

Ajayi, O. (1985).

A checklist of millet insect pests and their natural enemy in Nigeria. *Samaru Miscellaneous Paper,* 108, 16pp.

Ajayi, O. (1986).

The status of millet entomology in Nigeria. *Paper presented at the International Pearl Millet Workshop, ICRISAT, Hyderabad, India.* 7-11 April 1986.

Ajayi, O. (1987).

Insecticidal control of the sorghum stemborer. Pages 35-38 in Cereals Research programme Cropping Scheme Report, 1987. Samaru, Zaria, Nigeria. Institute for Agricultural Research.

Ajayi, O. and Tabo, R. (1995).

Effect of crop management practices on *Eurystylus immaculatus* pages 233-240. In: *Panicle insect pests of sorghum and millet: Proceedings of an International consultative workshop* 4-7 Oct. 1993. ICRISAT Sahelian centre, Niamey, Niger (Nwanze, K.F. and Youm O. eds) Internationhal Crops Research Institute for the Semi-Arid Tropics.

Akingbohungbe, A.E. (1978).

Observations on the cowpea flea beetles *Ootheca mutablis* (*Coleoptera: chrysomelidae) Journal of Entomology 1(3)*:19-25.

Altieri, M.A., Van Schoonhoven, A. and Doll, J. (1977).

The ecological role of weeds in insect pest management systems: a review illustrated by bean (*Phaseolus vulgaris*) cropping systems *PANS, 23*:195-205.

Amin, P.W. (1985).

Resistance of wild species of groundnut to insect and mite pests. In: ICRISAT; *Proceedings of an International Workshop on Cytogenesis of Arachis,* 31 Oct. - 2 Nov. 1983, Patancheru, AP, ICRISAT.

Andrews, D.J. and Kassam, A.H. (1976).

The importance of multiple cropping in increasing world food supplies. In : *Multiple Cropping*. R.I. Papendick, P.A. Sanchez and G.B. Triplett (eds.) Spl. pub. No. 27, American Society of Agronomy, Madison, Wisconsin, U.S.A. pp 1-10.

Akinfenwa, S. (1978).

Aphis craccivora and rosette virus disease of groundnut in Nigeria. *In Proceedings of National Seminar on groundnut in Nigeria.* Bagauda Lake Hotel, Kano. Febn. 13-14.

Anonymous (1966).

Annual report, Nigerian Stored product Research Instite (NSPRI). Page 9.

Anonymous (1970).

Control of pesticides: A survey of existing legislation. *International Dialogue on Health Legislation* (WHO) 150pp.

Anonymous (1976).

*FAO year production* 1977, *30*:102.

Anonymous (1978).

Facts on groundnut and the African groundnut council (AGC). African groundnut council information service. PP 3-19.

Anonymous (1989).

*Uses of tropical grain legumes.* Proceedings of a consultant meeting 27-30 March, 1989 ICRISAT Centre India.

Bhatnagar, V.S. and J.S., Davis (1981).

Pest management in intercrop subsistence farmer. *Proceedings of International Workshop on intercropping* 10-13 Jan. 1979. ICRISAT, Hyderabad pp. 249-257.

Booker, R.H. (1963).

The effect of sowing date and spacing on rosette disease of groundnut in northern Nigeria, with observations on the vector, *Aphis craccivora. Annals of Applied Biology, 52*:125-131.

Burleigh, J.H. (1973).

Strip cropping effects on beneficial insects and spiders associated with cotton in Oklahoma. *Environmental Entomology 2*:281-285.

Cameron, P.J., Allan, D.J., Walker, G.P. and Wightman, J.A. (1983).

Management experiments on aphids (*Acyrthosiphon* spp) and beneficial insects in lucerne. *Journal of Experimental Agriculture, 11*:343-349.

Chilvers, G.A. and Brittain, E.G. (1972).

Plant competition mediated by host specific parasites - a simple model. *Australlian Journal of Biological Sciences*. *25*:749-756.

Coutin, R., and Harris, K.M. (1969).

The taxonomy, distribution, biology and ecological importance of the millet grain midge. *Geromyia penniseti* Felt (Diptera: Cecidomyiidae) *Bulletin of Entomological Research 59*:259-273.

Conway, J.A. (1976).

The significance of *Elasmolomus sordidus* (Hemiptera: Lygaeidae) attacking harvested groundnuts in Gambia. *Tropical Science 18(3)*:187-190.

Cox, J. (1974).

How to plant a garden. In: *The Best Gardening Ideas I Know* (R. Rodate ed) pp 20-26.

