EVALUATION OF FOUR INSECTICIDE FORMULATIONS FOR THE MANAGEMENT OF FLOWERING AND POST FLOWERING INSECT PESTS OF COWPEA

BY

RASHEED OLAKITAN OYEWALE

DEPARTMENT OF CROP PROTECTION
FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY, ZARIA

JULY, 2014

EVALUATION OF FOUR INSECTICIDE FORMULATIONS FOR THE MANAGEMENT OF FLOWERING AND POST FLOWERING INSECT PESTS OF COWPEA

BY

Rasheed Olakitan OYEWALE
B. Agric. (Unimaid. 2005)
M. Sc./AGRIC/03025/2010-2011

A THESIS SUBMITTED TO THE SCHOOL OF POST GRADUATE STUDIES AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN CROP PROTECTION.

DEPARTMENT OF CROP PROTECTION
FACULTY OF AGRICULTURE, AHMADU BELLO UNIVERSITY,
ZARIA, NIGERIA.

JULY, 2014

DECLARATION

I declare that this Thesis entitled: Evaluation of Four Insecticide Formulations for the Management of Flowering and Post Flowering Insect Pest of Cowpea was carried out by me in the Department of Crop Protection under the supervision of Dr. L. J. Bamaiyi, Prof. A. M. Oparaeke and Prof. R. S. Adamu. All sources of information derived from the literature have been duly acknowledged in the text by way of references. No part of this thesis was presented in any previous study for higher degree or diploma at any University to the best of my knowledge.

…… …… ……

Name of Student Signature date

CERTIFICATION

This thesis entitled "Evaluation of Four Insecticide Formulations for the Management of Flowering and Post Flowering Insect Pests of Cowpea" by **Rasheed Olakitan OYEWALE** meets the regulation governing the award of the degree of Master of Science in Crop Protection of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

.

Dr. L. J. Bamaiyi	……	…….
Chairman, Supervisory Committee	Sign	Date
Prof. A. M. Oparaeke	……	…….
Member, Supervisory Committee	Sign	Date
Prof. R. S. Adamu	……	…….
Member, Supervisory Committee	Sign	Date
Prof. A. B. Zarafi	……	…….
Head, Department of Crop Protection	Sign	Date
Prof. A. A. Joshua	……	…….
Dean, School of Post graduate Ahmadu Bello University, Zaria	Sign	Date

DEDICATION

This piece of work is dedicated to Almighty Allah (SWT) for His infinite mercy upon me through all challenges and obstacles. Also to my wife, Mrs Shakirat and children (Rahimat, Al-ameen and Fauziyat) for their understanding, patience and prayers in the course of this study.

ACKNOWLEDGEMENT

Appreciation to omnipresent, omnipotent, incomprehensibility Almighty Allah who in His infinite mercy guided, protected and saw me through the challenges of this research work. My profound gratitude goes to Dr. L.J. Bamaiyi who enthusiastically encouraged, guided and supervised me both on the field and the write up. Also my thanks go to the members of my supervisory team; Prof. A. M. Oparaeke and Prof. R.S. Adamu whose criticisms, suggestions and corrections contributed to the success of this work.

I acknowledge and appreciate all teaching and non-teaching staff of the Department of Crop Protection for knowledge imparted in me, their encouragement and motivation made it possible to complete my study. I specifically appreciate the fatherly advice of Prof. M.D. Alegbejo.

I am indebted to acknowledge the support and tuition of Mr. Ishaku Musa (Head of Insect Museum) and his subordinates, Mr. Job James and Miss Faith Christopher. Also, my gratitude goes to Mr. Livinus Bawa and Muhammad Seshi of Storage Entomology and Legume Entomology laboratory respectively for assisting me in my research farm. I sincerely appreciate the understanding of the immediate past and present Head of the Department of Crop Protection: Dr. Chindo and Prof. A. B. Zarafi, I say thank you. I appreciate the support, encouragement and understanding of my wife (Mrs. Shakirat). I am grateful to my children; Rahimat (Amirat), Al-ameen and Fauziyat for their patience and prayers. Other members of the family, brothers and sisters are also appreciated.

I am indebted to Alhaji Bello L. Y. and his wife, Hajia Barr. Lateefat Bello for the assistance, advice, encouragement and company, as well as to their children; Tolani, Abdulbasit and Ummulkhaer. May Almighty Allah support them in all their endeavours. Finally, I wish to acknowledge the company of my postgraduate course mates at Ahmadu Bello University Zaria; Buhari, Mustapha, Moses, Bulus, Zaharadeen, Yetunde(Christiana), Mariam, Zainab and the taxonomy class mates; John, Danladi and Owoeye. I also appreciate the support of management of Federal University of Technology Minna for giving me opportunity to undergo the training.

TABLE OF CONTENT

Cover Page - i

Title Page - ii

Declaration - iii

Certification - - - - - - - -- -- - - - - - - - - - - - - - - - iv

Dedication - v

Acknowledgement - - - - - - - - - - - - - - - - - - -- vi

Table of Contents - - - - -- - - - - - - -- - - - - - - - - - - - - - - vii

List of Table - - - - -- - - - - - - -- - - - - - - - - - - - ------ - xi

List of Figure - - - - - ------ - - - - - - -- - - - - - - - - - - - - - - xii

List of Appendix - - - - -- - - - - - - -- - - - - - - - - - - - - - xiii

Abstract - xiv

CHAPTER ONE

1.0 INTRODUCTION - 1

1.1 Justification of the Study -- - - - - - - - - - - - - - - - - - - 2

1.2 Aim and Objective - 3

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution of Cowpea - - - - - - - - - - - - - - - 4

2.2 Importance and Uses of Cowpea - - - - - - - - - - - - - -6

2.3 Cowpea Cropping System - - - - - - - - - - - - - - - - 7

2.4 Constraints to Cowpea Production - - - - - - - - - - - - 8

2.4.1 Insect pests of cowpea - - - - - - - - - - - - - - - - - 9

2.4.2 Diseases of cowpea - - - - - - - - - - - - - - - - - - - 13

2.5 Management of Cowpea Pests - - - - - - - - - - - - - - 14

2.6 Botanical Insecticide - - - - - - - - - - - - - - - - 15

2.7 Insect Resistant Cowpea Varieties - - - - - - - - - - - - 16

2.8 Synthetic Insecticides - - - - - - - - - - - - - - - 18

CHAPTER THREE

3.0 MATERIALS

3.1 Study Area - 21

3.2 Field Preparation and Experimental Layout - - - - - - - - - - 21

3.3 Cowpea Variety and Sowing - - - - - - - - - - - - - - - 22

3.4 Insecticide Treatment - - - - - - - - - - - - - - - - - 23

3.5 Insects Sampling - 23

3.6 Damage Assessment - - - - - - - - - - - - - - - - - - - 23

3.7 Yield Assessment - 24

3.8 Data Analysis - 25

CHAPTER FOUR

4.0 RESULTS

4.1 Effect of Insecticide Rates on *M. sjostedti* Population on Cowpea Flower at Samaru and Wase- - - - - - - - - - -- 26

4.2 Effect of Insecticide Rates on *M. vitrata* Population on Cowpea Flowers / Pods at Samaru and Wase - 28

4.3 Effect of Insecticide Rates on *C. tomentosicollis* Population on Cowpea Pods at Samaru and Wase - 30

4.4 Effect of Insecticide rates on Aborted Flowers of Cowpea at Samaru and Wase - 33

4.5 Effect of Insecticide Rates on Number of Pod and Pod Damage at Samaru and Wase - 35

4.6 Effect of Insecticide Rates on Seed Damage Index of Cowpea at Samaru and Wase - 38

4.7 Effect of Insecticide Rates on Grain Yield of Cowpea at Samaru and Wase - - 41

CHAPTER FIVE

5.0 DISCUSSION - 43

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary - 48

6.2 Conclusion - - - - - - - - - - - - - - - 48

6.3 Recommendation - - - - - - - - - - - - - -- 49

REFERENCES - - - - - - - - - - - - - - - -- 50

APPENDIX I Meteorological data of Samaru and Wase 2012 cropping season - - - 59

APPENDIX II ANOVA Table -- - - - - - - - - - - - - -- - - - - - - - - - - 60

LIST OF TABLES

Table 4.1 Effect of Insecticide Rates on *M. sjostedti* Population on Cowpea Flower at Samaru and Wase - 27

Table 4.2 Effect of Insecticide Rates on *M. vitrata* Population on Cowpea Flowers / Pods at Samaru and Wase - 29

Table 4.3 Effect of Insecticide Rates on *C. tomentosicollis* Population on Cowpea Pods at Samaru and Wase - 31

Table 4.4 Effect of Insecticide rates on Aborted Flowers of Cowpea at Samaru and Wase - 34

LIST OF FIGURES

Figure 1.0 Effect of Insecticide Rates on Number of Pod at Samaru and Wase - - - - - 36

Figure 2.0 Effect of Insecticide Rates on Pod damaged at Samaru and Wase - - - - - - 37

Figure 3.0 Effect of Insecticide Rates on Seed Damage Index of Cowpea at Samaru - - - - -39

Figure 4.0 Effect of Insecticide Rates on Seed Damage Index of Cowpea at Wase - - - - - 40

Figure 5.0 Effect of Insecticide Rates on Grain Yield of Cowpea at Samaru and Wase - 42

LIST OF PLATES

Plate 1.0 Pictures of *Maruca vitrata, Megalurothrips sjostedti* and *Clavigralla tomentosicollis* - 12

ABSTRACT

Field trials on evaluation of four insecticide formulations for the management of flowering and post flowering insect pests of cowpea were conducted in two locations (IAR Research Farm Samaru, Zaria, Kaduna State (Lat.11^{o} 11^{1}N and 7^{o} 38^{1}N) and Wase, in Minjibir local government of Kano State (Lat. 12 10^{0} 60.00^{1} and 8 40^{0} 0.00^{1} E), under rainfed conditions in the Northern Guinea Savannah and Sudan Savannah of Nigeria respectively. Four insecticide formulations: Chlorpyrifos, Chlorpyrifos plus, Dimethoate and Imidacloprid. There was a standard check (Cyperdicot; 250+30 g a.i./ha) and an untreated control. The treatments were arranged in a randomized complete block design (RCBD) replicated three times. Population of thrips, *Megalurothrips sjostedti* Tryb, *Maruca. vitrata* and *Clavigralla. tomentosicollis* were sampled 24 hours before and after each spray for three weeks between 7.00 and 8.00am. The damage was assessed by counting the number of aborted flowers/plot; seed damage indices (Sdi) was determined by sorting the seed lot from each plot into 3 categories. The results showed that all the four insecticides effectively reduced the population and infestation of insect pests as well as increased the yields compared to untreated control. Most of the insecticides differ significantly from the standard check (Cyperdicot). The various levels (concentrations) 0.5, 1.0 and 1.5 l/ha were similar in their performance in reducing insects' population and infestation, pod and seed damage. Therefore the lower concentration range of 0.5-1.0 l/ha should be used so as to minimise cost and reduce risk of environmental pollution among other hazards. Application of Imidacloprid at 105 g a. i./ha (1.5 l/ha) with almost hundred per cent reduction was most effective in the control of *C. tomentosicollis* at both locations compared with other insecticide treatments. While Chlorpyrifos at 240 (0.5 l/ha) and 720 g a.i./ha (1.5l/ha) resulted in the highest number (176.00 and 135.33) of pods produced at Samaru and Wase. Chlorpyrifos at 240 g a.i. / gave highest significant grain yield of cowpea in both locations

CHAPTER ONE

1.0 INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is an important grain legume in the tropics and subtropics. It is native to central Africa and belongs to the family Fabaceae (Cobley, 1956). Cowpea is eaten in the form of grain, green pods, and leaves (Adejumo, 1997). The roots are eaten in Sudan and Ethiopia, and the peduncles and stems are used as source of fibres in Nigeria (Adejumo, 1997).

Cowpea is known as vegetable meat due to high amount of protein in the grain with better biological value on dry weight basis (Owolabi *et al*., 2012). Cowpea grain depending on varieties, for instance, IAR 48 (SAMPEA 7) contains 26.61 % protein, 3.99 % lipid, 56.24 % carbohydrates, 8.60 % moisture, 3.84 % ash, 1.38 % crude fibre, 1.51 % gross energy, and 54.85 % nitrogen free extract (Owolabi *et al*., 2012). Cowpea is mainly grown in tropical and sub tropical regions of the world for vegetable and grain and to a lesser extent as fodder crop. It is a very versatile pulse crop because of its smothering nature, drought tolerant character, soil restoring properties and multi-purpose uses. More than 11 million hectares are cultivated worldwide, 97 % of which is in Africa. Nigeria alone cultivates 4.5 million hectares annually representing over 60 % of total production (FAO STAT, 2011). The crop can be harvested in three stages; while the pods are young and green, mature and green and dry. It is mostly grown as an intercrop with sorghum, maize and millet (Asiwe, 2007; Voster *et al.,* 2007). Cowpea is usually preferred by farmers because of its role in increasing soil fertility through nitrogen fixation and production of nutritious fodder for livestock (Blade *et al.,* 1997 and Asiwe *et al.,* 2009). Under sole cropping, the potential grain yield is high (1.5 - 3.0 t ha-^{1}), especially, when insecticide was applied. However, the actual yields obtained by farmers in

Nigeria are much lower averaging less than 500 kg ha-^{1} (Asiwe, 2007). Insect pests are considered to be largely responsible for this, as their attack can result in 90 – 100 % yield reduction (Jackai and Daoust, 1986). The grain yield of cowpea in Nigeria is 700 kg/ ha (FAO STAT, 2011). The highest production of cowpea comes from the northern region of Nigeria (about 1.7 million tonnes from four million hectares).

The sale of cowpea seeds and fodder earns income to farmers. In Nigeria, farmers who cut and store cowpea fodder for sale at the peak of the dry season have been found to obtain as much as 25 % of their annual income by this means (FAO STAT, 2011). Cowpea also plays an important role in providing soil nitrogen to cereal crops (such as maize, millet and sorghum) grown after cowpea cropping (FAO STAT, 2011).

1.1 Justification of the Study

The low yield obtained from farmers' fields suggests that natural control (no management practices) by itself cannot afford enough protection as to enhance profitable commercial production (Jackai and Singh, 1988). The use of varieties that are resistant to attack by insect pests is one of the most promising alternative management strategies since it is economically and environmentally safe (Tamo *et al*., 1997). However, in spite of concerted efforts by many institutions over the last two decades to develop varieties with resistance to the cowpea insect pest complex, resistant varieties are still unavailable to farmers (Dzemo *et al*., 2010). Chemical control using synthetic insecticides therefore remains the most effective control tactic especially when the pests have exceeded the economic injury level. However, excessive use of chemical insecticides is hazardous to humans and the environment, and often leads to the elimination of ecologically beneficial insects as well as the development of resistance by insect pests. Chemical insecticides are not affordable to most peasant farmers. Total

abandonment of chemicals could however, spell doom to man as this will worsen the present food situation (Stern, 1973). Chemicals could be judiciously used in consonance with other control measures so as to minimise the large number of sprays in farms. Various synthetic chemicals are available in the market and new products with different trade names abound yearly. Their efficacy against the wide spectrum of cowpea pests should be tested. To enhance the efficacy of insecticides and reduce their indiscriminate use, their application should be carefully timed and managed to coincide with stages in crop phenology where pest pressure is high. Several studies in tropical Africa have suggested that spraying twice (once each at flowering and podding) is sufficient to manage insect pests and increase cowpea grain yield (Stern, 1973). This study therefore, aims to determine the minimal rate of four new insecticide formulations application that can substantially reduce cowpea insect pest infestations and increase yield.

1.2 Objectives of the Study

i- To evaluate four new synthetic insecticides for the management of flowering and post flowering insect pests of cowpea.

ii- To determine the minimum application rate required for efficacy against the flowering and post flowering insect pests of cowpea.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution of Cowpea

Cowpea (*Vigna unguiculata* (L) Walp) is a tropical, annual herbaceous legume, which belongs to the family Papilionaceae (Fabaceae), order Leguminosae and genus *Vigna (*Cobley, 1956; Martin and Leonard, 1956; Singh *et al.*, 1997). The genus *Vigna* consists of over one hundred different species widely found in the tropical and subtropical regions, and has great morphological and ecological diversity (Ng and Monti, 1990; Paino D'urzo *et al*, 1990). The common names of this crop include black- eye bean, southern pea, bean, cowpea, china pea and cow grain. In Nigeria, it is commonly referred to as beans, "ewa" (Yoruba), "wake" (Hausa) and "akidi" (Igbo) (Singh and Ajeigbe, 1998), "nyebbe" (Fulani), "ezor" (Ebira), "ezo" (Nupe), "evor" (Gbagi), "enje"(Idoma), "jok"(Bajju) and "ijik"(Ikulu).

The crop can be grown on many soil types, but does best on well-drained, fertile, sandy-loam soils. Cowpea production is considered suitable in areas with annual rainfall of 750-1500 mm (Anthonio, 1979). Cowpea varieties could be prostate, semi-erect, erect or climbing. Pods could be coiled, round, crescent or linear (Rachie and Singh, 1985). Most cowpea cultivars are indeterminate in nature, producing flowers and seed over a long period. However, some are determinate and produce flowers and seed within a season (Paino D'urzo *et al*., 1990).

The origin of cowpea has been very difficult to determine, due to the fact that various researchers have reported different areas as centres of origin. Faris (1965) postulated that, based on the presence of wild progenitors of cowpea in West and Central Africa, the region was the centre of domestication of cowpea. This view was corroborated by Steele (1965) and

Rawal (1975) who also reported that cowpea originated from sub-humid and semi-arid regions of West Africa. However, some studies on the genetic exploration of cowpea in Africa suggested that Swaziland may be the primary centre of origin of wild progenitors, because this country has higher species diversity throughout the world (Ng and Monti, 1990; Mongo, 1996).

Regardless of its centre of origin, cowpea is extensively cultivated in Africa, Asia, Australia, Brazil, the Caribbean's, India and the United States of America (U.S.A). The major areas of production in Central and West Africa, which account for about 89 % of the total area of world production, are Nigeria, Niger, Mali, Burkina Faso, Senegal, Cameroon and Democratic Republic of Congo, (FAO, 2008). Modest amounts also emanate from Mozambique, Tanzania, Uganda, Sudan, Kenya and Somalia. Other producers are Myanmar, Haiti, Serbia, Sri Lanka and Egypt (FAO, 2008). The main producing areas in Nigeria are within the Guinea and Sudan savannas (Mongo, 1996). However, some appreciable quantities are grown in the rain forest belts, particularly in the South West, which has two (2) growing seasons, namely; early (March – July) and late (August – November) (Ebong, 1965). The major producing states in Nigeria include; Kaduna, Katsina, Zamfara, Bauchi, Sokoto, Kebbi, Plateau, Adamawa, Taraba, Gombe, Borno, Yobe, Jigawa, Niger, Benue, Nasarawa and Kano where most cowpeas are traditionally grown as intercrops with cereals such as millet, maize and sorghum (Steele, 1965; Emechebe and McDonald, 1979). In this system, the yields are low; inter-specific competition is high, population density is undetermined and harvesting is complicated by differing maturities of the intercrops (Chemeda, 1997). Singh *et al* (1997) estimated a world total area of about 12.5 million hectares grown to cowpea annually.

Food and Agricultural Organization (FAO) of United Nations estimated a production of more than 5.2 million metric tonnes of dry cowpea grains worldwide in the year 2010 (FAO, 2011). The report also showed that cowpea production in Nigeria accounted for 58 % of the total world's output; making Nigeria the largest producer with an output of 2.9 million metric tonnes. Production in Nigeria is highest in the North East (703.13 metric tonnes from 641.03 ha), followed by the North West (519.51 metric tonnes from 1068.02 ha) and North Central (166.58 metric tonnes from 307.70 ha) (NAERLS and NFRA, 2009).