David, B.V., Vijayaraghavan, S. and Ramaswamy, K.A. (1965).

Field trials for the control of groundnut aphid. *Oilseeds Journal 9*:188-191.

Deeming, J.C. (1978).

Millet headworm - a pest new to science and to Nigeria *NOMA 2(1)*:1-2.

Dike, M.C. (1992).

Preliminary survey of Insect Pests of Kenaf and Roselle Around Zaria in the Northern Guinea Savanna of Nigeria. *Nigerian Journal of Plant Proetection 14*:13-20.

Egharevba, P. N. (1978).

A review of millet work at the Institute of Agricultural Research. *Samaru Miscellaneous Paper*. 27, 17pp.

Enyi, B.A.C. (1973).

Effects of intercropping of maize or sorghum with cowpeas, pigeon peas or beans. *Experimental Agriculture 9:*83-90.

Farrel, J.A.K. (1976).

Effects of groundnut crop density on the population dynamics of *Aphis craccivora* Koch (Hemiptera: Aphididae) in Malawi. *Bulletin of Entomological Research 66*:317-329.

FAO (1967).

Integrated systems of pest management. In: *insect pest management and control. Principles of plant and animal pest control* Vol. 3(ed) National Academy of Science 447-482pp.

Feaken, S.F. (1973).

*Pest control in groundnuts* PANS Mannual No. 2 London centre for Overseas Pest Research, Foreign and Commonwealth Office, Overseas Development Administration 197pp.

Gould, H.J. and C.W., Graham (1969).

The control of *Aphis fabae* Scop on spring sown field beans *(Vicia faba* L.) Annals of *Applied Biology 64*:1-10.

Hammons, R.O. (1973).

Early history and Origin of Peanut. *In: Peanut cultures and uses.* American peanut research and Education.

Harris, K.M. (1962).

Lepidopterous stemborers of cereals in Nigeria. *Bulletin of Entomological Research. 53*:139-161.

Harkness, C.K., Kolawole, B. and Yayock, J.Y. (1976).

Groundnut research in Nigeria. *Samaru conference paper No. 7.* Paper presented at Technical Workshop. University of Florida U.S.A., July 11-15, 1975.

Heathcote. G.D. (1970).

Effect of plant spacing and time of growing of sugar beet on aphid infestation and spread of virus yellows. *Plant pathology 19*:32-39.

Hill, D.S. (1975).

Agricultural insect pests of the tropics and their control. Cambridge University Press London 516pp.

Hill, L.V. and P. W. Santelman (1969).

Competitive effects of annual weeds on Spanish Peanuts. *Weed Science 17*:1-2.

Hills, L.D. (1972).

Pest control without poisons, *Henry Doubledeny Research Association.* Booking England 64pp.

ICRISAT (1981).

Annual report for 1979-1980. International Crops Research Institute for semi-arid tropics, Hyderabad, India.

ICRISAT (1985).

Annual report for 1984.

Johnson, R.A., Akinfenwa, S. and Raheja, A.K. (1978).

Pre and Post-harvest crop production. 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 Gumel, M.H. (1981).

Termite damage and crop loss studies in Nigeria, the incidence of termite-scarified groundnut pods and resulting kernel contamination in field and market studies. *Tropical Pest Management 27*:343-392.

Kassam, A.H. and Kowal, J.M. (1976).

Water use, energy balance and growth of "gero" millet at Samaru, northern Nigeria *Samaru Research Bulletin 263*:333-342.

Kennedy, J.S. and Moorhouse, J.E. (1969).

Laboratory observations and locust responses to wind-borne grass odour. *Entomological Experiment Applied. 62*:487-507.

Kharder, K.B.A. and Anatoly, K.J. (1968).

Intercropping: a paying proposition for areca growers. *Indian farming 18*:14-15.

Khun, C.W. and Smith, T.A. (1977).

Effectiveness of a disease index system in evaluating corn for resistance to maize dwarf virus. *Phytopathology. 67*-288-291.

Kulkarni, L.G., Varma, S.S., and Achuta, R.K. (1963).

Studies on weeding and interculture in relation to weed control in yield of groundnut. *Indian Oilseeds Journal 7*:126-129.

Litsinger, J.A. and Moody, K. (1976).

Integrated pest management in multiple cropping systems. *In: Multiple cropping*. R.I. Papendick, P.A. Sanchez and G.B. Tripplet (eds.) Spl. pub. No. 27 American society

of agronomy Madison, Wisconsin, U.S.A. pp 223-316.

Magar, W.Y. (1973).