2.2 Importance and Uses of Cowpea

Cowpea (*Vigna unguiculata* (L) Walp) is an important grain legume in the diet of many people in the third world countries as it provides not only high quality protein (25.4%) but also constitute the cheapest source of dietary protein for low income sectors of the population (Stanton, 1966; Rachie, 1985). It is also a good source of carbohydrate (56.8%) calcium, iron, vitamin B and carotene, although cultivated primarily for its edible seeds, direct consumption of cowpea leaves is also widespread in Africa (Nelson *et al*., 1997). In fresh form, the young leaves, immature pods and peas are used as vegetables, while snacks and main meal dishes are prepared from the dried grain (IITA, 2002). Beside its usefulness in human diet, it serves as an important fodder crop in different parts of Africa (Quin, 1997). The haulm containing about 20% protein is highly valued feed and is sold for almost the same price as cowpea grain on dry weight basis (IITA, 1997). In other words, cowpea promotes crop livestock integration, thereby leading to a better nutrient cycling and enhanced income generation (Yusuf *et al*., 1998).

2.3 Cowpea Cropping Systems

The predominance of mixed cropping systems in developing countries of the tropics and subtropics and northern Nigeria in particular was reported by Norman (1972). The advantages attached to these practices include profit maximization (Abalu, 1976), more efficient use of labour and land, reduction of soil erosion, yield stability and risk minimization (Okigbo and Greenland, 1976; Boller, *et al.,* 2004). Small scale farmers constitute the majority in Northern Nigeria, and where large scale farmers are found, they mostly practice mono-cropping.

Although cowpea has high grain yield potentials ranging from 1.5 to 3.0 t/ha (Alghali, 1993), actual yields in the traditional cropping systems in Africa are consistently low as the range is between 50 to 350kg/ha (Rachie, 1985; Jackai and Doust, 1986; Mortimore *et al*., 1997; Emechebe and Singh, 1997). With increase in population, the demand for land has also increased, resulting in intense cultivation with little or no fallow periods, hence the need for intercropping (Weber *et al.,* 1996). The popularity of maize and cowpea mixtures has been reported in the Savannah region of Nigeria (Willey and Osiru, 1972). Mixed cropping is used to include terms similar in meaning as inter planting (the partial mixing of crops where by a crop or crops are sown and harvested after another crop in the mixture (Baker, 1978)) and relay cropping, where the second crop is sown into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting (the growing period only overlaps briefly) (Willey and Osaru, 1972). In Nigeria, Baker (1978) reported that mixed cropping of cereals with legumes results in better returns which were obtained by alternating two rows of cowpea with one row of maize. There is a potential to integrate more legumes in the existing cropping systems as intercrops because the growing of sole crops has been

rejected by small scale farmers due to labour and land constraints (Kumwenda *et al.*, 1996). If legumes are intercropped in a timely manner, competition with maize crop for light, water and nutrients can be minimized while yield is increased. A relay intercropped legume is not likely to benefit companion maize crop but has the potential to increase yields of subsequent maize crop (Jeranyama *et al.*, 1998).

Cowpea is important in multiple cropping systems which involve mono-cropping, relay cropping and mixed intercropping. In Asia, cowpea is grown as an intercrop with cereals, cotton or sugarcane, and relay-cropped in standing rice. In Africa, cowpea is grown as an intercrop with millet, sorghum or maize (CABI, 2000). The practice of cereal-cowpea intercropping and crop rotation, coupled with effective soil fertility management can increase yields of cereals succeeding cowpea by fixing 150kg\ha of N, which can supply 80 - 90 % of plants total N requirement (Fatokun *et al.*, 2000). According to National Agricultural Extension and Research Liaison Services (NAERLS) and Project Coordinating Unit (PCU) (2004), cereal-legume mixtures are the predominant cropping pattern in Northern Nigeria. The mixtures are mostly Sorghum \ Millet \ Cowpea, Sorghum \ Millet \ Groundnut, Cassava \ Maize \ Cowpea, Cassava \ Yam \ Maize, Yam \ Maize \ Cowpea, Cassava \ Melon \ Vegetable, Millet \ Cowpea \ Okra, etc.

2.4 Constraints to Cowpea Production

In Nigeria, cowpea yield is very low, grain yield is below 250kg/ha in resource poor farmers fields (Oparaeke, 2004). This is due to several constraints such as weather, parasitic weeds, insects, and diseases. However, production can be improved through the use of improved pest-resistant and high-yielding varieties. Good land preparation, pest control, fertilizer

application, harvesting and storage also help to improve production. In addition, adequate and good distribution of rainfall especially from planting till mid- podding is very vital for high yield of cowpea.

Tamo *et al*., (2003) reported that the reasons for low yields are numerous but most of the time it involves a combination of limiting factors such as low plant density, shading by cereal crops, abiotic (e.g. drought, poor soil fertility) and biotic (e.g. arthropod pests, birds and rodents) factors. However, in most parts of West Africa, insect pests are the most important constraint to cowpea production (Booker, 1965; Singh *et al.,* 1978; Rachie 1985; Singh and Jackai, 1985; Jackai and Doust, 1986; Karungi *et al*, 2000). Jackai and Adalla (1997) listed at least 20 major insect pest species in various cowpea producing regions of the world in which the number vary from region to region and most damaging of all the insect pests are the flowering and post flowering insect pests. The major flowering and post flowering insect pests of cowpea in tropical Africa are the flower bud thrips, (*Megalurothrips sjostedti* Tryb.), cowpea pod borer (*Maruca vitrata* F.) and a complex of pod sucking bugs out of which *Clavigralla tomentosicollis* Stal is the dominant species (Jackai and Doust, 1986). Complete crop failure may occur especially in situation where control measures are not applied.

2.4.1 Insect pest of cowpea

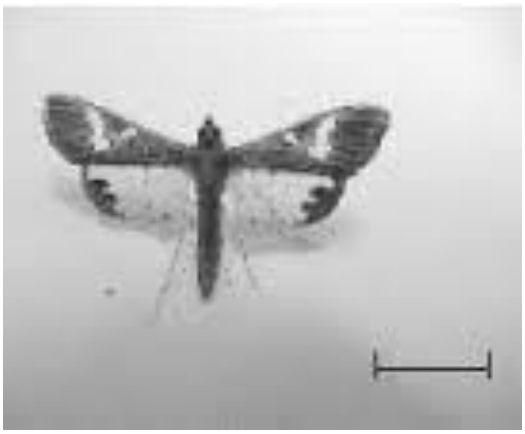
Cowpea is a hardy crop but it hosts many insect pests that attack vegetables. These include, leaf miners, whiteflies (*Bemisia tabaci*), leafhoppers (*Empoasca* sp.), mites (*Tetranychus* sp.), thrips (*Megalurothrips sjostedti* Stal), *Ootheca* sp., *Clavigralla* sp., *Maruca* sp. and aphids (*Aphis craccivora*). Cowpea's attraction for insects may be an advantage if the crop also attracts a sizable population of beneficial insects, but it is not, rather result to pest out breaks

and then move on to attack cash crops. Cowpea may also attract stinkbugs during podding. Careful weekly monitoring is important to ensure that the cowpea planting is not becoming a source of pests on the farm (Hector and Jody, 2002).

There are numerous important insect pests of cowpeas worldwide and most locations have 2 – 4 species being key pests (Agyen-Sampong, 1978).The most damaging pests are the legume pod borer, *Maruca vitrata* Fab. (Lepidoptera: Pyralidae) (Plate Ia), flower bud thrips, *Megalurothrips sjostedti* Tryb. (Thysanoptera : Thripidae) (Plate Ib), and the pod sucking bug (PSB) (Plate Ic), complex of which *Clavigralla* spp. Stal. (Hemiptera : Coreidae), *Anoplocnemis curvipes* Fab. (Hemiptera: Coreidae), *Riptortus dentipes* Fab. (Hemiptera : Alydidae) and *Aspavia armigera* are the most damaging (Tanzubil, 1991**,** 2000; Jackai, 1985**).** In Nigeria, major field insect pests of cowpea include aphids (*Aphis craccivora* Koch.), thrips (*Megalarothrips sjostedi* Trybom), legume pod borer (*Maruca vitrata*), spiny brown bug (*Clavigralla tomentosicollis* Stal.), flower beetle (*Mylabris* Species), leaf-footed plant bug (*Leptoglossus australis* F.) and foliage beetle (*Ootheca mutabilis* Salhib) (Malgwi and Onu, 2004). Attack by these insects is often so severe that farmers obtain no yields, especially when improved cowpea varieties are grown without insecticide protection (Tanzubil, 1991; 2000). However according to Oparaeke *et al*., (2000) yield losses in cowpea due to insect pests in Nigerian farms were estimated to be above 80 %.

In general, insect pests, diseases and weeds impose a serious threat to crop production in Nigeria. Population of weeds, insect pests and diseases have increased over the years especially by the introduction of monoculture farming in the country (Emosairue and Ubana, 1998). Traditionally, Nigerian farmers have been relying heavily on pesticides for the control of various weeds, insect pests and diseases, leading to the high importation of these products

and their price have become so high that it is becoming impossible for local farmers to afford (Nwanze, 1991; Schwab *et al.,* 1995; Van den and Nur, 1998; Okrikata and Anaso, 2008). These have created the need for alternatives to synthetic pesticides. But inadequate infrastructure for research and extension remains a constraint to the advancement and continuity of such important activity in Nigeria (Bugaje *et al.,* 2007). The major pests of cowpea in the field in northern Nigeria, Niger, and Burkina Faso include: the legume pod borer, *Maruca vitrata* Fabricius; the coreid pod-bugs, *Clavigralla tomentosicollis* Stal and *Anoplocnemis curvipes* (F.); the groundnut aphid, *Aphis craccivora* Koch; and, thrips, *Megalurothrips sjostedti* Trybom and *Sericothrips occipitalis* Hood. A limited amount of work has been done to understand these insect pests in these areas. Yields are however, generally low (Olatunde *et al*., 1991), sometimes total yield losses and crop failure occur (Singh and Jackai, 1985) due to the activities of a spectrum of insect pests which ravage the crop in the field at different growth stages (Singh and ven Emdem, 1979). The major insect pests which severely damage cowpea during all growth stages are the cowpea aphid (*Aphis craccivora* Koch), foliage beetles (*Ootheca* spp, *Medythia* spp), the flower bud thrips (*Megalurothrips sjostedti* Trybom) the legume pod borer (*Maruca vitrata* Fabricius) and the sucking bug complex, of which *Clavigralla* spp, *Anoplocnemis* spp, *Riptortus* spp, *Mirperus* spp, *Nezara viridula* Fab and *Aspavia armigera* L are most important and prevalent.



a. Adult *Maruca vitrata* (136 x 166 magnification)



b. Adult *Megalurothrips sjostedti* (78 x 147 magnification)



c. Adult *Clavigralla tomentosicollis* (224 x 148 magnification)

Plate I: pictures of adult *Maruca vitrata*, adult *Megalurothrips sjostedti* and adult *Clavigralla tomentosicollis*

2.4.2 Diseases of cowpea

Cowpea is susceptible to diseases that affect legumes. The fungal diseases include: Damping-off (*Pythium* spp.) which may occur on seedlings under moist conditions and in dense plantings. Root rot (*Verticillium* spp.) and stem rot (*Fusarium* spp.) may also be a problem. Cowpea is susceptible to powdery mildew (*Erysiphe polyqoni*) under humid conditions. Other diseases that affect cowpea include anthracnose (*Colletotrichum lindemuthianum)*, charcoal rot (*Sclerotium bataticola*), and fusarium wilt (*Fusarium oxysporum vr. tracheiphilum)*.Viral diseases include: Cowpea aphid-borne mosaic virus (CABMV) Genus potyvirus, blackeye cowpea mosaic virus (BLCMV) Genus potyvirus, cowpea mosaic virus (CPMV) Genus comovirus and cowpea mottle virus (CPMOV) Genus carmovirus. Nematodal diseases include: Root knot nematode (*Meloidogyne* spp.), root lesion nematode (*Pratylenchus* spp.) and dagger nematode (*Xiphinema* spp.).While bacterial diseases include: Cowpea blight (*Xanthomonas campestris pv. Vignicola*) and cowpea bacterial pustule *(Xanthomonas campestris pv. Vigna unguiculata*).

In the establishment phase, rodents and birds can be important pests by feeding on the seeds (Hector and Jody, 2002). Without their control, reasonable grain yield cannot be obtained (Jackai and Daoust, 1986; Suh *et al*., 1986). Several control measures are available (Jackai, 1985) but chemicals are most effective, giving several fold increase in grain yield (Jackai, 1993). Sometimes, however, farmers spray their farms as many as eight to ten times during the growing season (Omongo *et al.,* 1998). Hazard associated with the use of chemicals such as environmental pollution, toxicity to mammals, hazards to users and consumers (Alabi *et al*., 2003) has led to suggestions on alternative control measures being sought.

2.5 Management of Cowpea Insect Pests

Due to the devastating effect of insect pests of Cowpea at almost every stage of its development, several approaches have been adopted in its control. Research into the control of these insect pests has centred primarily on the use of synthetic insecticides (Echendu, 1991). Amongst the insecticides are Azodrin, Thiodan DDT, Dursban and Dimecron, which have been found to be effective against the leafhoppers. Over the years, chemical pesticides had made a great contribution to the fight against pests and diseases. However, their widespread and long-term use resulted in insecticide resistance and biomagnifications of insecticides, which in turn resulted in restrictions on their export. Problems, like soil and water contamination and dramatic increase of the harmful residues in many primary and derived agricultural products arose, which endangered both the general environment and human health. It is estimated that the financial cost of the damage to the environment and social economy is about $ 8.1 billion a year (Shen and Zhang, 2000). The use of synthetic organic insecticides in crop pest control programs around the world had caused tremendous damage to the environment, pest resurgence, pest resistance to insecticides, and lethal effects on non-target organisms (Alao and Adebayo, 2011). Insect pests of cowpea have mainly been controlled with synthetic insecticides (Kabaru and Gichia, 2001; Alao and Adebayo, 2011). Most insecticidal compounds fall within four main classes - organophosphates, organochlorines. carbamates and pyrethroids. Protecting the crop with insecticide application increased yields several fold and for the improved varieties, virtually no yields were obtained under no insecticide protection. Earlier studies by Tanzubil (1991**,** 2000) concluded that in Northern Ghana, complete crop failure often results when improved cowpea varieties are grown without insecticide sprays. The results confirm the economic impact of chemical control in cowpea production and further show that with proper timing; two insecticide applications (at flowering and again at podding) could produce as good a cowpea crop as 4

sprays. This would be advantageous from the perspectives of lower costs and environmental pollution (Ebenezer, 2010).

2.6 Botanical Insecticides

As a result of the problems of pesticide resistance and negative effects on non-target organisms including man and the environment, organochlorine has been reportedly banned in developed countries. These resuscitated the idea of botanical insecticides as a promising alternative to pest control. Botanical insecticides are naturally occurring chemical extracted from plants which break down readily in the soil and are not stored in plant or animal tissue. Often their effect are not long lasting as those of synthetic pesticides (Isman, 2006). Botanical insecticides are generally pest – specific and are relatively harmless to non-target organisms. They are biodegradable and harmless to the environment. Also, the possibility of insect developing resistance to botanical insecticide is less likely (Schmutterer, 1990). Over 2000 species of plants are known to possessed insecticidal activities despite this, only a few have been scientifically evaluated (Ojo, 1996; Isman, 2006) *Petiveria alliacea* which is commonly known as Anamu belongs to the family Phytolaccacea. Several biological compounds in the root of *P.alliacea* which include: benzaldehyde, dibenzyltrisulfide, cis and trans-stibene *e.t.c* of which dibenzyltrisulfide is an insecticidal compound. Laboratory and field tests have shown the effectiveness of this plant extract against armyworm, leaf-cutting caterpillars, ants, whiteflies and the three stages of mosquitoes (Alao and Adebayo, 2011). Fish bean (*Tephrosia vogelii*) which has been listed sxamong plants that possess insecticidal properties (Jackai and Adalla, 1997) contains rotenoids (McDavid and Lesseps, 1995) of which the leaves contain the highest concentrations (Merck, 1996). Rotenone is both stomach and contact poison, useful against sucking and biting insects. Also formulation of *T. vogelii* + locust lotion was observed to be effective as Lambdacyalothrin in the control of insect pests

of Okra in the field (Alao and Adebayo, 2011). *Caryedon serratus* on groundnut was effectively controlled by *T. vogelii*. Research in recent years has been turning more towards selective biorational pesticides, generally perceived to be safer than the synthetic (Arnason *et al*., 1989), while extensive works on the use of plant extracts in pest control were also documented (Mordue and Blackwell, 1993), the use of inexpensive and safe protectants of plant origins was extensively reviewed (Lale, 1995). The use of Cashew Nut Shell Liquid (CNSL) has been gaining more attention due to its possession of the active Phenolic compounds, Anacardic acid and Cardol, which also have corrosive and abrasive properties (Olotuah and Ofuya, 2010). It was demonstrated that low concentration of CNSL could be effective in controlling *Callosobruchus maculatus* (Echendu, 1991). Similar work was also reported in preventing oviposition in *C. maculatus* (Ofuya and Fayape, 1999).

2.7 Insect Resistant Cowpea Varieties

There are few alternatives to pesticide sprays for many of these pest species. Two notable exceptions to this situation exist. The first is *Maruca vitrata,* where a potential biotechnology-based pest control solution exists. Transgenic cowpea expressing the Bt-protein Cry1Ab, effective against *M. vitrata* already exists. However, these plants are unlikely to be available for use by African farmers during the current CRSP funding cycle. However, before transgenic Bt-cowpea can be released there will be a need for an insect resistance management (IRM) plan (IITA, I974).

Although transgenic plants, and traditional plant breeding for insect resistant varieties are potentially effective methods for controlling at least two pests of cowpeas, a better understanding of pest populations is needed in order to integrate these, and other pest control options into an overall integrative pest management (IPM) plan to maximize cowpea

production in the field. IPM refers to a pest control strategy where a variety of complementary approaches are used to minimize the negative effects of pests on a given crop or cropping system (AATF, 2012).

The use of leafhopper resistant cowpea varieties was also adopted at the International Institute of Tropical Agriculture (IITA, 1974). The varieties include Tvu59, Tvu123, VITA - 1, VITA- 3 that do not need insecticide protection against leafhoppers. *Bt* is an abbreviation for *Bacillus thuringiensis*, a soil bacterium that is common around the world. These bacteria produce specialised proteins, called *Bt*,. *Bt* crops have significantly improved the cost effectiveness and sustainability of crop production in North and South America, Europe, Africa, the Middle East, Asia and Australia. *Bt* proteins selectively kill certain types of insects without affecting other living organisms (AATF, 2012). As such, *Bt* bacteria and *Bt* proteins have been used for years as biological controls for certain insect pests in farming, especially in the organic food industry. Modern biotechnology has produced *Bt* crops which are modified to produce specific *Bt* proteins in the plant cells to protect against specific pests. These crops do not need conventional pesticide sprays to destroy the pests that are controlled by the specific *Bt* protein. The *Bt* gene comes from a soil bacterium called *Bacillus thuringiensis*. The *Bt* gene used in *Maruca*-resistant cowpeas (*cry1Ab*) is the same gene used in several *Bt* maize events that have been approved for use in many countries, including Argentina, Australia, Canada, China, Brazil, the EU, Japan, Korea, Mexico, Netherlands, Philippines, South Africa, Switzerland, Taiwan, the UK, the US and Uruguay. The gene was identified and developed by Monsanto and is used successfully in several commercial crops (AATF, 2012). However, despite concerted efforts by many institutions over the last two decades to develop varieties with resistance to the cowpea insect pest complex, resistant varieties have still not reach farmers very well. Chemical control using synthetic insecticides

therefore remains the most popular control tactic especially when these pests have exceeded the economic injury level (Jackai *et al*., 2001).Without their control, reasonable grain yield cannot be obtained (Jackai and Daoust, 1986; Suh *et al*., 1986). Several control measures are available (Jackai, 1985) but chemicals are most effective, giving several fold increase in grain yield (Jackai, 1993). Sometimes, however, farmers spray their farms as many as eight to ten times during the growing season (Omongo *et al.*, 1998). Because of the danger of the use of chemicals such as environmental pollution, toxicity to mammals, hazards to users and consumers (Alabi *et al*., 2003), alternative control measures are being sought. But total abandonment of chemicals could however, spell doom to man as this will worsen the present food situation (Stern, 1973).

2.8 Synthetic Insecticides

The introduction of synthetic pyrethroids to the Agricultural market is a welcome addition to a wide range of pesticides already in use on different crops in Nigeria (Dina, 1979). The advantages have been enumerated by Elliot (1976). The synthetic pyrethroids are generally safe. A reduction in the number of insect pests and proper applications would not only increase the profit margin accruing to the farmer but would also be in consonance with pest management practices (Dina, 1982). Chemical methods are the only ones employed at present on a large scale for the control of insect pests of cowpea in Nigeria, particularly those infesting the flowers and pods. The pod borer complex of cowpea, of which *Maruca vitrata* Geyer is the most important, also include *Cydia ptychoda* Meyrick, *Virachola antalus* Hopkins and *Heliothis armigera* Hubner. In order to minimise hazards due to the use of excessive amounts of insecticide, breeders and entomologist are actively engaged in research to produce varieties which combine insect resistance with the qualities of grain preferred by

consumers. However, until the advent of such varieties, it is expedient to combine other pest management practices, as was suggested by Taylor (1967) for *C. ptychoda*, with minimum but effective insecticide spray schedules that can be based on a reduction in the frequency or rate of application or both (Dina and Medaigedu, 1976).

Because of the persistent nature of organochlorine insecticides, the organophosphate group was looked to as an alternative, and monocrotophos proved quite effective (Dina and Medaiyedu, 1976) despite its high mammalian toxicity. The appearance of the synthetic pyrethroids therefore opened a new vista in cowpea pest control work. Trial conducted in Nigeria have already indicated that the synthetic pyrethroids are promising in cowpea pest control (Caswell and Raheja, 1977; Dina. 1979). The advantages of the pyrethroids enumerated by Elliot (1976) include high potency to insect pests, low mammalian toxicity and short persistence. They are therefore, likely to cause minimum disturbance to the environment and make possible the production of crops devoid of residues.

In addition, experiments were carried out in four soybean fields. The overall environmental impact of each pesticide was estimated using the Environmental Impact Quotient (EIQ), ingredients in the pesticide on a number of organisms, including birds, fish, bees, in addition to other factors such as the toxicity to beneficial organisms, such as the ladybird and flower bug. The conventional insecticide Dimethoate and the two organic insecticides, mineral oil and *Beauveria bassiana* had the highest environmental impact. The impact of the mineral oil insecticide, for example, was more than ten times greater than that of Dimethoate because it has to be used in high doses. The organic insecticides did not offer significant protection of crop yields compared with the untreated control, and were least selective in that they killed both aphids and the natural control insects. The synthetic insecticides were the most selective

– even the least selective synthetic insecticide, Dimethoate, was still more selective than the organic insecticides. The researchers suggest that certain organic management practices are not necessarily more environmentally sustainable than conventional systems. An integrated pest management approach might be more suitable, as such a system is flexible enough to include whichever practices have the smallest environmental impact (Bahlai *et al.*, 2010).

The four insecticide formulations utilised were: Chlorpyrifos which belongs to the chemical family of organophosphate and the active ingredient is Chlorpyrifos. The mode of action is systemic which is absorbed by plant tissues which function as Acetylcholine esterase inhibitors on the insects that suck the plant sap; Chlorpyrifos plus contains both Chlorpyrifos and cypermethrin as its active ingredients belong to the chemical family, organophosphate and pyrethroids which are systemic and contact in their mode of actions. Cypermethrin functions as the insects' sodium channel modulators; Imidacloprid belongs to the chemical family of neonicotinoids which is also a systemic in its mode of action, it is translocated and deposited in plant tissues thereby functions as nicotinic acetylcholine receptor against antagonists (wwwheydchem.com). Cyperdicot used as standard check contains Dimethoate 25 % +Cypermethrin 3 % (EC) is a systemic and contact organophophorus insecticide for the control of all sucking pests. It is compatible with all insecticides and fungicides having non alkaline nature (Modern Insecticide Ltd. 2012).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

Field trials were conducted in two locations: IAR Research Farm Samaru, Zaria (Lat.11^0 $11^{'}$ N and 7^0 $38^{'}$ E) and Wase (Lat. 12^0 10' N and 8^0 $40^{'}$ E) in Minjibir local government area of Kano state) under rain fed conditions in the Northern Guinea Savannah and Northern Sudan Savannah of Nigeria, respectively, with mean annual rainfall between 1,150 to 1,350 mm and temperatures range from 25 – 32 ^{0}C in the dry harmattan and harvest period (November - December) at Samaru. While Wase had mean annual rainfall between 1,350 to 1,850 mm and temperatures range from 28 – 35 ^{0}C. The temperature fluctuates from 18 – 24 ^{0}C. The soil type at Samaru is clay-loam with organic matter content less than 0.02 % and sandy loam at Wase. The colour of the topsoil varies from a slight- brown to dark- brown and the pH ranges from 6.5 - 8.5 (IAR, 2012).

3.2 Field Preparation and Experimental Layout

The fields were sprayed with Glyphosate (5 l/ha) to control grasses, sedges, some broad leaf and creeping weeds. After two weeks, the fields were disc harrowed and ridged.

An area measuring 1,671.9 m^2 each was marked out for the experiment with three replications (blocks) and each replication consisted of 14 plots each measuring 5.25 m x 5 m. Each block was separated from the next by a distance of 1.5 m. Each plot consisted of seven ridges (five main ridges and two discard ridges, one on either side of the main ridges) and spaced at 0.75 m apart. Each plot size was 26.25 m^2 (gross) and separated by a 1.5 m wide border margin on all sides. Four insecticide formulations: Chlorpyrifos 480

g/L E.C, Chlorpyrifos 475 g/L + Cypermethrin 47.5 g/L, Dimethoate 400 g/L, Imidacloprid 70 WG, standard check (Cypermethrin +Dimethoate) and untreated control. Each was applied at 1.5, 1.0 and 0.5 litre per hectare as follows: (Chlorpyrifos; 720 g a.i./ha, (480 g a.i./ha, and 240 g a.i./ha Chlorpyrifos plus; 712.5 g a.i. + 71.25 g a.i./ha, 475 g a.i. + 47.5 g a.i. /ha, and 237.5 g a.i. + 23.75 g a.i. /ha; Imidacloprid; 105 g a.i./ha, 70 g a.i. /ha and 35 g a.i. /ha; Dimethoate; 600 g a.i/ ha, 400 g a.i./ha, and 200 g a.i./ha, standard check (Cyperdicot ; 250+ 30 g a.i. /ha) and an untreated control were also used. All the treatments were replicated three times. The treatments were arranged in a randomized complete block design (RCBD).

3.3 Cowpea Variety and Sowing

Cowpea variety, SAMPEA 6 characterised by extra- large white seed with black eye, rough seed coat texture, adapted to Sudan and Guinea savannah. Late maturing (90 – 100 days), with estimated yield of 1000 – 1500 kg/ha, spreading habit, susceptible to scab, bacterial blight, septorial leaf spot, brown blotch, susceptible to beetles, thrips, *Maruca* pod borer, pod sucking bugs and chrysomelids. IAR crop seeds were dressed with Apron Star (Metalaxyl + Thiomethoxam) at rate of 10g /2 kg seed and three seeds per hole were sown at 0.2 m apart intra row in the second week of August in both locations. Seedlings were thinned to two plants per stand two weeks after sowing (WAS). Compound fertilizer (NPK 15:15:15) was applied as side dressing at the rate of 37.5 kg a. i. / ha two WAS. Fungicide, Mancozeb extra 80WP (Mancozeb 650g/kg + Carbendazim 150 g/kg WP) was applied at the rate of 1.5 kg a i/ha before flowering at three weeks interval.

3.4 Insecticide Treatment

Field applications of insecticides at varying levels (dosages); 0.5, 1.0, and 1.5 lha^{-1} using a 20 litre CP-3 Knapsack sprayer at the rate of 200 litre of water per hectare, commenced at 9 WAS which coincided with the period of onset of flowers in this cowpea variety. Foliar spraying started from 9.00 a.m. each day after insects sampling. All the insecticides were sprayed once every week for three weeks

3.5 Insects Sampling

Population of thrips, *Megalurothrips sjostedti* Tryb, *Maruca vitrata* and pod sucking bugs were monitored. Twenty flowers were randomly removed from 10 plants per plot weekly before and after spraying and stored in a solution of 30 % ethanol. The keels of the flowers were separated in a Petri dish under a binocular microscope to free the thrips and *Maruca* pod borers before counting the insects. The counts were converted to log number before analysis (Dina, 1982). Insect pests sampling was conducted 24 hours before and after each spray every week between 7.00 and 8.00 a.m. (that is the period the insects were inactive). The flowers were then taken to the laboratory and dissected. Thrips found were counted and recorded. *M. vitrata* and *C. tomentosicollis* were also sampled 24 hours after each spray for three weeks. *M. vitrata* was sampled by removing 20 flowers at random per plot and placed in vials containing 30 % ethanol. It was then taken to the laboratory where larvae found were counted and recorded accordingly. *C. tomentosicollis* were sampled visually and the number of the bugs on 5 plants/ plot randomly selected (Oparaeke, (2005).

3.6 Damage Assessment.

The damage was assessed based on the following:

Number of aborted flowers/plant by counting the number of flowers that dropped pod on the ground from five stands selected randomly at 10 WAS.

Pod damage assessment involved counting the number of damaged pods per plant and divided by the total number of pods produced per plant in a random sample of 10 plants per plot. These were expressed in percentages according to the method used by Oparaeke, (2005,).

Seed damage indices (Sdi), was determined by sorting the seed lot from each plot into 3 categories as described by Gilman *et al.*, (1982). Category A consisted of seeds with no feeding damage; category B, seeds with obvious feeding punctures but with mild wrinkles and category C, seeds with holes and/or seeds that are severely wrinkled and shrunken to small sizes. The proportion of each category from each treatment subplot were weighed and expressed as percentage of the total weight of seeds assessed. To compute the Sdi, weights was used as illustrated below: Sdi = 0.5 (% seed weight in category B) + (% seed weight in category C).

Percentage seed weight in each category = 100 (seed weight in that category) ÷ total seed weight per plot

3.7 Yield Assessment

Harvesting of cowpea dried pods commenced when more than 50 % of the pods dried. Subsequent harvesting was also carried out to ensure that the cowpea was fully harvested. Pods harvested from each plot were placed in separate polythene bag, labelled and taken to the laboratory where the pod and seed weights were taken using an electric balance. Grain yield was recorded from threshed grains harvested from each plot. The pods and seed weights were calculated using the following formula (Aliyu *et al.*, 2011).

$$\text{Seed/pod weight (kg/ha)} = \frac{a \times 10{,}000}{b \times 1000}$$

where a = plot yield in grams (g),

b = Net plot size.

Pod density (a measure of efficacy of insecticide against thrips and borer larvae infestation on flowers) were assessed at 11 WAS by counting pods produced from a random sample of 10 plants per plot.

3.8 Data Analysis

All data were analyzed using Analysis of Variance (ANOVA) with SAS package (SAS, Institute,2003) and treatment means separated by Duncan Multiple Range Test (DMRT) at 5% level of significant (SAS Institute, 2003).

CHAPTER FOUR

4.0 RESULTS

4.1: Effect of Insecticides Rates on *Megalurothrips sjostedti* Population on Cowpea Flowers at Samaru and Wase during 2012 Cropping Season

The effect of different rates of insecticides on *M. sjostedti* population is shown on Table 4.1. The result showed that there was significantly higher *M. sjostedti* population on the cowpea flowers at Samaru than Wase before insecticide application. After first week of insecticide application there was significant difference ($p<0.05$) between the insecticide treated plots and untreated control, but there was no significant difference among the insecticidal treatments in the two locations. Before the second application of the insecticides, the untreated control had the highest (2.79) ($p<0.05$) thrips population compared with the insecticides treated plots. After the second week of application, the insecticidal treatments drastically reduce ($p<0.05$) thrips population in treated plots compared with the untreated control but there was also no significant difference among the treated plots except for Imidacloprid at 35 g a. i/ha at Samaru with higher($p< 0.05$) insect population (1.38). At the third week of insecticide application, there was no significant difference before spraying among the treated plots except for Imidacloprid (35 g a.i/ha). Higher number of thrips ($p<0.05$) was observed in the untreated plots compared with the treated plots in both locations. After third week of spraying, the thrips population was significantly reduced ($p<0.05$) in insecticides treated plots compared with untreated plots. However, among the treated plots, there were significant differences ($p<0.05$) between Dimethoate (200 g a.i/ha) and Imidacloprid (35 g a. i./ha) only in Samaru compared with other insecticide treated plots in Samaru which were not significantly different and Imidacloprid (35 g a.i/ha) in Wase only (Table 4.1). There were no significant difference among various rates of insecticides at first and second week except for Imidacloprid at 35 g a.i./ha which was significantly higher ($p<0.05$) than at 70 and 105 g a. i. /ha, the same thing at third week in Samaru. In Wase, there was no significant difference at

TABLE 4.1: Effect of insecticides rates on *Megalurothrips sjostedti* population on cowpea flowers at Samaru and Wase in 2012 cropping season

Treatment (g a.i/ha)	Mean Thrips Population per plant											
	SAMARU-ZARIA						WASE-MINJIBIR					
	WEEK1		WEEK2		WEEK3		WEEK1		WEEK2		WEEK3	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Chlorpyrifos 240	8.67^{b}	0.71^{b}	1.22^{bc}	0.71^{c}	0.71^{c}	0.71^{c}	6.67^{bcd}	0.81^{b}	1.33^{bc}	0.71^{c}	0.71^{c}	0.71^{c}
480	4.67^{c}	0.71^{b}	1.05^{bc}	0.71^{c}	0.71^{c}	0.71^{c}	3.67^{d}	0.81^{b}	1.00^{bc}	0.71^{c}	0.71^{c}	0.71^{c}
720	8.67^{b}	0.88^{b}	1.68^{b}	0.71^{c}	0.71^{c}	0.71^{c}	6.67^{bcd}	0.90^{b}	2.00^{b}	0.71^{c}	0.71^{c}	0.71^{c}
Chlorpyrifos plus												
237.5+23.75	6.33^{bc}	0.71^{b}	1.05^{bc}	0.71^{c}	0.71^{c}	0.71^{c}	6.67^{bcd}	0.90^{b}	1.33^{bc}	0.71^{c}	0.71^{c}	0.71^{c}
475+47.5	7.33^{bc}	0.71^{b}	1.05^{bc}	0.71^{c}	0.71^{c}	0.71^{c}	6.67^{bcd}	0.71^{b}	1.33^{bc}	0.71^{c}	0.71^{c}	0.71^{c}
712+71.2	5.67^{bc}	0.71^{b}	0.88^{c}	0.71^{c}	0.71^{c}	0.71^{c}	5.00^{cd}	0.71^{b}	0.67^{bc}	0.71^{c}	0.71^{c}	0.71^{c}
Dimethoate 200	8.33^{b}	0.88^{b}	1.22^{bc}	0.71^{c}	0.71^{c}	1.25^{b}	7.00^{abcd}	0.71^{b}	1.33^{bc}	0.71^{c}	0.71^{c}	0.71^{c}
400	6.67^{bc}	0.71^{b}	1.17^{bc}	0.71^{c}	0.71^{c}	0.71^{c}	6.67^{bcd}	0.71^{b}	1.00^{bc}	0.71^{c}	0.71^{c}	0.71^{c}
600	7.67^{bc}	0.71^{b}	1.05^{bc}	0.71^{c}	0.71^{c}	0.71^{c}	4.57^{cd}	0.81^{b}	1.33^{bc}	0.71^{c}	0.71^{c}	0.71^{c}
Imidacloprid 35	13.67^{a}	0.71^{b}	1.32^{bc}	1.38^{b}	1.18^{b}	1.18^{b}	10.33^{a}	0.71^{b}	0.90^{bc}	0.71^{C}	1.81^{b}	1.12^{b}
70	6.33^{bc}	0.71^{b}	1.05^{bc}	0.71^{c}	0.71^{c}	0.71^{c}	7.00^{abcd}	0.71^{b}	1.33^{bc}	0.71^{c}	0.71^{c}	0.71^{c}
105	9.00^{b}	0.71^{b}	1.05^{bc}	0.71^{c}	0.71^{c}	0.71^{c}	7.00^{abcd}	0.71^{b}	1.67^{bc}	0.71^{c}	0.71^{c}	0.71^{c}
Cyperdicot 250+30	7.33^{bc}	0.71^{b}	1.46^{bc}	0.71^{c}	0.71^{c}	0.71^{c}	7.33^{abc}	0.71^{b}	1.33^{bc}	0.71^{c}	0.71^{c}	0.71^{c}
Control	8.00^{bc}	2.66^{a}	2.74^{a}	2.41^{a}	2.48^{a}	2.34^{a}	9.67^{ab}	6.67^{a}	6.33^{a}	7.00^{a}	6.00^{a}	4.00^{a}
S.E +	1.08	0.09	0.23	0.18	0.13	0.15	1.06	0.25	0.36	0.57	0.29	0.41

Mean followed by different letter (s) in the same column are significantly different at 5% probability level of significance using Duncan multiple Range test (DMRT)

first and second week of application among the various rates but higher *M. sjostedti* population was recorded in plot treated with Imidacloprid at 35 g a.i. /ha compared to other higher rates. All the insecticides at various rates performed significantly better than the untreated control (Table 4.1).The population of thrips was reduced by almost hundred percent. For instance, the plots treated with Chlorpyrifos at 240 g a. i/ha reduced thrips population from 8.67 to 0.71 at Samaru. Similarly the thrips population were reduced from 10.33 to 0.71 after spraying Imidacloprid at 35 g a. i./ha in Wase.