Problem of storage handling of groundnut and other food grains and animal feeds. *Symposium on problems of storage and handling of groundnuts and other food grains and animal feeds.* Kaduna 2-6 April, 1973. PP 26, 29, 30 and 40.

Malaka, S.L.O. (1972).

Some measures applied in the control of termites in parts of Nigeria. *Nigerian Entomologists Magazine,* 2:137-141.

Mayeux, A. (1984).

Le pureron de (arachide) Billogie et control *Oleagineux, 39*:425-435.

Mercer, P.C. (1978).

Pests and diseases of groundnut in Malawi III Wilts. Post harvest physiological and minor disorders. *Oleagineux 33(12)*:619-624.

Misari, S.M. (1975).

Insects and other arthropod pests of groundnut in northern Nigeria. *Samaru Agricultural Newsletter 17*:4-9.

Misari, S.M. and Raheja, A.K. (1976).

Notes of field pests of groundnuts in northern Nigeria. *International symposium on field pests of groundnut and millets,* Kaolack, Senegal 21-23 April, 1976.

Moericke, V. (1950).

Vber den Farbensinn der pfirsichblattlaur *M. Persicae* sulz Z. *Tierpsychol 7*:265-274.

Moody, K. (1978).

Weed control in intercropping in tropical Asia. *Paper presented at the International weed science conference* 3-7 July 1978. Los Banos, Philipines.

Nickel, J.L. (1973).

Pest situation in changing agricultural systems. A review. *Bulletin of Entomological Society of America 54*:76-86.

O'conor, B.A. (1950).

Premature nut fall of coconuts in British Solomon Islands Protectorate *Agricultural Journal of Fiji. 21*:1-22.

Ogunlela, V.B. and Egharevba, P.N. (1981).

Acceleration of sorghum and millet production in Nigeria through timely operations. *Paper presented at the 5th NAFPP National sorghum, millet and wheat workshop* held at Zaria Nigeria. April 27-30 pp 1-2.

Olugbemi, L.B. (1984).

Effect of varieties and nitrogen fertilizer on yield of irrigated wheat in northern Nigeria. *Samaru Journal of Agricultural Research 2(1 and 2)*: 25-32.

Pagham, D.E., Timmins, F.M. and Ranga Rao, G.V. (1989).

Mechanisms of resistance in groundnut (*Arachis hypogea* L.) to *Aphis craccivora* (Koch) *Annals of Applied Biology 100*:61-72.

Piontel, J.G. and Dense, J.P.L. and Hernandz, S. (1979).

Evaluation and development of the infestation of experimental stacks of groundnut in their shells in Senegal by *Caryedon gonagra* F. (Coleoptera: Bruchidae). *Agronomique*

*Tropicale 34(2)*: 196-207.

Prokopy, R.J., Moerke, V. and Bush, G.L .(1973).

Attraction of apple maggot flies to odour of apples. *Environmental Entomology* 2:743-137.

Protocor, D.L. and Ashman, F. (1972).

The control of insects in exported Zambian groundnuts using phosphine and Polythene lined sacks. *Journal of Stored Products Research* 8:127-137.

Rabb, R.L. (1970).

Introduction to pest management. *In: Concepts of Post Management*. R.L. Rabb and F.E. Autherie (eds). North Carolina State University, Raleigh, North Carolina, U.S.A. pp 1-5.

Rachie, K.O. (1975).

History and world production of millets. *In: The millets, importance, utilization and Outlook* pp 9-22. Pub. International Crops Research Institute for Semi-Arid Tropics ICRISAT, Hyderabad, India.

Raheja, A.K. (1975).

Millipedes on groundnuts, *Arachis hypogea* L. *Nigerian Journal of Plant Protection 1*:91-91.

Raheja, A.K. (1977).

*Pests and diseases relationship with various crop mixtures.* Research programme for cropping systems, 1976-77. Institute for Agricultural Research, Samaru, Nigeria.

Raros, R.S. (1973).

*Prospects and Problems of insect pest control in multiple cropping.* IRRI Saturday Seminar, Los Banos Phillipines.

Reddy, D.V.R. and Wightman, J.A. (1988).

Tomato spotted wilt virus: Thrips transmission and control. *Advances in Diseases Vector Research 5*:202-220.

Rosingh, C. (1980).

Unter uchungen Uber die Reistenx der Kuherbs, *Vigna unguiculata* (Trybom) (Thysanoptera: Thripidae). Hoshschulverlag. Preiburg.

Robisson, J. (1976).

Millipedes, groundnut pests in general. *In: minutes of international symposium on field pests of groundnuts and millets,* Kaolack pp 21-23. Senegal.

Rudd, A.L. (1964).

Pesticides and the living landscape. Faber and Faber limited. London, 320pp.

Sands, W.A. (1962).

The evaluation of insecticides and soil mound poisons against termites in agricultural and Forestry in West Africa. *Bulletin of Entomological Research, 33*:179-192.

Smith, J.W. and Barfield, C.S. (1982).

Management of post-harvest insects. In: Pattee, H.E. and Young, C.T. (eds)., *Peanut science and Technology,* Yoakum, Texas, American peanut Research and Education Society, 825p.

Smith, J.C. (1969).

Some effects of crop background on populations of aphids and their natural enemies on brussels sprouts. *Annals of Applied Biology. 63*:326-330.

Stern, M.W., Mutter, A., Sevacharian, V. and Way, M.J. (1969).

Lygus bug control in cotton through alfalfa interplanting. *Carlifornia Agriculture* 23:8-12.

Storey, H. (1925).

Transmission of groundnut rosette virus *Nature 116*:97-98.

Taylor, T.A. (1977).

Mixed cropping as an input in the Management of Crop pests in tropical Africa. *African environment 2(4)*:111-126.

Thakare, R.B. (1980).

The implication and scope of benchmark survey for sorghum/millet production in Nigerian Agriculture *Bagauda Trade Journal 1*:19-23 Kano State.

Thorsteinson, A.J. (1960).

Host selection in Phytophagous insects *Annual Review of Extension 5*:193-218.

Trenbath, B.R. (1974).

Biomass productivity of mixtures *Advances in Agronomy 26*:177-210.

Usenbo, E.F. (1976).

Approaches to integrated control of cotton pests in mid-western Nigeria. *Ph.D. Thesis*, University of London.

Uvah, I.I. (1978).

A study of insect pests of cowpea in some indegenous cropping systems in the Zaria area of Nigeria. *M.Sc. Thesis*, Ahmadu Bello University Zaria, Nigeria.

Uvah, I.I. and Raheja, A.K. (1984).

Studies on the effect of intercropping sorghum with a relay crop of millet and cowpea on the major pests of cowpea. *Nigerian Journal of Plant Protection. 8*:100-107.

Van Emden, H.F. (1977).

Insect Pest management in multiple cropping systems. A strategy. *Proceedings of Symposium on Cropping Systems Research and Development for the Asian Rice Farmer,* 21-24 Sept. 1976. IRRI Los Banos, Phillipines pp 325-343.

Van Emden, H.F. and Williams, G. (1974).

Insect stability and diversity in agro-ecosystems. *Annual Review of Entomology 19*:455-475.

Vogel, S. and Graham, M. (1978).

Sorghum and millets. Food production and use pp 64, pub. International development and Research centre, Ottawa, Canada.

Way, M.J. (1953).

The relationship between certain species with particular reference to biological control of the coreid, *Theraptus* spp. *Bulletin of Entomological Research 44*:669-691.

Way, M.J. (1977).

Pest and disease status in mixed stands Vs monoculture; the relevance of ecosystem stability In: *Origins of Pest, Parasite, Disease and Weed Problems* (eds. J.M. Cherret and S.R. Sagar) pp 127-138 Blackwell Sci. Publo. Oxford.

Way, M.J. (1976).

Diversity and stability concepts in relation to tropical insect pest management. *In: Entomology and the Nigerian Economy* A. Youdeowei (ed) *Entomological Society of Nigeria* Oct. Publ. *57*:409-423.

Way, M.J. and Heatcote, G.D. (1966).

Interactions of crop density of field beans, abundance of *Aphis fabae* scop., Virus incidence and aphid control by chemicals. *Annals of Applied Biology. 57*:409-423.

Weaving, A.J.S. (1980).

Observations on *Hilda patruelis* Stal. (Homoptera: Tettigometridae) and its infestation of groundnut in Rhodesia. *Journal of the Entomological Society of Southern Africa 43*:151-167.

Weeks, J.C. (1979).

Safety systems of work with pesticides. The role of government departments. *Pests and diseases 3*:837-842.

Wheatley, A.R.D., Wightman, J.A., Williams, J.H. and Wheatley, S.J. (1989). The influence of drought stress on the distribution of insects on four groundnut genotypes grown near *Hyderabad. Bulletin of Entomological Research. 4*:465-472.

Wightman, J.A. and Amin, P.W. (1988).

Groundnut pests and their control in the semi-arid tropics. *Tropical Pest Management 34*:218-226.

Wood, T.G., Johnson R.A. and Ohiagu, C.E. (1977).