4.2 **Effect of Insecticides Rates on *M*aruca*. vitrata* Population on Cowpea Flowers and Pods at Samaru and Wase in 2012 Cropping Season**

The effect of insecticides and rates on the cowpea pod borer *M. vitrata* population on cowpea after the first week of insecticidal treatments, there was significant difference ($p<0.05$) among the different treatments (Table 4.2) in both locations, but no significant difference among the insecticides in Samaru. In Wase, Cyperdicot (250+30 g a.i/ha), Chlorpyrifos (720 g a.i/ha, Imidacloprid (70 g a.i/ha) and Chlorpyrifos plus (712 g a.i/ha) showed significantly higher ($p<0.05$) number of *M. vitrata* compared with Dimethoate at 200 g a.i/ha, Chlorpyrifos plus at 475+47.5 g a.i/ha and 712+71.2 g a.i./ha, Dimethoate at 400 and 600 g a.i/ha and Imidacloprid at 35 and 105 g a.i/ha. The results of *M. vitrata* populations before spraying also showed that there was significant difference ($p<0.05$) among the insecticidal treated plots and the untreated control in both locations. After the second week application of treatment, there was significant reduction ($p<0.05$) of *M. vitrata* in the insecticidal treated plots compared with untreated control but there was no significant difference among the insecticidal treatments in both Samaru and Wase. After the second week of application, there was a significant reduction ($p<0.05$) of *M. vitrata* in the insecticide treated plots compared to the untreated control, but no significant differences among the insecticidal treatment in Samaru. However, significant differences ($p<0.05$) were recorded among the insecticidal treatments in

TABLE 4.2: Effect of insecticide rates on *M. vitrata* population on cowpea flowers/ pods at Samaru and Wase in 2012 cropping season

Treatment (g a.i/ha)	Mean M. *Vitrata* Population per plant											
	SAMARU-ZARIA						WASE-MINJIBIR					
	WEEK1		WEEK2		WEEK3		WEEK1		WEEK2		WEEK3	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Chlorpyrifos 240	6.33^{bc}	1.33^{b}	1.00^{cd}	0.71^{b}	0.81^{b}	0.71^{b}	6.67^{ab}	1.33^{bc}	1.33^{cd}	0.71^{b}	0.71^{b}	0.71^{b}
480	6.00^{bc}	0.71^{b}	1.24^{bcd}	0.71^{b}	1.24^{b}	0.71^{b}	5.00^{bcd}	1.00^{bcd}	1.00^{d}	0.81^{b}	1.00^{b}	0.71^{b}
720	6.67^{abc}	1.33^{b}	0.90^{cd}	0.71^{b}	0.90^{b}	0.71^{b}	6.67^{ab}	1.67^{b}	1.00^{d}	0.81^{b}	0.67^{b}	0.71^{b}
Chlorpyrifos plus												
237.5+23.75	5.67^{bc}	0.90^{b}	0.90^{cd}	0.71^{b}	0.71^{b}	0.71^{b}	5.33^{abcd}	1.00^{bcd}	0.90^{d}	0.71^{b}	0.81^{b}	0.71^{b}
475+47.5	5.00^{bc}	0.81^{b}	0.90^{cd}	0.71^{b}	0.90^{b}	0.71^{b}	5.00^{bcd}	0.71^{cd}	1.57^{bc}	0.81^{b}	0.90^{b}	0.71^{b}
712+71.2	6.67^{bc}	1.24^{b}	0.90^{cd}	0.81^{b}	0.81^{b}	0.71^{b}	7.00^{a}	0.90^{cd}	0.90^{d}	0.90^{b}	0.81^{b}	0.71^{b}
Dimethoate 200	5.33^{bc}	0.90^{b}	0.71^{d}	0.71^{b}	0.81^{b}	0.71^{b}	5.00^{bcd}	0.57^{d}	0.81^{d}	0.71^{b}	0.90^{b}	0.71^{b}
400	6.00^{bc}	2.00^{b}	1.67^{b}	0.71^{b}	0.71^{b}	0.71^{b}	5.67^{abcd}	0.81^{cd}	0.90^{d}	0.81^{b}	0.90^{b}	0.71^{b}
600	5.33^{bc}	2.00^{b}	1.33^{bc}	0.81^{b}	0.90^{b}	0.71^{b}	5.00^{bcd}	0.81^{cd}	2.00^{b}	0.71^{b}	0.71^{b}	0.71^{b}
Imidacloprid 35	10.00^{a}	0.90^{b}	0.81^{cd}	0.81^{b}	2.14^{b}	0.71^{b}	4.67^{cd}	0.81^{cd}	0.90^{d}	0.71^{b}	0.81^{b}	2.47^{a}
70	6.00^{bc}	0.71^{b}	1.00^{cd}	0.71^{b}	0.81^{b}	0.71^{b}	5.00^{bcd}	1.67^{b}	0.90^{d}	0.71^{b}	0.81^{b}	0.71^{b}
105	5.00^{bc}	0.81^{b}	0.71^{d}	0.71^{b}	1.00^{b}	0.71^{b}	4.33^{cd}	0.81^{cd}	0.90^{d}	0.71^{b}	1.00^{b}	0.71^{b}
Cyperdicot 250+30	3.67^{c}	2.00^{b}	0.90^{cd}	1.00^{b}	0.91^{b}	0.71^{b}	4.00^{d}	1.67^{b}	0.90^{d}	0.81^{b}	0.71^{b}	0.71^{b}
Control	8.00^{ab}	6.67^{a}	7.00^{a}	5.33^{a}	5.67^{a}	5.00^{a}	6.00^{abc}	5.00^{a}	3.33^{a}	3.67^{a}	3.67a	3.67^{a}
S.E +	1.13	1.46	0.18	0.20	0.45	0.15	0.56	0.21	0.18	0.11	0.14	0.49

Mean followed by different letter (s) in the same column are significantly different at 5% probability level of significance using Duncan multiple Range test (DMTR)

Wase. Plots treated with Imidacloprid at 35 g a.i/ha had higher ($p<0.05$) *M. vitrata* than other insecticidal treatment but not significantly different from untreated control in Wase. There was significant lower ($p<0.05$) *M. vitrata* population count at first week in plot treated with Imidacloprid at 70 g a.i. /ha than at 35 and 105 g a.i. /ha only in Wase.

Population of *M. vitrata* reduced drastically with insecticide treatments. For instance, the population of the insects were reduced from 6.67 t0 1.33 in plots treated with Chlorpyrifos at 720 g a.ai./ha in Samaru and from 6.67 1.33 in plots treated with Chlorpyrifos at 240 g a.i./ha in Wase. The same trend followed for the rest of the insecticide treatments in both locations.

4.3 Effect of Insecticides Rates on *Clavigralla tomentosicollis* Population on Cowpea Pod at Samaru and Wase in 2012 Cropping Season

The effect of insecticides rates on *C. tomentosicollis* population on cowpea pod is shown in Table 4.3 which indicated that after the first week of treatment application, there was significant reduction ($p<0.05$) in the population of the insects in the treated plots compared with untreated control which had highest population of *C. tomentosicollis* in both locations during the season. Significant differences ($p<0.05$) were also recorded among the insecticides treated plots. Imidacloprid(105 g a.i/ha). Dimethoate (400 g a.i /ha), Chlorpyrifos plus (237.5+23.75, 475+47.5 and 712+71.2 g a.i/ha), Chlorpyrifos at 480 and 720 g a.i/ha had the lowest insect population compared to other insecticide treated plots. At the second week before spraying, the population count of *C. tomentosicollis* was higher and significantly different ($p<0.05$) in the control than in the insecticide treated plots, except for plots treated with Imidacloprid at 70 g a.i/ha. There were significant differences among the insecticide treated plots, where Imidacloprid (105 g a.i/ha) showed significantly lower ($p<0.05$) *C. tomentosicollis* counts. Chlorpyrifos at 237.5+23.75 g a.i./ha and Dimethoate at 400 g a.i./ha had significantly lower ($p<0.05$) pod sucking bugs counts than Chlorpyrifos at 240 g a.i./ha, Imidacloprid (35 g a.i./ha and 70 g a.i./ha) and Cyperdicot (250+30 g a.i./ha) in Samaru.

TABLE 4.3: Effect of insecticide rates on C. *tomentosicollis* population on cowpea pods at Samaru and Wase in 2012 cropping season

Treatment (g a.i./ha)	Mean *C. tomentosicollis* population per plant											
	SAMARU-ZARIA						WASE-MINJIBIR					
	WEEK1		WEEK2		WEEK3		WEEK1		WEEK2		WEEK3	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Chlorpyrifos 240	8.67^{a}	4.67^{bc}	4.00^{bc}	2.67^{cd}	3.00^{cd}	1.33^{bc}	5.67^{cde}	4.00^{bc}	3.67^{b}	2.33^{bcd}	2.67^{bc}	1.24^{bc}
480	7.67^{abc}	2.00^{efg}	2.66^{cde}	1.67^{defg}	2.00^{cde}	1.33^{bc}	8.33^{a}	1.67^{e}	3.67^{b}	2.67^{bc}	2.00^{cd}	1.00^{bc}
720	8.00^{ab}	2.33^{efg}	3.00^{cde}	2.00^{cdef}	1.67^{de}	1.24^{bc}	7.67^{ab}	1.67^{e}	2.67^{cd}	1.67^{def}	2.00^{cd}	0.90^{bc}
Chlorpyrifos plus												
237.5+23.75	5.67^{cde}	2.00^{efg}	1.67^{ef}	1.33^{efg}	1.00^{e}	0.81^{bc}	8.67^{a}	2.67^{cde}	1.33^{ef}	0.90^{f}	1.33^{d}	0.81^{c}
475+47.5	9.33^{a}	1.67^{fg}	2.33^{def}	1.33^{efg}	2.00^{cde}	1.00^{bc}	7.00^{ab}	2.00^{de}	4.00^{b}	2.67^{bc}	2.00^{cd}	1.00^{bc}
712+71.2	6.00^{bcd}	2.67^{def}	3.33^{cd}	2.33^{cde}	2.33^{cde}	0.90^{bc}	4.67^{def}	2.67^{cde}	2.33^{cde}	1.33^{ef}	1.67^{cd}	1.00^{bc}
Dimethoate 200	4.67^{de}	3.33^{cde}	3.33^{cd}	1.67^{defg}	1.67^{de}	0.90^{bc}	3.67^{f}	1.67^{e}	2.33^{cde}	1.67^{def}	2.00^{cd}	0.90^{bc}
400	3.67^{de}	1.00^{g}	1.67^{ef}	1.00fg	1.33^{de}	0.81^{bc}	4.33^{ef}	2.24^{de}	1.33^{ef}	1.00^{f}	1.67^{cd}	0.90^{bc}
600	3.67^{de}	2.00^{efg}	2.67^{cde}	1.67^{defg}	1.33^{de}	0.81^{bc}	5.67^{cde}	2.67^{cde}	2.33^{cde}	1.00^{f}	1.00^{d}	0.90^{bc}
Imidacloprid 35	4.00^{de}	4.00^{cd}	4.00^{bc}	3.00^{c}	2.33^{cde}	0.90^{bc}	4.00^{ef}	3.33^{bcde}	3.33^{bc}	2.00^{cde}	1.67^{cd}	0.90^{bc}
70	4.00^{de}	2.10^{efg}	7.00^{a}	5.67^{a}	4.67^{ab}	2.24^{bc}	6.36^{bcd}	4.67^{b}	1.67^{def}	1.33^{ef}	2.00^{cd}	1.67^{b}
105	3.33^{e}	1.00^{g}	1.00^{f}	0.90^{g}	1.67^{de}	0.71^{c}	3.00^{f}	2.00^{de}	1.00^{f}	0.90^{f}	0.90^{ssd}	0.81^{c}
Cyperdicot 250+30	8.33^{a}	4.33^{c}	5.00^{b}	4.00^{b}	3.67^{bc}	1.33^{bc}	6.33^{bcd}	3.67^{bcd}	4.00^{b}	3.00^{b}	3.33^{b}	1.67^{b}
Control	8.33^{a}	7.00^{a}	8.00^{a}	6.33^{a}	5.67^{a}	6.33^{a}	8.33^{a}	7.67^{a}	8.33^{a}	6.67^{a}	5.67^{a}	6.67^{a}
S.E +	0.72	0.48	0.48	0.32	0.54	0.98	0.60	0.51	0.62	0.26	0.33	0.25

Means followed by different letter (s) in the same column are significantly different at 5% probability level of significance using Duncan multiple Range test (DMRT)

Similarly, in Wase, significant differences ($p<0.05$) were recorded between the insecticide treated plots and untreated control, on one hand and among insecticide treated plots, on the other. Imidacloprid at 105 g ai./ha had significantly lower ($p<0.05$) *C. tomentosicollis* population than other insecticidal treatments. Imidacloprid (70 g a.i./ha), Dimethoate at 200, 400 and 600 g a.i./ha and Chlorpyrifos plus at 237.5+23.75 g a.i./ha were also significantly different ($p<0.05$) from Chlorpyrifos at 240 and 480 g a.i./ha, Chlorpyrifos plus at 475+47.5 g a i./ha and Cyperdicot (250+30 g a. i./ha) in Wase. After the second week of insecticides application, there was significant difference ($p<0.05$) between insecticide treated plots and untreated control in Samaru and Wase except for Imidacloprid at 70 g a.i./ha in Samaru only while significant differences ($p<0.05$) were also recorded among the insecticide treated plots. Imidacloprid at 105 g a.i./ha, Chlorpyrifos at 480 g a.i./ha, Chlorpyrifos plus at 237.5+23.75 and 475+47.5 g a.i./ha and Dimethoate at 400 g a.i./ha did not show any statistical difference with Cyperdicot (250+30 g a.i./ha) in Samaru. In Wase, there was also significant reduction ($p<0.05$) in *Clavigralla. tomentosicollis* population among the insecticide treated plots. At the third week of insecticide application, there was significant difference ($p<0.05$) in Samaru between the insecticide treated plots and untreated control before spraying except for Imidacloprid at 70 g a.i./ha. and among the insecticide treated plot. After application of insecticides, there was significant reduction ($p<0.05$) of *C. tomentosicollis* population compared with untreated control and among the insecticide treated plots in both locations (Table 4.3). Imidacloprid at 105 g a.i./ha had lowest insect population compared with other treated plots but not significantly different from other insecticide treatments in Samaru but was significantly different ($p<0.05$) from Cyperdicot (250+30 g a.i./ha) and Imidacloprid at 70 g a.i./ha only in Wase. There were also significant differences among the insecticidal treated plots; Chlorprifos plus (237.5+23.75 g a.i./ha), Imidacloprid at 105 g a.i./ha were significantly lower ($p<0.05$) than Cyperdicot (250+30 g a.i./ha) and Imidacloprid at 70 g

a.i./ha among other insecticide treatments. At second week after insecticide application, plots treated with Chlorpyrifos at 480 g a. i. /ha were significantly different ($p<0.05$) from Chlorpyrifos at 720 g a.i. /ha, also significantly lower *C .tomentosicollis* was recorded in Chlorpyrifos plus at 237.5+ 23.75 g a.i. /ha than at 475+47.5 g a.i. /ha. Dimethoate at 400 and 600 g a.i. /ha had lower ($p<0.05$) *C. tomentosicollis* population count than at 200 g a. i. /ha. Imidacloprid at 105 g a.i. /ha had higher ($p<0.05$) *C. tomentosicollis* count than at 35 g a.i. /ha. At third week after application, Imidacloprid at 105 g a. i. /ha showed significantly lower ($p<0.05$) insect population count than at 70 g a.i. /ha.

4. 4: Effect of Insecticide Rates on Flower Abortion of Cowpea due to Insect Pest at Samaru and Wase in 2012 cropping season

The effect of insecticide rates on flower abortion of cowpea is shown on Table 4.4, the result showed that the untreated control plots had significantly higher ($p<0.05$) number of aborted flowers than the insecticide treated plots at both locations. Similarly, among the treated plots, there were significant differences ($p<0.05$); Chlorpyrifos at 240 g a.i./ha and Chlorpyrifos plus at 712+71.2 g a.i./ha had significantly higher ($p<0.05$) number of aborted flowers compared with Dimethoate at 400 g a.i./ha and Imidacloprid at 105 g a.i./ha in Samaru. However, in Wase-Minjibir, Dimethoate at 200 and 400 g a.i./ha had significantly higher ($p<0.05$) number of aborted flowers compared with Dimethoate at 600 g a.i./ha only. All other treated plots have no significant difference among each other.

TABLE 4.4: Effect of insecticide rates on flower abortion of cowpea due to insect pest at Samaru and Wase in 2012 cropping season

Treatment (g a.i./ha)		Aborted flowers/ plant	
		SAMARU	WASE
Chlorpyrifos	240	2.33^{b}	1.67^{bc}
	480	2.00^{bc}	1.67^{bc}
	720	2.00^{bc}	1.67^{bc}
Chlorpyrifos plus			
	237.5+23.75	2.00^{bc}	1.33^{bc}
	475+47.50	1.67^{bc}	1.33^{bc}
	712+71.20	2.33^{b}	1.33^{bc}
Dimethoate	200	1.67^{bc}	2.00^{b}
	400	1.00^{c}	2.00^{b}
	600	1.24^{bc}	0.67^{c}
Imidacloprid	35	1.00^{c}	1.00^{bc}
	70	1.57^{bc}	1.33^{bc}
	105	1.00^{c}	1.33^{bc}
Cyperdicot	250+30	1.67^{bc}	1.67^{bc}
Control		5.33^{a}	4.33^{a}
S.E $\pm$		0.36	0.31

Means followed by different letter (s) in the same column are significantly different at 5% probability level of significance. 237.5; 475; 712 = Chlorpyrifos, 23.75; 47.5; 71.2 = Cypermethrin

4.5: Effect of Insecticide Rates on Pods Production and Damage at Samaru and Wase in 2012 Cropping Season

The effect of insecticides rates on pods production and damage is shown on Figure 1. The results showed that there was significant different ($p<0.05$) between Chlorpyrifos at 240 g a. i. /ha and Dimethoate at 400 g a.i. /ha but no significant difference among other insecticidal treatments and also between the insecticidal treatments and untreated control for number of pod produced in Samaru. In Wase, there was significant difference ($p<0.05$) in pod produced between plots treated with Chlorpyrifos at 240 g a.i./ha, and Chlorpyrifos plus at 475+47.5 g a.i /ha, on one hand between Chlorpyrifos at 240 g a. i. /ha and the untreated control, with Chlorpyrifos at 720 g a. i. /ha producing the highest pod number. On pods damage, Figure 2 showed significant difference ($p< 0.05$) among the insecticide treatments and between insecticide treatments and untreated control, with untreated control gave the highest percentage pod damage in Samaru. Plots treated with Chlorpyrifos at 240 g a. i./ha, 720 g a.i./ha, Cyperdicot (standard) at 250+30 g a. i./ha showed significant difference ($p< 0.05$) from other insecticide treatments except for Chlorpyrifos plus at 475+47.5 g a. i./ha, Dimethoate (200 and 600 g a.i./ha) and Imidacloprid at 105 g a.i./ha in Samaru. Also in Wase, there were significant differences ($p<0.05$) among the insecticidal treatments and between insecticidal treatments and untreated control. Plots treated with Chlorpyrifos at 240 g a. i./ha had significant difference ($p<0.05$) compared to plots treated with Imidacloprid at 70 g a.i./ha, Dimethoate at 600 g a.i./ha, Chlorpyrifos plus (475+47.5 and 712+71.2 g a.i./ha) and Chlorpyrifos at 480 and 720 g a.i./ha but not significantly different from plots treated with Cyperdicot (250+30 g a.i./ha), Imidacloprid (35 and 105 g a.i./ha), Dimethoate at 200 and 400 g a.i./ha. Chlorpyrifos at 240 g a. i./ha had the highest number of pods (186.00) at Samaru while the highest pod number (135.33) was obtained in plots treated with Chlorpyrifos at 720 g a.i./ha at Wase.

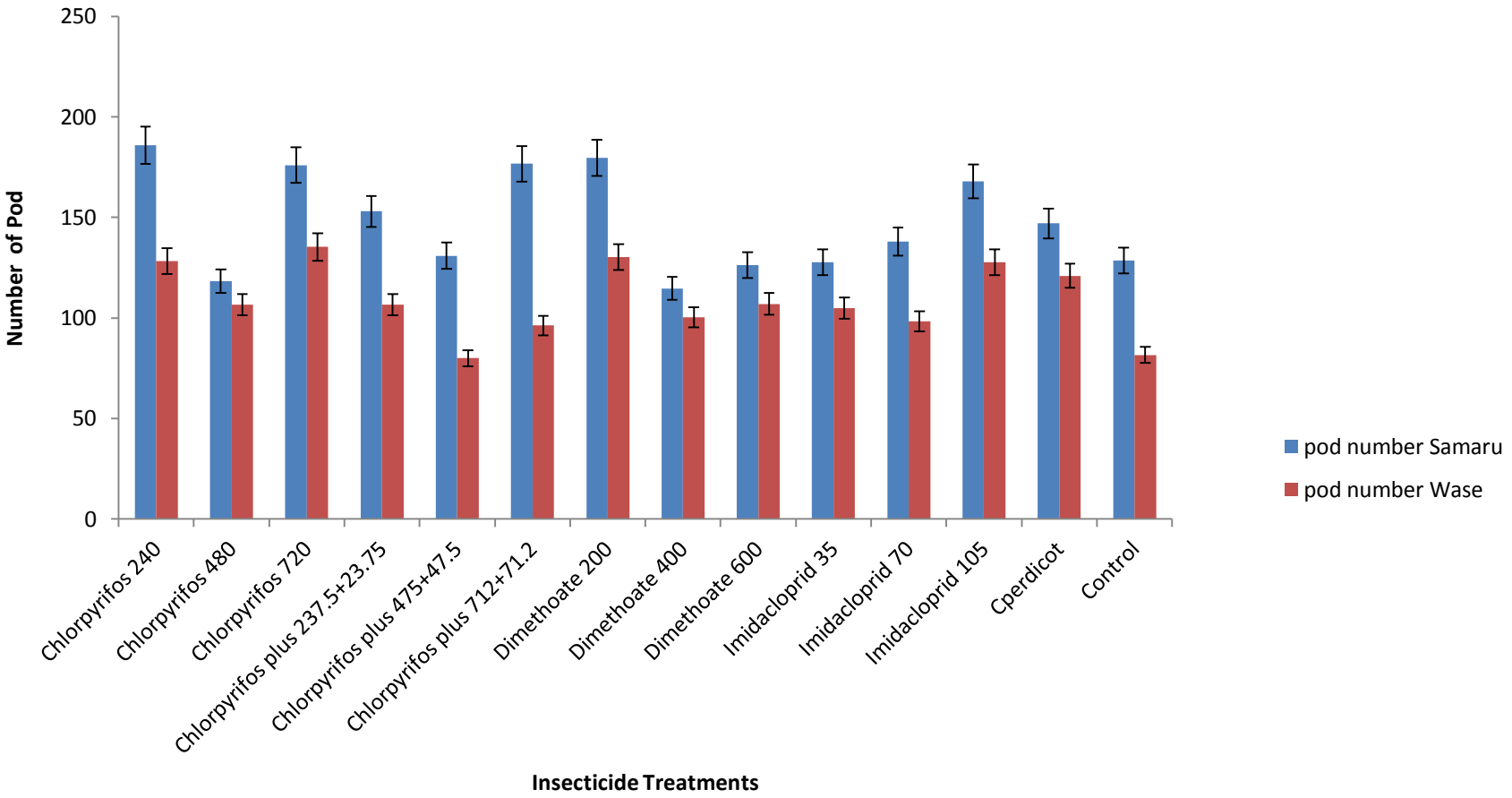


Figure 1: Effect of insecticide rates on number of pods at Samaru and Wase

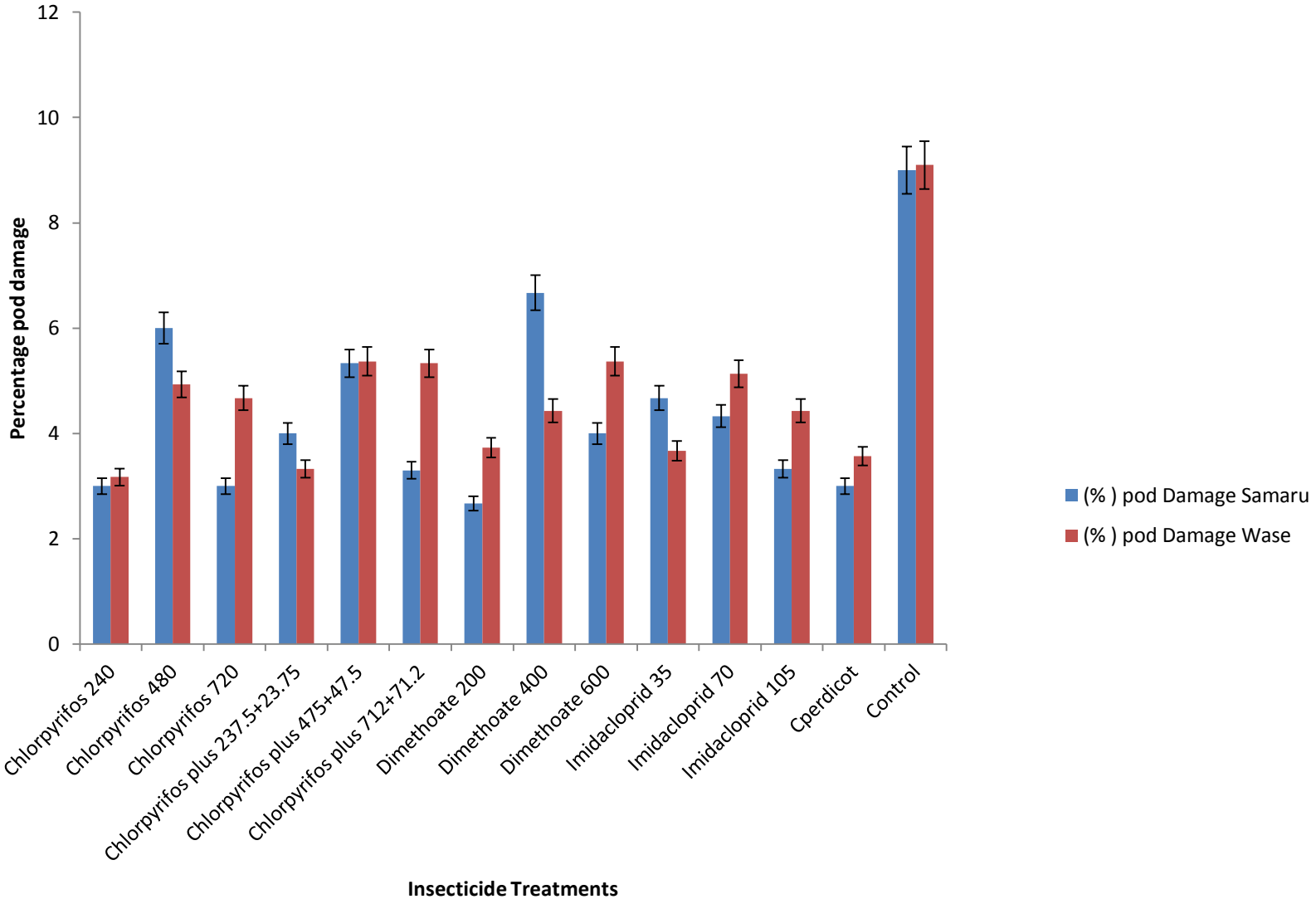


Figure 2: Effect of insecticide rates on pod damaged at Wase and Samaru

Moreover, percentage pod damage was higher ($p<0.05$) in plot treated with Chlorpyrifos at 480 g a.i. /ha than at 240 and 720 g a.i. /ha, Chlorpyrifos plus at 475+47.5 than at 237.5+23.75 and 712+71.2 g a. i. /ha, lower percentage pod damage ($p<0.05$) was recorded in Dimethoate at 200 g a. i. /ha than at 400 and 600 g a. i. /ha as well as in Imidacloprid at 105 g a. i. /ha than at 35 and 70 g a. i. /ha in Samaru. Similarly, in Wase plot treated with Chlorpyrifos at 240 g a. i. /ha had lower ($p<0.05$) pod damage than at 480 and 720 g a. i. /ha. Chlorpyrifos plus at 237.5+ 23.75 had lower pod damage ($p<0.05$) than at 475+47.5 and 712+ 71.2 hg a.i. /ha.

4.6: Effect of Insecticide Rates on Seed Damage Index of Cowpea at Samaru and Wase in 2012 Cropping Season

The effect of insecticide rates on seed damage index of cowpea is shown on Figure 3. The seed damage index was determined by sorting the seed lot from each plot into three categories: Category A consisted of seeds with no feeding damage; category B, seeds with obvious feeding punctures but with mild wrinkles and category C, seeds with holes and/ or seeds that are severely wrinkled and shrunken to small sizes. The result in Samaru showed that in Category A there was no significant difference among the insecticide treatments and between the insecticide treatments and untreated control, although, plots treated with Imidacloprid at 35 g a.i./ha had the highest undamaged seeds (2.37) at Samaru while highest undamaged seeds (2.25) was observed in plots treated with Chlorpyrifos plus at 237.5 +23.75 g a.i./ha in Wase. In category B, there was significant difference ($p< 0.05$) between the insecticide treatments and untreated control except for plots treated with Chlorpyrifos plus at 237.5+ 23.75 and 712+71.2g a.i./ha, Imidacloprid at 35 g a.i./ha and 70 g a.i./ha. plots treated with Chlorpyrifos plus at 237.5 + 23.75 had the highest value (0.44 and 0.41) among the treated plots at Samaru and Wase respectively. In category C, there were no significant difference among the insecticide treatments but there was significant difference ($p<0.05$)

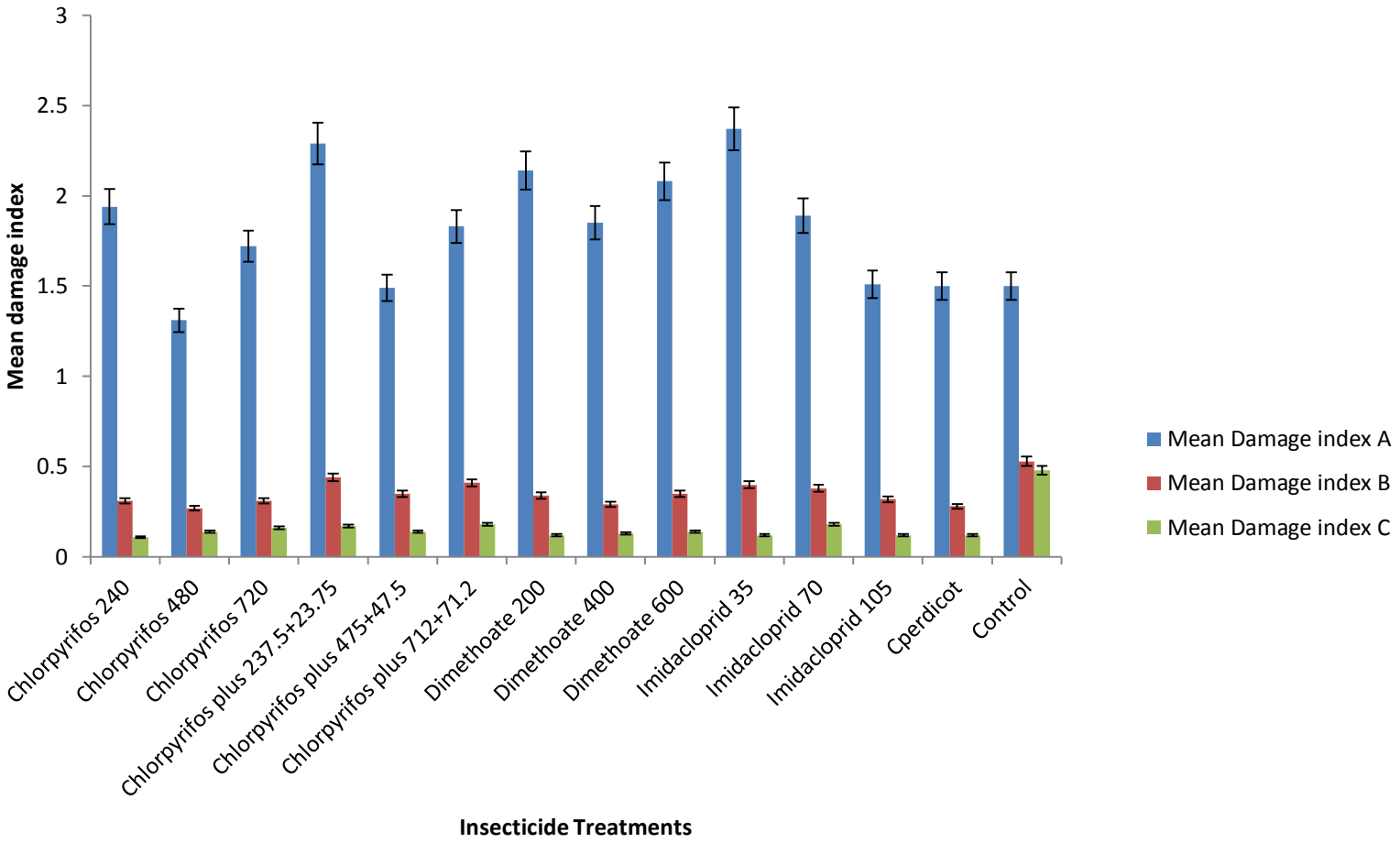


Figure 3:Effect of insecticide rates on seed damage index of cowpea at Samaru

Key: A=Undamaged seeds B= Damaged seeds C= Severely damaged seed

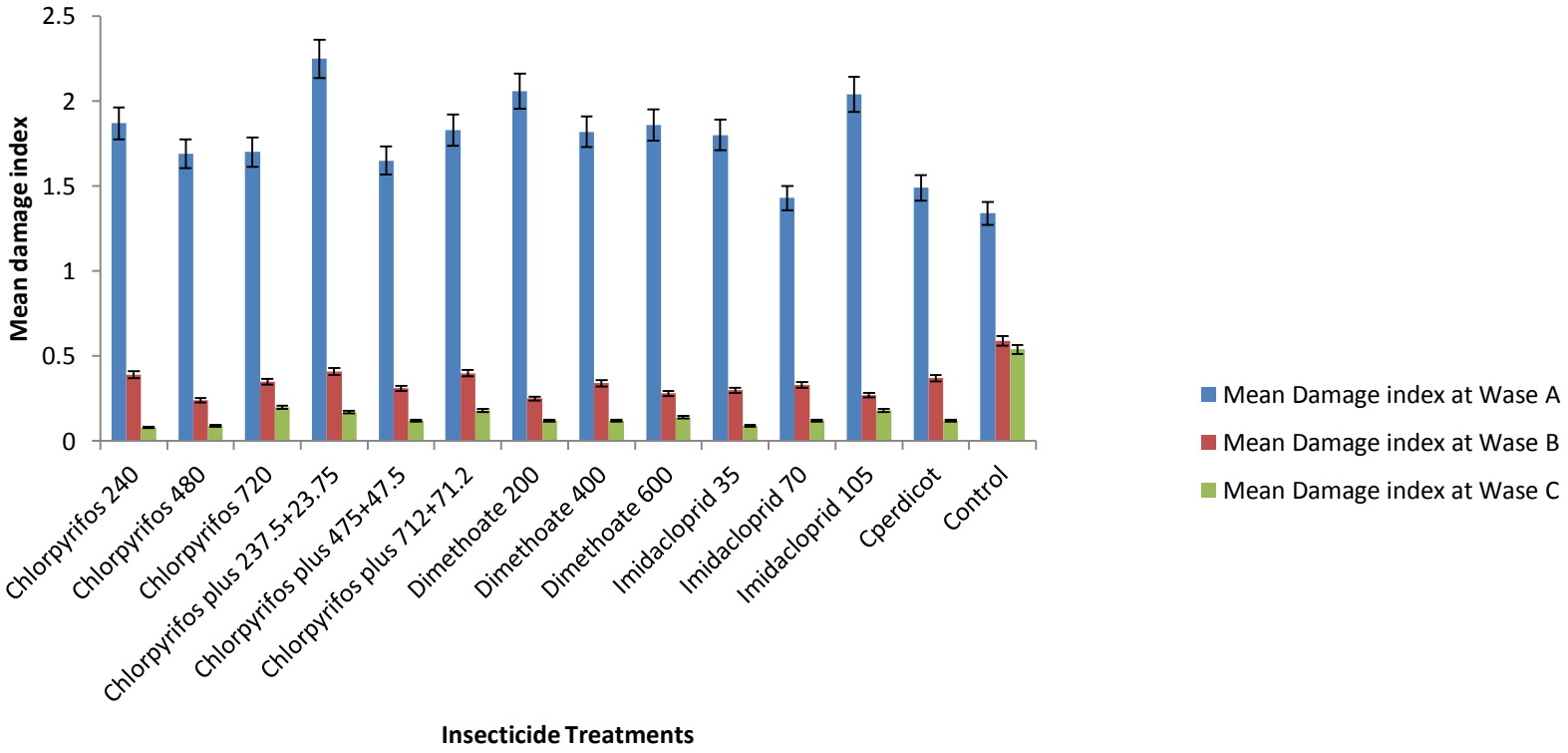


Figure 4: Effect of insecticide rates on seed damage index of cowpea at Wase

between insecticide treatments and untreated control at Samaru. The lowest damaged index were obtained in plots treated with Chlorpyrifos at 240 g a.i./ha in both locations. However at Wase, Figure 4, there were significant differences ($p<0.05$) among the insecticide treatments in category A as plots treated with Chlorpyrifos plus at 237.5+23.75 g a.i./ha were significantly different from plots treated with Imidacloprid at 70 g a.i./ha and Cyperdicot (standard) at 250+30 g a.i./ha. Similarly, plot treated with Chlorpyrifos plus at 237.5+ 23.75 g a.i./ha, Dimethoate at 200 g a.i./ha were significantly different ($p<0.05$) from untreated control. At the same Wase location, Category B showed significant difference ($p<0.05$) between insecticide treatments and untreated control but no significant difference was recorded among the insecticide treatments. The same trend was followed in category C, where there was no significant differences among the insecticide treated plots but untreated control had significantly higher ($p<0.05$) seed damage index in the untreated control than in the insecticide treated plots.

4.7: Effect of Insecticide Rates on Yield of Cowpea at Samaru and Wase in 2012 Cropping Season

Figure 5 shows the effect of insecticides rates on yield of cowpea at Samaru and Wase. The result showed a significant difference ($p<0.05$) in the yield of cowpea among the insecticidal treated plots in Samaru. Plots treated with Chlorpyrifos at 240 g a i/ha had higher ($p<0.05$) grain yield than plots treated with Chlorpyrifos plus at 237.5+23.75 and 712+71.2 g a i/ha, Dimethoate at 200 and 400 g a i/ha, Imidacloprid at 35 and 105 g a i/ha and untreated control. Similarly, in Wase, Chlorpyrifos at 240 g a i/ha had higher ($p<0.05$) grain yield than plots treated with Dimethoate at 400 and 600 g a i/ha, Imidacloprid at 35 and 105 g a.i./ha and control recorded the lowest grain yield. Yield of cowpea was higher in most of the insecticide treated plots at Samaru than at Wase.

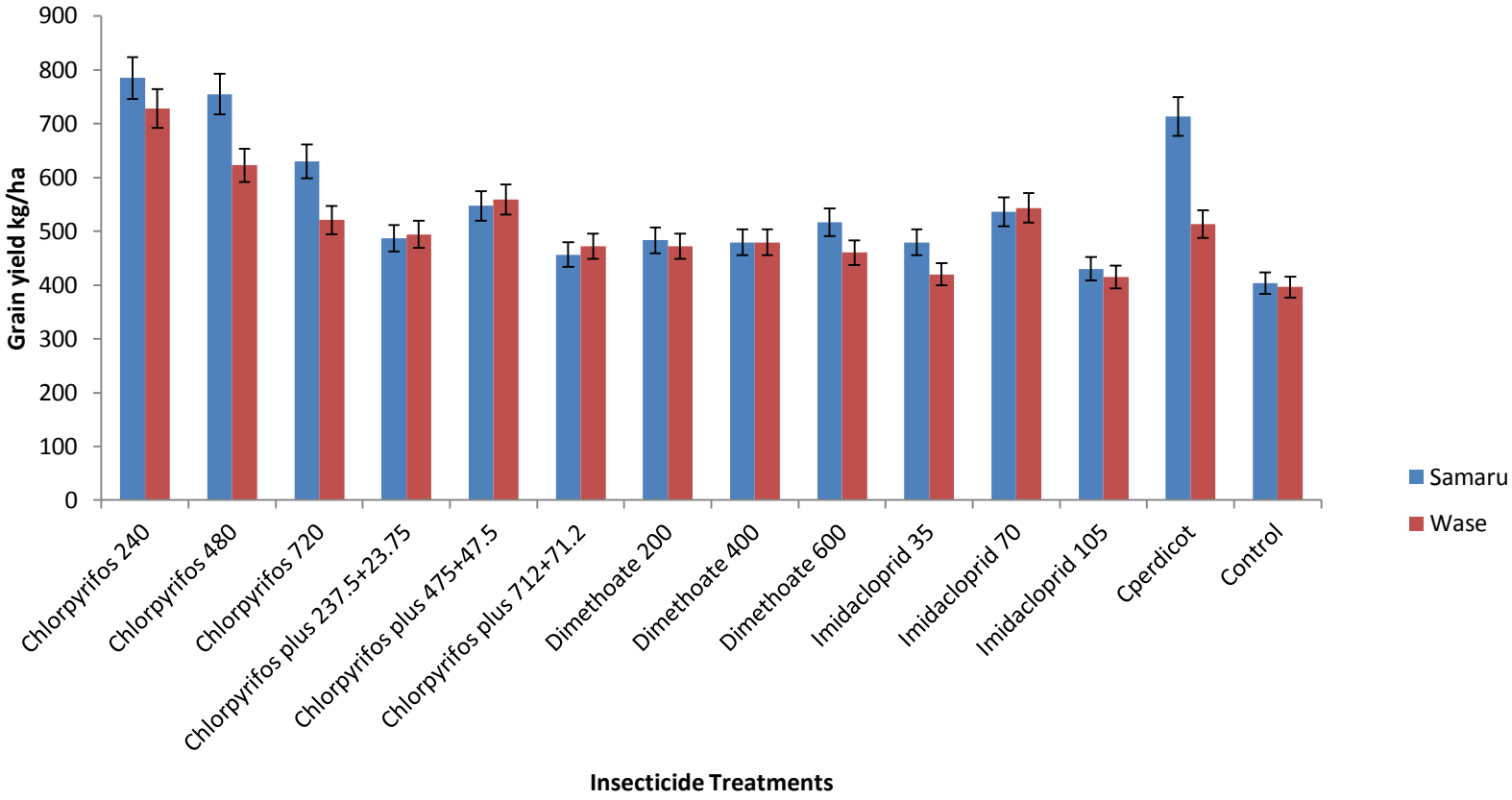


Figure 5: Effect of insecticide rates on yield of cowpea at Samaru and Wase

CHAPTER FIVE

5.0 DISCUSSION

Cowpea is known to shed up to 80 % of its flowers due to natural causes such as insect pests during development, and this could negatively affect pod formation (Ojehomon, 1968; Dzemo *et al.*, 2010). Pod set could also be affected by other factors such as growing conditions, soil fertility, moisture content and flower abortion/damage by insect pests. Pod and seed damage as observed in this study, were clearly related to the effects of insect infestation. Results from this study also showed the importance of insect pests as limiting factors to increased and sustainable cowpea production. Applications of different insecticides at various rates on cowpea plants showed that *Megalurothrips sjostedti, Maruca vitrata* and pod sucking bug (*Clavigralla tomentosicollis*) control are essential to guarantee sustainable production of the crop. *M sjostedti* is an important pest of the reproductive structures (flowers) of cowpea, with early feeding leading to flower bud and flower shedding, consequently poor pod setting (Singh & Taylor, 1978; Tamo *et al*., 1993). There is therefore usually the need for farmers to apply insecticides at appropriate rate during flowering to minimise such damage. Protecting the crop with insecticide application increased yields several fold (Tanzubil, 2000). In nature, peak populations of pod pests do not occur at early flowering unless the crop is planted late. Therefore, high levels of pod pests could lead to total loss of the crop, especially where there is little or no rain to trigger new flushes or re-growth. The study had shown that the four synthetic insecticide formulations (Chlorpyrifos, Chlorpyrifos plus, Dimethoate and Imidacloprid) were effective on *M. sjostedti* and pod borer (*Maruca vitrata*) population control since the unprotected plots had higher population counts and damage than insecticide protected plots. This result concurred with reports that

application of insecticides generally reduces cowpea pest infestation and markedly increases crop yields (Karungi *et al*., 2000; Ebenezer, 2010). The result of this study on pod borer revealed that two spray applications of these insecticides would not totally take care of the insects like the thrips, it was the third applications that actually reduced the population of the insects. The first application of insecticide treatments at onset of flowers reduced the insects (*Maruca. vitrata*) population and the second application further reduced the insect population which implies that application of these insecticides thrice could produce good yield of cowpea crop as four and five spray regimes as reported by Dina (1979). This is of critical importance from the point of view of lower costs, environmental hazards and the effects of spray frequencies and intensity on non-target organisms. The insecticide treatments application at flower budding controls thrips infestation and ensures optimal flowering. The second spray protects the pods from damage by pod borer and pod sucking bugs. Drastic reduction in population of *M. vitrata* was recorded which proved the effectiveness of the insecticide treatments as reported also by Ebenezer (2010).