Population of termites (Isoptera) in natural Agricultural Systems in Southern Guinea Savannah, Mokwa, Nigeria. *International Journal of Tropical Ecology and Geography 1*:139-148.

Woodford, J.A.T., Hamson B.D. and Aneyard, C.S. (1983).

Insecticidal control of aphids and the spread of potato leaf wilt virus in potato crops in eastern Scotland. *Annals of Applied Biology 103*:177-130.

Yayock, J.Y. (1978).

A review of the agronomic principles of groundnut production. *In: Proceedings of National Seminar on groundnut production,* Kano. pp 39-43.

Yayock, J.Y., Rossel, M.W. and Harkness C. (1976).

A review of the 1975 groundnut rosette epidemic in Nigeria. *In: Minutes of international symposium on field pests of groundnut and millet. Kaolack,* Senegal, April 21-23 pp 129-137.

Zdarkova, E. and Reska, M. (1976).

Weight losses of groundnut *(Arachis hypogea L.)* from infestation by the mites *Acasmiro* L. and *Tynophagus putrescentia* Schrawla. *Journal of Stored Products Research.*

**Appendix 1: Meteorological Data during the period of the experimental Trials (1995 and 1996)**

| | | Rainfall | | Temperature °C | | | | Relative Humidity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1995 | 1996 | 1995 | | 1996 | | 1995 | | 1996 | |
| | | Means | | Min. | Max | Min. | Max | 10.am | 4pm | 10.am | 4pm |
| June | 1-10 | - | | | | | | | | | |
| | 11-12 | - | | | | | | | | | |
| | 21-30 | - | 1.9 | | | 18.4 | 29.8 | | | 25.7 | 61.3 |
| July | 1-10 | 3.7 | 5.0 | 21.8 | 29.0 | 19.3 | 28.4 | 79.6 | 59.6 | 78.4 | 55.6 |
| | 11-12 | 5.2 | 6.5 | 22.7 | 30.2 | 16.4 | 27.6 | 79.4 | 66.9 | 74 | 57.1 |
| | 21-30 | 6.8 | 7.0 | 20.8 | 30.3 | 19.3 | 27.3 | 82.2 | 73.4 | 73.4 | 74.9 |
| Aug. | 1-10 | 8.8 | 3.1 | 19.9 | 28.7 | 20 | 28.4 | 84.4 | 75.3 | 80.1 | 70.6 |
| | 11-12 | 7.5 | 11.6 | 19.5 | 29.1 | 19.0 | 26.9 | 82.8 | 73.1 | 83.4 | 76.6 |
| | 21-30 | 9.8 | 12.1 | 21.0 | 28.5 | 19.7 | 28.0 | 78.6 | 87.6 | 82.2 | 66.8 |
| Sept. | 1-10 | 3.9 | 8.0 | 23.9 | 29.5 | 21.0 | 29.4 | 81.9 | 78.1 | 82.6 | 70.0 |
| | 11-12 | 8.1 | 6.0 | 18.9 | 29.4 | 19.3 | 30.2 | 81.6 | 58.7 | 81.9 | 69.6 |
| | 21-30 | 3.8 | 3.4 | 18.6 | 28.1 | 19.7 | 30.4 | 80.5 | 63.5 | 80.3 | 69.6 |
| Oct. | 1-10 | 3.1 | 2.9 | | | 20.0 | 31.6 | 77.9 | 68.7 | 78.1 | 60.2 |
| | 11-12 | - | 3.1 | | | 19.9 | 30.6 | | | 76.9 | 68.3 |
| | 21-30 | - | - | | | | | | | | |

**Appendix 2: Physico-chemical properties of soil samples collected to a depth of 230cm from the experimental site at Samaru in 1995 and 1996 cropping seasons.**

| Soils composition | Characteristics | |
|---|---|---|
| | 1995 | 1996 |
| % Sand | 38 | 35 |
| % Silt | 30 | 38 |
| % Clay | 32 | 27 |
| Textural class | Sandy loam | Loam |
| Chemical Properties | | |
| pH in $H^2O$ | 6.0 | 5.8 |
| *1:2 : 5) $Cacl_2$ | 5.5 | 5.5 |
| Carbon % | 0.15 | 0.54 |
| Available $P_2O_5$ *ppm) | 27.5 | 16.13 |
| Total nitrogen % | 0.072 | 0.084 |
| Exchangeable cations | | |
| meq/100g soil | | |
| Ca | 4.0 | 3.40 |
| Mg | 1.3 | 0.53 |
| K | 0.27 | 0.26 |
| Na | 0.15 | 0.03 |
| C.E.C. | 8.0 | 5.70 |