The second and third applications could sustain the reduction of the insect's (pod borers) population couple with appropriate rates. *Clavigralla tomentosicollis* population shot up at second week of treatment because that was when the crop (cowpea) started podding. Imidacloprid at 70 g a.i./ha was less effective because high insects population count was recorded. Chlorpyrifos plus at 237.5+23.75 g a. i. /ha maintained lowest C. *tomentosicollis* population count in both locations. The drastic reduction in the population of insects under studied resulted from the killing of insects attributed to the knock down action of the insecticides, their active ingredients and mode of actions, as all except Chlorpyrifos plus who has both systemic and contact (Chlorpyrifos and Cypermethrin) are systemic which are

absorbed by plant tissues and kill the sucking insects that feed on the crop (www.hedydchem. com., 2010).

On aborted flowers, plots treated with Chlorpyrifos at 240 g a. i./ha and Chlorpyrifos plus at 712+71.2 g a. i./ha had higher number of aborted flowers than other treatments in Samaru, but in Wase Dimethoate at 200 g a. i./ha showed higher aborted flowers than other treatments, although no significant difference was noticed. The different insecticides at various concentrations were very effective. The percentage pod damage to number of pods obtained was very minimal. Chlorpyrifos at 240 and Dimethoate at 200g a. i. /ha recorded higher number of pods at Samaru while higher number of pods were obtained in Chlorpyrifos (720g a. i./ha) and Dimethoate(200g a. i./ha) at Wase compared to other treatments.

Most of the insecticide treated plots had higher number of pods than the untreated control. Similarly, all the insecticide treated plots at Samaru produced higher number of pods than insecticide treated plots at Wase. The lowest number of pods (114.67) were obtained in plots treated with Dimethoate at 400g a.i./ha at Samaru while the lowest number of pods (80.00) was gotten from plots treated with Chlorpyrifos plus at 475+47.5 g a.i./ha at Wase. On pod damage, all the insecticide treated plots had lower pod damage than untreated plots. The lowest pod damaged (2.67) was observed in plots treated with Dimethoate at 200 g a.i./ha in Samaru while the lowest pod damage (3.17) was obtained in plots treated with Chlorpyrifos at 240 g a.i./ha at Wase. Untreated plots had highest pod damage (9.00 and 9.10) in both locations respectively. Pod damage was higher (6.67) compared to other insecticide treated plots at Samaru in plots treated with Dimethoate at 400 g a.i./ha while in Wase, plots treated with chlorpyrifos plus at 475 + 47.5 g a.i./ha and Dimethoate at 600 g a.i./ha had the highest pod damage.

Furthermore, results from aborted flowers and damaged pods (damage assessment) indicated that the insecticides spray treatments influenced number of pods and grain yields. For example there was decrease in aborted flowers and damaged pods compared to untreated control plots particularly in Wase. Results from this study then indicate that properly timed insecticide application remains an important strategy for suppressing cowpea insect pests on the field if properly managed. The results of the seed damage index also confirmed the effectiveness of the four new insecticides formulations at different rates in reducing the infestations of cowpea pests in both locations because highest proportion of seeds were recorded in category A (seeds with no feeding damage) compared to seeds with obvious feeding punctures but with mild wrinkles and the lowest infestation of seeds were obtained in category C (seeds with holes and/ or seeds that are severely wrinkled and shrunken to small sizes in all insecticide treatments). Untreated plots had the lowest in category A and highest in category B and C.

Most of the yield related components such as number of pods per plot, pod damage, pod evaluation index and wrinkled seeds from different treatments had values which suggested that the insecticides differences both in terms of type and concentration had effects on yield output. Highest infestation and lowest yield were recorded in untreated plots, although number of pod per plant and grain yield per hectare were low in Wase, the relatively low yield was due to low amount of rainfall and other environmental conditions such as humidity, temperature, sunshine and soil type of the area compared to Samaru. The yield obtained supports earlier reports by Jackai (1997) that, cowpea yield is increased when treated with synthetic chemicals and that unprotected plots usually have the lowest yields. The results also suggested that Samaru -Zaria ecological zone favoured cowpea production than Wase –Minjibir (appendix I). It is concluded therefore, that insect pest infestations at

flowering and podding stages are significant limiting factors to increased and sustainable cowpea grain production in Samaru and Wase.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

Trials were carried out in two locations, Samaru (Zaria) and Wase (Minjibir) to evaluate the four insecticide formulations (Chlorpyrifos, Chlorpyrifos plus, Dimethoate and Imidacloprid) at three levels for the management of cowpea field pests in 2012 cropping season. The results showed that all the insecticides and dosages were effective in reducing the infestation of the major insect pests at flowering and podding stages as well as increasing the grain yields in both locations compared to untreated control. The four insecticides did not differ significantly from the standard check (Cyperdicot), particularly in terms of yield, seed damage index and number of pod and pod damage, and flower abortion. The various levels (concentrations) 0.5, 1.0 and 1.5 l/ha were similar in their performance in reducing insects' number of abundance and damage thereby reducing number of aborted flowers and increased yield, but lower levels seemed to perform better than higher levels especially with respect to number of pods and grain yield. Therefore, the concentration to be used should not exceed 0 .5l/ha so as to minimise cost and reduce risk of environmental pollution among others.

6.2 Conclusion

This study showed that the four different insecticide formulations (Chlorpyrifos, Chlorpyrifos plus, Imidacloprid and Dimethoate) effectively reduced the infestation of *Megalurothrips sjostedti, Maruca vitrata,* and *Clavigralla tomentosicollis* on cowpea in both locations. There were significant differences in the three concentrations from 0.5, 1.0 and 1.5l/ha. Application of Imidacloprid at 105 g a. i./ha (1.5 l/ha) was most effective for the control of *C. tomentosicollis* at both locations, while Chlorpyrifos at 240 (0.5 l/ha) and 720 g a.i./ha (1.5l/ha) had the highest number of pods produced at Samaru and Wase respectively.

Chlorpyrifos at 240 g a. i. /ha gave the highest grain yield (784.91 and 728.30) in both Samaru and Wase locations respectively. Hence, the lower concentrations (0.5 and 1.0 l/ha) of all the insecticides would be adequate to effectively manage the flowering and post flowering insect pests of cowpea such as *Megalurothrips sjostedti*, *Maruca vitrata* and *Clavigralla tomentosicollis* and increase productivity.

6.3 Recommendations

The four insecticide formulations (Chlorpyrifos, Chlorpyrifos plus, Dimethoate and Imidacloprid) could be used at the application rate of 0.5 l/ha - 1.0 l/ha to effectively reduce infestation of insect pests of cowpea and increase grain yield. They could also be used complementarily with other pest control options to significantly improve cowpea grain yields, thereby generating income to poor farmers in rural areas. Chlorpyrifos at 240 g a.i. /ha could be used for optimum grain yield of cowpea.

REFERENCES

African Agricultural Technology Foundation (AATF), (2012). Maruca- Resistant Cowpea Frequently asked question. Nairobi, Kenya www.aatf-africa.org accessed July,2013.

Abalu, G.O.I. (1976). A Note on Crop Mixture under Indigenous conditions. *Journal of Developmental Studies* 12: 212-220

Adejumo, T. O. (1997). Identification, incidence, severity and methods of control of the causal organism of false smut disease of cowpea *Vigna unguiculata* L. Walp. *Ph.D.Thesis*, University of Ibadan, Ibadan, Nigeria. 236pp

Agyen-Sampong, M. (1978). Pests of cowpea and their control in Ghana. In S R Singh, H F van Emden and T A Taylor (eds). , Pests of grain legumes 63pp.

Alabi, O.Y., Odebiyi, J.A. and Jackai, L.E.N. (2003). Field evaluation of cowpea cultivars (*Vigna unguiculata* (L) Walp.) for resistance to flower bud thrips (*Megalurothrips sjostedti* Trybom) Thysanoptera: Thripidae) *International Journal of Pest Management.* 49 (4), 287-291.

Alao, F. O. and Adebayo, T. A. (2011). Comparative Toxicity of Botanical and Synthetic Insecticides Against Major Field Insect Pests of Cowpea (*Vigna unguiculata* (L) Walp). *Journal of Natural Production and Plant Resources* 1(3): 86-95

Alghali, A.M. (1993). Intercropping as a component of insect pest management for grain cowpea *Vigna unguiculata* (L.) Walp production in Nigeria. *Insect Science and its Application* I4 (1):49–53.

Aliyu, M., Yusuf, S. R. and Abdullahi, J. (2011). Evaluation of kane plant Extracts (*Anogeissus leiocarpus* Guill and Parr.) for the control of three post Flowering Insect Pests of Cowpea (*Vigna unguiculata* (L.) Walp) in Bauchi: *Savannah Journal of Agriculture* 6 (1) 1-10.

Anthonio, Q.B.O. (1979). *General Agriculture for West Africa*, London, George Allen and Unwin 103pp. .

Arnason, J.T., B.J.R., Philogen and P., Morand. (1989). Lale, N.E.S., 1995. An over view of the use of plant Insecticides of Plant Origin. ACS, *Symposium Series* No. 387, American Chemical Society Washington, D.C. USA, pp: 213.

Asiwe, J.A.N. (2007). Baseline survey on the production, constraints and utilization of cowpea in South Africa: Implications to cowpea improvement. *Proceedings International Conference on indigenous vegetables and legumes*: Prospects for fighting poverty, hunger and malnutrition. Organized by IPGRI, ICRISAT and ISHS, 12-15 December 2006 in Hyderabad, India. pp. 621-622.

Asiwe JAN; Belane D and Dakora F.D. (2009). Evaluation of cowpea breeding lines for nitrogen fixation at ARC-Grain Crops Institute,Potchefstroom, South Africa. *Abstract*, the 16th *InternationalCongress on Biological Nitrogen Fixation*, Montana,

USA, pp. 14 -19.

Bahlai, C.A., Xue Y. and McCreary, C.M. (2010) Choosing Organic Pesticides over Synthetic Pesticides May Not Effectively Mitigate Environmental Risk in Soybeans. *PLoS ONE* 5(6): e11250.

Baker, E.F.I. (1978). Mixed Cropping in Northern Nigeria 1. Cereal and Legumes, *Experimental Agriculture* 14: 293-298.

Blade, S.F, Shetty, S.V.R., Terao, T., Singh, B.B. (1997). Recent developments in cowpea cropping systems research. In: Singh BB, Mohan Raj DR, Dashiell KE, Jackai LEN (eds.) *Advance. Cowpea Research*. Copub. of IITA and JIRCAS., IITA, Ibadan, Nigeria. 89- 97p.

Boller, E., Hani, F., Poehling Editors. (2004). *Ecological Infrastructures*: Ideal book on functional biodiversity at the farm level, l.IOBC, OILB, Mattenbach AG, Winterther, Switzerland. 2: 291 –295.

Booker, R.H. (1965). Pests of Cowpea & their Control in northern Nigeria. *Bulletin of Entomological Research*, 55, 663-672

Bugaje S.M., Kuta D.D, Magashi A.F and Ubale A.S. (2007). Food security in Nigeria. Paper presented at the conference of young agricultural specialists, organized by *SELHOZ (A Nigerian Non Governmental Organization Based in Russia).* Held on 22nd July – 5th August at The People's Friendship University, Russia, Moscow.

CABI. Cr*op Protection Compendium* (2000). *Global module,* 2nd edition CABI publishing, Wallingford,UK. 76pp.

Caswell. G.H. and Raheja A.K. (1977). Preminary trials using synthetic pyrethroids to control pests of cotton and cowpea. *Samaru Agricultural Newsletter* 19,46-49.

Chemeda, F.(1997). Effect of planting pattern, relative planting date and intra-row spacing on a haricots bean\maize intercrop. *African Crop Science Journal* 5 (1) 15 – 22.

Cobley, S.L. (1956). *Introduction to the Botany of Tropical Crops*. Longman Group Limited. Essex, England. Pp: 79 – 98.

Dent, D. (1991). *Insect pest management.S*econd edition. Redwood press limited Witshire, U.K. 603pp

Dina, S.O. and Medaigedu J. A. (1976). Field tests with insecticides to control *Maruca vitrata* and other pod boring insects of cowpea in southern Nigeria. *Journal of Economic Entomology* 69,173-177

Dina, S.O. (1979). Synthetic pyrethroids for the control of cowpea insect pests. *Journal of Agricultural science* ,Cambridge **93**, 735-747.

Dina, S.O. (1982). Interactions between rate, spray interval and number of applications of the synthetic pyrethroid Decis in cowpea (*Vigna unguiculata*) pest control. *Journal of Agricultural science,* Cambridge 99, 471- 478.

Dzemo,W.D., Niba, A.S. and Asiwe, J.A.N. (2010). Effect of insecticide spray application on insect pest infestation and yield of cowpea [*Vigna unguiculata* (L) Walp.] in the Transkei, South Africa. *African Journal of Biotechnology* 9 (11)1673-1679.

Ebenezer, O.O. (2010). Management of major field pests and yield of cowpea (*Vigna unguiculata* (L) Walp) under calendar and monitored application of synthetic chemicals in Asaba, Southern Nigeria. *African Journal of General Agriculture.* 6 (3)177-186.

Ebong, U.U. (1965). Cowpea production in Nigeria *Memorandum* No.8, pp.9 Federal Department of Agricultural Research, Ibadan.

Echendu, T.N.C. (1991). Ginger, cashew and neem as surface protectants of cowpea against infestation and damage by *Callosobruchus maculatus* (Fab.) *Tropic Science*, 31: 209-211.

Elliot, M. (1976). Properties and applications of pyrethroids *Environmental Health Perspective* 14, 3-13.

Emechebe, A.M. and McDonald D. (1979). Seed-borne pathogenic fungi and bacteria of cowpea in Northern Nigeria. PANS 25 (4): 401-404.

Emechebe, A. M. and Singh, B. B. (1997). Technology options and research challenges to increase cowpea production under striga and draught stress in Semi-arid Africa. Pages 207 – 217. In: Technology Options for sustainable Agriculture in sub-sahara Africa, T. Benzuneh, A.M. Emechebe, J. Sedgo and M. Ouedrago (eds.). Published by *SAFRAGRAD*, Ouagadougou, Burkina Faso.

Emosairue, S. O. and Ubana, U. B. (1998). Field evaluation of neem for the control of some cowpea insect pests in Southern Nigeria. *Global Journal of Pure and Applied Science*. 4: 237-241

Faris, D.G. (1965). The origin and evolution of cultivated farms of vigna sinensis. *Canadian Journal of Genetics and Cytology.* 7: 433-452

Fatokun, C.A. (2000). Breeding cowpea for resistance to insect pests: attempted crosses between cowpea and *Vigna vexillata*. In: Fatokun CA, Tarawali SA, Singh BB, Kormawa PM, Tamo M, Eds. Challenges and opportunities for enhancing sustainable cowpea production. Ibadan-Nigeria: IITA 2000: 52-61

Food and Agricultural Organisation (FAO).(2008). Agricultural production status worldwide. http:www.fao.org/faostat accessed July, 2012

Food and Agricultural Organisation (FAO). (2009). Agricultural production status world. http:www.fao.org/faostat accessed September, 2012

Food and Agricultural Organisation (FAO). STAT. (2011). Bulletin of Tropical Legumes. http//.www.Icrisat.org/tropical legumes 11 accessed March, 2013

Gilman, D.F, McPherson, R.M, Newsom, L.D, Herzog D.C, Williams, C. (1982). Resistance in Soybeans to the Southern Green Stink Bug. *Crop Science*. 22: 573-576

Hector V. and Jody S. (2002). *Sustainable Agriculture, Green manure crops*: Cowpea 3pp.

International Institute for Tropical Agriculture (IITA). (1974). *Research Highlights*, Ibadan, Nigeria, IITA 143pp.

International Institute for Tropical Agriculture (IITA). (1997). Cowpea Cereal systems improvement in the dry savannas. IITA *Annual report*. Project11, Ibadan Nigeria.63pp.

International Institute for Tropical Agriculture (IITA). (2002). Improving and intensifying cereal legume systems in the moist and dry savannas of West and Central Africa. *Project F.* Ibadan Nigeria. 313 pp.

Institute for Agricultural Research (IAR). (2012). Metoreological Report of Samaru and Wase for 2012 cropping season.

Isman, M.B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annual Review of Entomology*. 51: 45-66.

Jackai, L.E.N. (1985). Cowpea Entomology Research at IITA and its impact on food production in the tropics. *Nigerian Journal of Entomology.*6, 87-97.

Jackai, L.E.N. (1993). The use of neem in controlling cowpea pests. *IITA Research* No. 7, 5-11pp.

Jackai, L.E.N. and Daoust R.A. (1986). Insect pests of cowpea. *Annual Review of Entomology* 31**:** 9 – 119.

Jackai, L.E.N. and C.B., Adalla (1997). Pest Management Practices in Cowpea: A review. Pages 240-258 *in* Advances in Cowpea Research, edited by B. B. Singh, D. R. Mohan, Raj, K. E. Dashiell, and L. E. N. Jackai. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.

Jackai, L.E.N. and Singh, S.R. (1988). Screening Techniques for Host Plant Resistance to Insect Pests of cowpea. *Tropical Grain Legume Bulletin* 35: 2-18

Jackai L.E.N., Goudou C., Asiwe, J.A.N., Tayo B.O. (2001). Integrated control of the cowpea aphid using seed dressing and varietal resistance. *Samaru Journal of Agricultural Research*. 17: 13-23.

Jeranyama, P., O.B. Hesterman and C.C Sheaffer. (1998). Planting Date Effect on Dry Matter and Nitrogen Accumulation when clear – seeded or intercropped with corn. *Agronomy Journal*. 90: 601 – 606.

Kabaru, J.M. and Gichia, L. (2001). Management of Legumes in the Tropics. *African Journal of Science and Technology (AJST)*` 2:44–47

Karungi, J., Adipala, E., Ogenga-latigo, M.W., Kyamanywa, S. and Oyobo, N. (2000) Pest Management in cowpea. Part 1 Influence of planting time and plant density on cowpea field pests infestation in eastern Uganda. *Crop Protection*. 19: 231-136.

Kumwenda, J.D.T, S.R. Waddigton, S.S. Snapp, R.B. Jones and M.J. Blackie. (1996). Soil Fertility Management Research for Maize Cropping Systems of small-holders in Southern Africa. A review NRG Paper 96 – 102, CIMMYT, Mexico, DF.s

Lale, N.E.S. (1995). An overview of the use of plant Insecticides of Plant Origin. ACS, *Symposium Series* No. 387 American Chemical Society Washington, D.C. USA, pp: 213.

Malgwi A.M, Onu J.I. (2004). Insect Pests of Cowpea and Groundnut in Girei Local Government Area of Adamawa State. *Nigerian. Journal of Entomology* 21:137-151.

Martin, J.H. and Leonard, W.H. (1956). *Principles of field crops production.* London, U.K. collier MacMillan pp: 186.

McDavid, A. and R.S.J., Lesseps. (1995). *Proceedings from the first National Symposium* Lutsaka, Zambia, 135 – 147.

Merck, N.J. (1996). *The Merck Index*, 12th ed., Merck Research Laboratories Whitehouse station10330

Modern Insecticide Limited. (2012). *Manufacturer instruction* 4pp

Mongo, C.M. (1996). Biology and epidemiology of *Sphaceloma* sp. The pathogen of cowpea scab. Department of Crop Protection, Ahmadu Bello University Zaria, *Ph. D Thesis*. (unpublished) 86p

Mordue, A.J. and A. Blackwell. (1993). Azadirachtin: An update. *Journal of Insect Physiology*, 39: 903-924.

Mortimore, M J; Singh, B.B., Harris, F., and Blade, S.F. (1997). *Cowpea in international cropping system.* Pages 99 – 113. D.R. Mohar Raj, K.E. Dashiell and L.E.N. Jackai. Co-publication of international institute of Tropical Agriculture IITA and Japan International Research centre for Agricultural Science (JIRCAS), IITA, Ibadan, Nigeria.

NAERLS and PCU. (2004). Field Situation Assessment of Wet Season Agricultural Production in Nigeria. *Crop Protection* 22: 57 – 64.

NAERLS and NFRA. (2009). Annual Agricultural Performance Survey Report of Nigeria National Research Council. 2000. *The Future Role of Pesticides in US Agriculture* Washington, DC: Natl. Acad. Press. 301pp.

Nelson,S.S.; T.A. Ohlev, and C.A. Mitchel, (1997). Cowpea leaves for Consumption, Production and Utilization and Nutrient Composition. In: B.B.Sigh, D.R. Mashan Ray, K.E. Dashiell And Len Jackai (Eds) *Advances in Cowpea Research* Devon Science Publishing 326- 332.pp.

Ng, N.O and L.M. Monti. (1990). *Cowpea Genetic Resources*. International Institute of Tropical Agriculture IITA. Amarin Printing Group Co. Ltd. 200pp.

Norman, D.W. (1972). An Economic Survey of Three Villages in Zaria Province 2. Input-Output Study Vol. 1 *Samaru Miscellaneous Paper* No. 37. IAR, A.B.U Zaria.

Nwanze, K.F. (1991). Components for the management of two insect pests of pearl millet in Sahelian West Africa. *Insect Science Application.* 12: 673-678.

Ofuya, T.I. and O.E. Fayape. (1999). Evaluation of cashew nut shell liquid and powder for the control of *Callosobruchus maculatus* (Fabricus) (Coleoptera: Bruchidae) Infesting Stored Seeds of Cowpea, *Vigna unguiculata* (L.) Walpers. *Applied Tropical Agriculture,* 4: 72- 77.

Ojehomon, O.O. (1968). Flowering, fruit production and abscission in cowpea (*Vigna unguiculata* (L.) Walp. *Journal of West African Science Association.* 13: 227-234.

Ojo. I.O. (1996). On the effectiveness of insecticides of biological origin. *Proceeding of 25th Annual Conference.* Entomological Society of Nigeria 30:25-31

Okigbo, B.N and Greenland, D. J. (1976). *Intercropping System in Tropical Africa.* Madison, Wisconsin, American Society of Agronomy 6:43- 47pp.

Okrikata, E. and Anaso, C.E. (2008). Influence of some inert diluents of neem kernel powder on protection of sorghum against pink stalk borer (*Sesamia calamistis*, Homps) in Nigerian Sudan savannah. *Journal of Plant Protection Research*. 48(2): 161- 168.

Olatunde, J.A. Odebiyi, Chiang, H.S. and Jackai, L.E.N. (1991) Identification of sources of resistance in cowpea, *Vigna unguiculata* L. Walp. to *Clavigralla tomentosicollis*. Stal. (Hemipera: Coreidae) *Insect Science Application* 12 (4), 455-461

Olotuah, O.F. and Ofuya, T.I. (2010). Comparative Protection of Cowpea, *Vigna unguiculata* (L.) Walp Against Field Insect Pests Using Cashew Nut Shell Liquid and Cypermethrin (Cymbush). *Pakistan Journal of Nutrition* 9(2):158-161

Omongo, C. A., Adipala, E., Ogenga Latigo, M. W. and Kyamanywa, S. (1998). Insecticide application to reduce pest infestation and damage on cowpea in Uganda. *African Journal of Plant Protection* 4 (2): 91-100

Oparaeke, A.M. and Daria, V.I. (2004). Toxicity of herbal powders to emph *Callosobruchus maculatus* (Fab.) on stored cowpea grains, *Nigerian journal of Entomology* 12: 42-48

Oparaeke, A.M. (2005). Studies on the insecticidal potentials of extracts of *Gmelina arborea* product for the control of field pests of cowpea M*aruca vitrata* and *Clavigralla tomentosicollis, Journal of Plant Protection Research*. 45 (1): 1 -7.

Oparaeke A.M, Dike M.C, Amotobi C.I. (2000). Insecticidal Potentials of Extracts of Garlic, *Allium sativum* (Linneaus) Bulb and African Nut-Meg, *Monodora myristica* (Gaertn) Dunal Seed for Insect Pest Control on Cowpea. In. Entomology in Nation Building: The Nigerian Experience. Dike, M. C., Okunade, S. O., Okoronkwo, N. O. and Abba, A. A. (Eds). Entomology Society of Nigeria, *Occasional Publication.* 32:169-174.

Owolabi, A.O, Ndidi, U.S, James, B.D, Amune, F.A. (2012). Proximate, Antinutrient and Mineral composition of five varieties (improved and local) of cowpea, *Vigna unguiculata,* commonly consumed in Samaru community, Zaria-Nigeria *Asian Journal of Food Science and Technology* 4(2):70-72.

Paino D'urzo, M., M. Pedalino, S Grillo, R. Rao, and M. Tucci (1990). Variability in major seed protein in different Vigna species. International Institute for Tropical Agriculture 2000pp.

Quin, F.M. (1997).Introduction in:Advance in Cowpea Research, Devon Science Publishing pp. 4-15

Rachie, K.O. (1985). Introduction. Pages xxi –xxiii. In: Research, Production and utilization, S.R. Singh and O.K. Rachie (eds). John Wiley and Sons, Chichester, UK. Raheja A.K. and Hays, A.M. (1975). Sole crop cowpea production by farmers using improved practices. *Tropical Grain Legumes Bulletin*. 1(1);6-17.

Rachie, K.O and Singh S.R. (1985). *Cowpea research production and utilization*. John Wiley and Sons. New York. Brisbanepp: 22-25

Rawal, K.M. (1975). Natural hybridization among wild weedy and cultivated *Vigna unguiculata* (L) Walp *Euphytica* 24:699-707.

Schmutterer, H. (1990). Properties and potentials of natural pesticides from the neem tree, *Azadirachta indica*. *Annual Review of Entomology*, 35: 271–298.

Schwab A.I., Jager I., Stoll G., Gorgen R., Prexterschwab S. and Attenburger R. (1995). Pesticide in tropical agriculture: hazards and alternatives. The Pesticide Registration Regulations (2005). Retrieved July 10, 2010 From PANACTA

Shen, Y.C and Zhang Y.B. (2000). *Biopesticides.* Chemical Industry Press, Beijing pp31- 35

Singh, S.R. and Jackai, L.E.N. (1985). Insect pests of cowpeas in Africa, their life cycle, Economic importance and potentials for control. Pages 217 – 231. In: *cowpea Research production and utilization,* edited by S.R. Singh, and K.O. Rachie John Wiley, and Sons, N.Y.

Singh, B.B. Chambliss, O.L. and Sharma, B. (1978). Recent Advances in Cowpea breeding, pages 30 – 49. In: Advances in Cowpea research, edited by B.B. Singh, D.R. Mohar Raj, K.E. Dashiell and LEN Jackai. CO. Publication of intentional institute of Tropical Agriculture IITA and Japan International Research Centre for Agricultural Science (JIRSCA), Ibadan, Nigeria. Stanton, R.W.(1966).Grain Legume Pest in Africa. *PANS*.12; 100-1003.

Singh, S.R. and Van emdem, H.F. (1979). Insect pests of grain legumes. *Annual Reviews of Entomology* 24: 255-278.

Singh, B.B. Mohan Raj, D.R. Dashiell, K. E, and Jackai, L.E.N. (1997). *Advances in cowpea research.* IITA, Ibadan, Nigeria and JIRCA, Japan.

Singh, S.R and Taylor, T.A. (1978). Pests of grain legumes and their control in Nigeria. In S R Singh, HF van Emden and TA Taylor (eds). Pests of grain legumes: Ecology and control. London/New York, Academic Press. 99 – 111.

Statistical Analysis System, SAS. (2003). SAS user's guide statistics 2003 ed. Statistical Analysis System Institute, version 9.0, Cary, NC.

Stanton, R.W. (1966). Grain Legume Pest in Africa. *PANS*. **12**: 100 – 1003.

Steele, W.M. (1965). The cowpea, (*Vigna unguiculata* (L) Walp) the bambara nut (*Voandzia subterranean* L (DC) Lima bean, (*Phaseolus lunatus L*) in Northern Nigeria Paper read at *FAO Technical meeting on Improvement of Vegetable and Grain Legume Production in Africa*, Dakar18-24th January,1965.

Stern, V. M. (1973). Economic threshholds. *Annual Review of Entomology* 18. 259-280.

Suh, J.B., Jackai, L.E.N. and Hammond, W.N.O. (1986). Observations on pod sucking bug populations on cowpea at Mokwa, Nigeria. *Tropical Grain legume Bulletin* 33: 17-19.

Tamo, M. Baumgartner, I. Delucchi, V. and Herren, H. R. (1993). Assessment of key factors responsible for the pest status of the bean flower thrips, *Megalurothrips sjostedti* in West Africa. *Bulletin of Entomological Research.* 83: 251 – 258.

Tamo, M; Bottenberg, H., Arodokoun D. and Adeoti R (1997). The feasibility of classical biological control of two major cowpea insect pests. In: Singh BB, Mohan Raj DR, Dashiell KE and Jackai LEN (eds). *Advances in Cowpea Research. Copublication of International Institute of Agriculture and Japan International Center for Agricultural Sciences,* Nigeria, pp. 259-270

Tamo, M. Arodokoun, D. Zenz, C. and Adeoti, R. (2003). The importance of alternative host plants for Biological Control of two Cowpea Insect Pests, the Pod borer, *Maruca vitrata* Fabricius) and the Flower thrips, *Megalurothrips sjostedti* Trybom. Proceedings of the 3rd world Cowpea Research Conference, Ibadan Nigeria. Pp.187- 193.

Tanzubil, P.B. (1991). The control of insect pests of cowpea with neem (Azadirachta indica) in Northern Ghana. *Tropical Pest Management* 37 (3): 216 -217.

Tanzubil, P.B. (2000). Field evaluation of Neem extracts for control of insect pests of cowpea in Northern Ghana. *Journal of Tropical Forest Products* (Malaysia) 6: 165 – 172.

Taylor, T.A. (1967). A review of 50 years of applied entomology in Nigeria: Legume crops. *Proceedings of the Entomology Society of Nigeria.* 20-24pp.

Van den, B.J. and Nur A.F (1998). Chemical control. In: Andrew P (ed.) African Cereal Stem borers: Economic Importance, Taxonomy, Natural Enemies and Control *CAB International in association with the ACP-EU Technical Centre for Agricultural and Rural Co-operation* (CTA). pp. 319-332.

Voster, I.H.J., Jansen V.R.W., Van Zijl J.J.B., Venter S.L. (2007). The importance of traditional leafy vegetables in South Africa. *African Journal of Food, Agriculture and Nutritional Development, 7:* 1-13.

Weber, G; Elemo, K and Lagoke, S.T.O. (1996). Weed communities in intensified cereal – based cropping systems of Northern Guinea Savannah. *IITA Research* No.13.

Willey, R.W and Osiru, D.S.O (1972) Studies on Mixture of Maize and Beans (Phaseolus vulgaris) with particular reference to plant population. *Journal of Agricultural Science* (Cambridge) England 79: 519-529.

www.heydchem.com. (2011). Table of Pesticides Mode of Actions. Accessed June, 2014

Yusuf, S.R., Ahmed, B.I., Chaudhary, J.P.and Yusuf, A.U. (1998). Laboratory evaluation of some plant products for the control of maize weevil (*Sitophilus zeamais* Mots.) in stored maize. *ESN Occassional publications*. 31: 203-213.

APPENDICES

Appendix I

Metereological data in Wase and Samaru for 2012 cropping season

Month	WASE Total Rainfall Relative(mm)	WASE Average maximum Temperature(^{o}C)	WASE Average minimum Temperature(^{o}C)	WASE Average humidity %	SAMARU Total Rainfall Relative(mm)	SAMARU Average maximum Temperature(^{o}C)	SAMARU Average minimum Temperature(^{o}C)
January	-	29.84	14.32	16.19	-	32	12.65
February	-	34.55	19.24	15.31	-	36.21	16.76
March	-	35.81	21.13	9.94		35.35	18.32
April	-	41.30	26.17	51.67	7.30	39.03	22.80
May	12.70	38.26	31.58	68.58	263.4	33.77	21.16
June	229.30	33.87	23.20	72.64	120.72	31.55	21.00
July	459.30	31.45	22.58	82.61	122.4	30.29	20.06
August	383.00	30.68	21.84	84.87	426.72	29.10	20.10
September	792.00	33.97	21.87	77.23	261.80	30.37	20.50
October	1.00	33.97	22.74	70.23	79.6	27.19	20.81
November	-	33.81	18.20	33.73	-	34.30	17.43
December	-	33.57	18.10	24.36	-	31.19	16.00

Source: Metereological department, Institute for Agricultural Research, Samaru Zaria.

Appendix II : **ANOVA TABLE**

Analysis for the Population *Megalurothrips sjostedti in Samaru*

The ANOVA Procedure

Dependent Variable: MB1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	60.0476190	4.0031746	0.48	0.9320
Error	26	218.5238095	8.4047619		
Corrected Total	41	278.5714286			

R-Square	Coeff Var	Root MSE	MB1 Mean
0.215556	37.58088	2.899097	7.714286

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	6.14285714	3.07142857	0.37	0.6974
TRT	13	53.90476190	4.14652015	0.49	0.9085

The SAS System 18:32 Wednesday, December 29, 2012 101

The ANOVA Procedure

Dependent Variable: MA1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Model 15 123.3809524 8.2253968 23.51 <.0001

Error 26 9.0952381 0.3498168

Corrected Total 41 132.4761905

R-Square	Coeff Var	Root MSE	MA1 Mean
0.931344	112.9138	0.591453	0.523810

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.9047619	0.4523810	1.29	0.2915
TRT	13	122.4761905	9.4212454	26.93	<.0001

The ANOVA Procedure

Dependent Variable: MB2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	106.0714286	7.0714286	10.46	<.0001
Error	26	17.5714286	0.6758242		
Corrected Total	41	123.6428571			

R-Square	Coeff Var	Root MSE	MB2 Mean
0.857886	60.57470	0.822085	1.357143

Source	DF	Anova SS	Mean Square	F Value	Pr > F

REP 2 0.4285714 0.2142857 0.32 0.7311

TRT 13 105.6428571 8.1263736 12.02 <.0001

The SAS System 18:32 Wednesday, December 29, 2012 103

The ANOVA Procedure

Dependent Variable: MA2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	79.28571429	5.28571429	222.00	<.0001
Error	26	0.61904762	0.02380952		
Corrected Total	41	79.90476190			

R-Square	Coeff Var	Root MSE	MA2 Mean
0.992253	40.50463	0.154303	0.380952

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.04761905	0.02380952	1.00	0.3816
TRT	13	79.23809524	6.09523810	256.00	<.0001

The SAS System 18:32 Wednesday, December 29, 2012 104

The ANOVA Procedure

Analysis for the Population of *Maruca vitrata in Samaru*

The ANOVA Procedure

Dependent Variable: VB1

Sum of

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	15	34.42857143	2.29523810	1.75	0.1026
Error	26	34.14285714	1.31318681		
Corrected Total	41	68.57142857			

R-Square	Coeff Var	Root MSE	VB1 Mean
0.502083	20.05401	1.145944	5.714286

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	3.85714286	1.92857143	1.47	0.2487
TRT	13	30.57142857	2.35164835	1.79	0.0999

The ANOVA Procedure

Dependent Variable: VA1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	38.30952381	2.55396825	2.68	0.0132
Error	26	24.76190476	0.95238095		
Corrected Total	41	63.07142857			

R-Square	Coeff Var	Root MSE	VA1 Mean
0.607399	80.36824	0.975900	1.214286

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.57142857	0.28571429	0.30	0.7433
TRT	13	37.73809524	2.90293040	3.05	0.0075

The SAS System 18:32 Wednesday, December 29, 2012 106

The ANOVA Procedure

Dependent Variable: VB2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	35.09523810	2.33968254	4.19	0.0007
Error	26	14.52380952	0.55860806		
Corrected Total	41	49.61904762			

R-Square	Coeff Var	Root MSE	VB2 Mean
0.707294	68.24095	0.747401	1.095238

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	1.47619048	0.73809524	1.32	0.2841
TRT	13	33.61904762	2.58608059	4.63	0.0004

The SAS System 18:32 Wednesday, December 29, 2012 107

The ANOVA Procedure

Dependent Variable: VA2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	91.6904762	6.1126984	1.30	0.2695

Error	**26**	**122.1428571**	**4.6978022**
Corrected Total	**41**	**213.8333333**	

R-Square	Coeff Var	Root MSE	VA2 Mean
0.428794	**260.0930**	**2.167441**	**0.833333**

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	**2**	**19.19047619**	**9.59523810**	**2.04**	**0.1500**
TRT	**13**	**72.50000000**	**5.57692308**	**1.19**	**0.3412**

The ANOVA Procedure

Dependent Variable: VB3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	**15**	**32.71428571**	**2.18095238**	**7.22**	**<.0001**
Error	**26**	**7.85714286**	**0.30219780**		
Corrected Total	**41**	**40.57142857**			

R-Square	Coeff Var	Root MSE	VB3 Mean
0.806338	**76.96153**	**0.549725**	**0.714286**

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	**2**	**0.14285714**	**0.07142857**	**0.24**	**0.7912**
TRT	**13**	**32.57142857**	**2.50549451**	**8.29**	**<.0001**

The SAS System 18:32 Wednesday, December 29, 2012 109

The ANOVA Procedure

Duncan's Multiple Range Test for MB1

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

The ANOVA Procedure

Class Level Information

Class	Levels	Values
TRT	14	T1 T10 T11 T12 T13 T14 T2 T3 T4 T5 T6 T7 T8 T9
REP	3	1 2 3

Number of observations 42

The SAS System 19:08 Wednesday, December 29, 2012 89

The ANOVA Procedure

Dependent Variable: VA3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	31.14285714	2.07619048	21.80	<.0001
Error	26	2.47619048	0.09523810		
Corrected Total	41	33.61904762			

R-Square	Coeff Var	Root MSE	VA3 Mean
0.926346	129.6148	0.308607	0.238095

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.19047619	0.09523810	1.00	0.3816
TRT	13	30.95238095	2.38095238	25.00	<.0001

The SAS System 19:08 Wednesday, December 29, 2012 90

Analysis for the population of *Clavigralla tomentosicollis* in Samaru

The ANOVA Procedure

Dependent Variable: CB1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	12.52380952	0.83492063	1.44	0.2020
Error	26	15.09523810	0.58058608		
Corrected Total	41	27.61904762			

R-Square	Coeff Var	Root MSE	CB1 Mean
0.453448	84.21685	0.761962	0.904762

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.90476190	0.45238095	0.78	0.4692
TRT	13	11.61904762	0.89377289	1.54	0.1690

The ANOVA Procedure

Dependent Variable: CA1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	5.57142857	0.37142857	6.15	<.0001
Error	26	1.57142857	0.06043956		
Corrected Total	41	7.14285714			

R-Square	Coeff Var	Root MSE	CA1 Mean
0.780000	172.0912	0.245845	0.142857

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.42857143	0.21428571	3.55	0.0435
TRT	13	5.14285714	0.39560440	6.55	<.0001

The ANOVA Procedure

Dependent Variable: CB2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	74.7380952	4.9825397	0.78	0.6868
Error	26	166.0476190	6.3864469		

Corrected Total 41 240.7857143

R-Square	Coeff Var	Root MSE	CB2 Mean
0.310393	41.62352	2.527142	6.071429

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	5.28571429	2.64285714	0.41	0.6654
TRT	13	69.45238095	5.34249084	0.84	0.6213

The ANOVA Procedure

Dependent Variable: CA2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	83.2857143	5.5523810	2.19	0.0383
Error	26	65.8571429	2.5329670		
Corrected Total	41	149.1428571			

R-Square	Coeff Var	Root MSE	CA2 Mean
0.558429	50.63958	1.591530	3.142857

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.14285714	0.07142857	0.03	0.9722
TRT	13	83.14285714	6.39560440	2.52	0.0215

The ANOVA Procedure

Dependent Variable: CB3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	115.3095238	7.6873016	3.50	0.0025
Error	26	57.0952381	2.1959707		
Corrected Total	41	172.4047619			

R-Square	Coeff Var	Root MSE	CB3 Mean
0.668830	41.77114	1.481881	3.547619

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.9047619	0.4523810	0.21	0.8151
TRT	13	114.4047619	8.8003663	4.01	0.0013

The ANOVA Procedure

Dependent Variable: CA3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	93.6190476	6.2412698	5.26	0.0001
Error	26	30.8571429	1.1868132		
Corrected Total	41	124.4761905			

R-Square	Coeff Var	Root MSE	CA3 Mean
0.752104	43.16528	1.089410	2.523810

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	2.47619048	1.23809524	1.04	0.3666
TRT	13	91.14285714	7.01098901	5.91	<.0001

The ANOVA Procedure

Analysis for Aborted Flowers in Samaru

The ANOVA Procedure

Dependent Variable: ABT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	44.45238095	2.96349206	4.83	0.0002
Error	26	15.95238095	0.61355311		
Corrected Total	41	60.40476190			

R-Square	Coeff Var	Root MSE	ABT Mean
0.735909	41.64360	0.783296	1.880952

Source	DF	Anova SS	Mean Square	F Value	Pr > F

REP	**2**	**0.04761905**	**0.02380952**	**0.04**	**0.9620**
TRT	**13**	**44.40476190**	**3.41575092**	**5.57**	**0.0001**

The SAS System 19:08 Wednesday, December 29, 2012 99

The ANOVA Procedure

Dependent Variable: DASS

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	**15**	**79.1654762**	**5.2776984**	**2.56**	**0.0173**
Error	**26**	**53.6595238**	**2.0638278**		
Corrected Total	**41**	**132.8250000**			

R-Square	**Coeff Var**	**Root MSE**	**DASS Mean**
0.596013	**32.28321**	**1.436603**	**4.450000**

Source	**DF**	**Anova SS**	**Mean Square**	**F Value**	**Pr > F**
REP	**2**	**0.10714286**	**0.05357143**	**0.03**	**0.9744**
TRT	**13**	**79.05833333**	**6.08141026**	**2.95**	**0.0092**

The SAS System 19:08 Wednesday, December 29, 2012 100

Analysis for Number of Pod in Samaru

The ANOVA Procedure

Dependent Variable: POD

Sum of

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	15	26286.16667	1752.41111	1.23	0.3135
Error	26	37124.61905	1427.86996		
Corrected Total	41	63410.78571			

R-Square	Coeff Var	Root MSE	POD Mean
0.414538	25.54420	37.78717	147.9286

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	7664.71429	3832.35714	2.68	0.0872
TRT	13	18621.45238	1432.41941	1.00	0.4760

The SAS System 19:08 Wednesday, December 29, 2012 101

Analysis for Pod Damage in Samaru

The ANOVA Procedure

Dependent Variable: INA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	10.84158810	0.72277254	1.96	0.0646
Error	26	9.60509048	0.36942656		
Corrected Total	41	20.44667857			

R-Square	Coeff Var	Root MSE	INA Mean

0.530237 32.66513 0.607805 1.860714

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	3.60104286	1.80052143	4.87	0.0159
TRT	13	7.24054524	0.55696502	1.51	0.1804

The SAS System 19:08 Wednesday, December 29, 2012 102

The ANOVA Procedure

Dependent Variable: INB

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	0.39516190	0.02634413	4.02	0.0009
Error	26	0.17020000	0.00654615		
Corrected Total	41	0.56536190			

R-Square	Coeff Var	Root MSE	INB Mean
0.698954	22.41523	0.080908	0.360952

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.16173333	0.08086667	12.35	0.0002
TRT	13	0.23342857	0.01795604	2.74	0.0138

The SAS System 19:08 Wednesday, December 29, 2012 103

The ANOVA Procedure

Dependent Variable: INC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	0.40272381	0.02684825	8.91	<.0001
Error	26	0.07833333	0.00301282		
Corrected Total	41	0.48105714			

R-Square	Coeff Var	Root MSE	INC Mean
0.837164	33.70387	0.054889	0.162857

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.03720000	0.01860000	6.17	0.0064
TRT	13	0.36552381	0.02811722	9.33	<.0001

Analysis for Seed Indices in Samaru

The ANOVA Procedure

Dependent Variable: s1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	1192.904762	79.526984	0.91	0.5678

Error 26 2282.714286 87.796703

Corrected Total 41 3475.619048

R-Square Coeff Var Root MSE s1 Mean

0.343221 19.21580 9.369990 48.76190

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	438.6190476	219.3095238	2.50	0.1018
TRT	13	754.2857143	58.0219780	0.66	0.7810

The ANOVA Procedure

Dependent Variable: s2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	127.4761905	8.4984127	0.70	0.7631
Error	26	316.1428571	12.1593407		
Corrected Total	41	443.6190476			

R-Square Coeff Var Root MSE s2 Mean

0.287355 22.12312 3.487025 15.76190

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	3.1904762	1.5952381	0.13	0.8776
TRT	13	124.2857143	9.5604396	0.79	0.6675

The SAS System 19:08 Wednesday, December 29, 2012 106

The ANOVA Procedure

Dependent Variable: s3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	62.5476190	4.1698413	0.63	0.8275
Error	26	173.2857143	6.6648352		
Corrected Total	41	235.8333333			

R-Square	Coeff Var	Root MSE	s3 Mean
0.265220	23.83047	2.581634	10.83333

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	30.04761905	15.02380952	2.25	0.1251
TRT	13	32.50000000	2.50000000	0.38	0.9663

The SAS System 19:08 Wednesday, December 29, 2012 107

The ANOVA Procedure

Dependent Variable: s4

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	36.0952381	2.4063492	0.93	0.5487
Error	26	67.5238095	2.5970696		
Corrected Total	41	103.6190476			

R-Square	Coeff Var	Root MSE	s4 Mean
0.348346	72.00510	1.611543	2.238095

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	2.47619048	1.23809524	0.48	0.6261
TRT	13	33.61904762	2.58608059	1.00	0.4820

Analysis for Grain Yield in Samaru

The ANOVA Procedure

Dependent Variable: GRAIN

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	7.23032857	0.48202190	2.91	0.0082
Error	26	4.30923333	0.16573974		
Corrected Total	41	11.53956190			

R-Square	Coeff Var	Root MSE	GRAIN Mean
0.626569	27.83895	0.407111	1.462381

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	2.88243333	1.44121667	8.70	0.0013
TRT	13	4.34789524	0.33445348	2.02	0.0619

The SAS System 11:51 Thursday, December 30, 2012 1

The ANOVA Procedure

Class Level Information

Class	Levels	Values
TRT	14	T1 T10 T11 T12 T13 T14 T2 T3 T4 T5 T6 T7 T8 T9
REP	3	1 2 3

Number of observations 42

The SAS System 11:51 Thursday, December 30, 2012 3

Analysis for the population of *Melagulothrips sjostedti* in Wase

The ANOVA Procedure

Dependent Variable: MB1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	57.4523810	3.8301587	0.83	0.6349
Error	26	119.3333333	4.5897436		
Corrected Total	41	176.7857143			

R-Square	Coeff Var	Root MSE	MB1 Mean
0.324983	30.92079	2.142369	6.928571

Source	DF	Anova SS	Mean Square	F Value	Pr > F

REP	**2**	**0.00000000**	**0.00000000**	**0.00**	**1.0000**
TRT	**13**	**57.45238095**	**4.41941392**	**0.96**	**0.5095**

The SAS System 11:51 Thursday, December 30, 2012 4

The ANOVA Procedure

Dependent Variable: MA1

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	**15**	**119.4047619**	**7.9603175**	**25.12**	**<.0001**
Error	**26**	**8.2380952**	**0.3168498**		
Corrected Total	**41**	**127.6428571**			

R-Square	**Coeff Var**	**Root MSE**	**MA1 Mean**
0.935460	**87.56131**	**0.562894**	**0.642857**

Source	**DF**	**Anova SS**	**Mean Square**	**F Value**	**Pr > F**
REP	**2**	**0.4285714**	**0.2142857**	**0.68**	**0.5172**
TRT	**13**	**118.9761905**	**9.1520147**	**28.88**	**<.0001**

The SAS System 11:51 Thursday, December 30, 2012 5

The ANOVA Procedure

Dependent Variable: MB2

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	**15**	**76.35714286**	**5.09047619**	**11.25**	**<.0001**
Error	**26**	**11.76190476**	**0.45238095**		

Corrected Total 41 88.11904762

R-Square	Coeff Var	Root MSE	MB2 Mean
0.866523	42.16253	0.672593	1.595238

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.90476190	0.45238095	1.00	0.3816
TRT	13	75.45238095	5.80402930	12.83	<.0001

The ANOVA Procedure

Dependent Variable: MA2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	136.6428571	9.1095238	127.53	<.0001
Error	26	1.8571429	0.0714286		
Corrected Total	41	138.5000000			

R-Square	Coeff Var	Root MSE	MA2 Mean
0.986591	53.45225	0.267261	0.500000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.1428571	0.0714286	1.00	0.3816
TRT	13	136.5000000	10.5000000	147.00	<.0001

Analysis for population of *Maruca vitrata in Wase*

The ANOVA Procedure

Dependent Variable: VB1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	24.64285714	1.64285714	1.38	0.2296
Error	26	31.00000000	1.19230769		
Corrected Total	41	55.64285714			

R-Square	Coeff Var	Root MSE	VB1 Mean
0.442875	20.38266	1.091928	5.357143

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	1.00000000	0.50000000	0.42	0.6618
TRT	13	23.64285714	1.81868132	1.53	0.1740

The ANOVA Procedure

Dependent Variable: VA1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	52.61904762	3.50793651	6.28	<.0001
Error	26	14.52380952	0.55860806		
Corrected Total	41	67.14285714			

R-Square	Coeff Var	Root MSE	VA1 Mean
0.783688	65.39758	0.747401	1.142857

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.14285714	0.07142857	0.13	0.8805
TRT	13	52.47619048	4.03663004	7.23	<.0001

The ANOVA Procedure

Dependent Variable: VB2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	20.71428571	1.38095238	3.29	0.0038
Error	26	10.90476190	0.41941392		
Corrected Total	41	31.61904762			

R-Square	Coeff Var	Root MSE	VB2 Mean
0.655120	59.13068	0.647622	1.095238

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	1.76190476	0.88095238	2.10	0.1427
TRT	13	18.95238095	1.45787546	3.48	0.0033

The ANOVA Procedure

Dependent Variable: VA2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	35.97619048	2.39841270	14.08	<.0001
Error	26	4.42857143	0.17032967		
Corrected Total	41	40.40476190			

R-Square	Coeff Var	Root MSE	VA2 Mean
0.890395	91.23067	0.412710	0.452381

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.90476190	0.45238095	2.66	0.0892
TRT	13	35.07142857	2.69780220	15.84	<.0001

The ANOVA Procedure

Dependent Variable: VB3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	32.35714286	2.15714286	8.47	<.0001
Error	26	6.61904762	0.25457875		
Corrected Total	41	38.97619048			

R-Square	Coeff Var	Root MSE	VB3 Mean
0.830177	73.07391	0.504558	0.690476

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.04761905	0.02380952	0.09	0.9110
TRT	13	32.30952381	2.48534799	9.76	<.0001

The ANOVA Procedure

Dependent Variable: VA3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	37.50000000	2.50000000	105.00	<.0001
Error	26	0.61904762	0.02380952		
Corrected Total	41	38.11904762			

R-Square	Coeff Var	Root MSE	VA3 Mean
0.983760	58.91582	0.154303	0.261905

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.04761905	0.02380952	1.00	0.3816
TRT	13	37.45238095	2.88095238	121.00	<.0001

Analysis for population of *Clavigralla tomentosicollis in Wase*

The SAS System 11:51 Thursday, December 30, 2012 13

The ANOVA Procedure

Dependent Variable: CB1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	2.90476190	0.19365079	0.66	0.8009
Error	26	7.66666667	0.29487179		
Corrected Total	41	10.57142857			

R-Square	Coeff Var	Root MSE	CB1 Mean
0.274775	76.02294	0.543021	0.714286

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	1.00000000	0.50000000	1.70	0.2031
TRT	13	1.90476190	0.14652015	0.50	0.9063

The SAS System 11:51 Thursday, December 30, 2012 14

The ANOVA Procedure

Dependent Variable: CA1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	7.73809524	0.51587302	2.51	0.0189
Error	26	5.33333333	0.20512821		

Corrected Total 41 13.07142857

R-Square	Coeff Var	Root MSE	CA1 Mean
0.591985	211.3584	0.452911	0.214286

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.00000000	0.00000000	0.00	1.0000
TRT	13	7.73809524	0.59523810	2.90	0.0100

The ANOVA Procedure

Dependent Variable: CB2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	60.3333333	4.0222222	0.97	0.5055
Error	26	107.2857143	4.1263736		
Corrected Total	41	167.6190476			

R-Square	Coeff Var	Root MSE	CB2 Mean
0.359943	34.40186	2.031348	5.904762

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.04761905	0.02380952	0.01	0.9942
TRT	13	60.28571429	4.63736264	1.12	0.3840

The ANOVA Procedure

Dependent Variable: CA2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	89.9523810	5.9968254	4.59	0.0003
Error	26	33.9523810	1.3058608		
Corrected Total	41	123.9047619			

R-Square	Coeff Var	Root MSE	CA2 Mean
0.725980	38.70580	1.142743	2.952381

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.04761905	0.02380952	0.02	0.9819
TRT	13	89.90476190	6.91575092	5.30	0.0002

The SAS System 11:51 Thursday, December 30, 2012 17

Number of observations 42

The SAS System 11:51 Thursday, December 30, 2012 33

The ANOVA Procedure

Dependent Variable: CB3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	119.3333333	7.9555556	6.77	<.0001
Error	26	30.5714286	1.1758242		
Corrected Total	41	149.9047619			

R-Square	Coeff Var	Root MSE	CB3 Mean
0.796061	36.72813	1.084354	2.952381

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.7619048	0.3809524	0.32	0.7261
TRT	13	118.5714286	9.1208791	7.76	<.0001

The SAS System 11:51 Thursday, December 30, 2012 34

The ANOVA Procedure

Dependent Variable: CA3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	80.66666667	5.37777778	8.07	<.0001
Error	26	17.33333333	0.66666667		
Corrected Total	41	98.00000000			

R-Square	Coeff Var	Root MSE	CA3 Mean
0.823129	40.82483	0.816497	2.000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.00000000	0.00000000	0.00	1.0000
TRT	13	80.66666667	6.20512821	9.31	<.0001

The SAS System 11:51 Thursday, December 30, 2012 35

The ANOVA Procedure

Analysis for Aborted Flowers in Wase

The ANOVA Procedure

Dependent Variable: ABOT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	32.85714286	2.19047619	6.72	<.0001
Error	26	8.47619048	0.32600733		
Corrected Total	41	41.33333333			

R-Square	Coeff Var	Root MSE	ABOT Mean
0.794931	34.25823	0.570971	1.666667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.19047619	0.09523810	0.29	0.7491
TRT	13	32.66666667	2.51282051	7.71	<.0001

Analysis for Damage Pods

The ANOVA Procedure

Dependent Variable: DASS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	67.81785714	4.52119048	3.84	0.0013
Error	26	30.65190476	1.17891941		

Corrected Total 41 98.46976190

R-Square	Coeff Var	Root MSE	DASS Mean
0.688718	22.95057	1.085781	4.730952

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.63476190	0.31738095	0.27	0.7661
TRT	13	67.18309524	5.16793040	4.38	0.0007

Analysis for Number of Pod in Wase

The ANOVA Procedure

Dependent Variable: POD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	9680.33333	645.35556	2.09	0.0479
Error	26	8023.28571	308.58791		
Corrected Total	41	17703.61905			

R-Square	Coeff Var	Root MSE	POD Mean
0.546800	16.38100	17.56667	107.2381

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	596.047619	298.023810	0.97	0.3939
TRT	13	9084.285714	698.791209	2.26	0.0369

Analysis for Seed Pod Damage in Wase

The ANOVA Procedure

Dependent Variable: INA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	5.46965238	0.36464349	4.13	0.0008
Error	26	2.29397619	0.08822985		
Corrected Total	41	7.76362857			

R-Square	Coeff Var	Root MSE	INA Mean
0.704523	16.54133	0.297035	1.795714

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	1.72895714	0.86447857	9.80	0.0007
TRT	13	3.74069524	0.28774579	3.26	0.0050

The SAS System 11:51 Thursday, December 30, 2012 41

The ANOVA Procedure

Dependent Variable: INB

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	0.19195714	0.01279714	0.88	0.5895
Error	26	0.37700476	0.01450018		
Corrected Total	41	0.56896190			

R-Square	Coeff Var	Root MSE	INB Mean

0.337381 35.31775 0.120417 0.340952

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.02266190	0.01133095	0.78	0.4682
TRT	13	0.16929524	0.01302271	0.90	0.5658

The SAS System 11:51 Thursday, December 30, 2012 42

The ANOVA Procedure

Dependent Variable: INC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	0.29320476	0.01954698	1.35	0.2433
Error	26	0.37635714	0.01447527		
Corrected Total	41	0.66956190			

R-Square	Coeff Var	Root MSE	INC Mean
0.437905	74.09320	0.120313	0.162381

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.04417619	0.02208810	1.53	0.2363
TRT	13	0.24902857	0.01915604	1.32	0.2619

The SAS System 11:51 Thursday, December 30, 2012 43

Analysis for Seed Indices in Wase

The ANOVA Procedure

Dependent Variable: s1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Model 15 644.142857 42.942857 0.83 0.6382

Error 26 1343.476190 51.672161

Corrected Total 41 1987.619048

R-Square Coeff Var Root MSE s1 Mean

0.324078 15.05035 7.188335 47.76190

Source DF Anova SS Mean Square F Value Pr > F

REP 2 29.1904762 14.5952381 0.28 0.7562

TRT 13 614.9523810 47.3040293 0.92 0.5504

The ANOVA Procedure

Dependent Variable: s2

Source DF Sum of Squares Mean Square F Value Pr > F

Model 15 135.1190476 9.0079365 0.71 0.7512

Error 26 329.0000000 12.6538462

Corrected Total 41 464.1190476

R-Square Coeff Var Root MSE s2 Mean

0.291130 24.69478 3.557225 14.40476

Source DF Anova SS Mean Square F Value Pr > F

REP 2 14.3333333 7.1666667 0.57 0.5744

TRT 13 120.7857143 9.2912088 0.73 0.7153

The ANOVA Procedure

Dependent Variable: s3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	115.0476190	7.6698413	1.08	0.4161
Error	26	184.2857143	7.0879121		
Corrected Total	41	299.3333333			

R-Square	Coeff Var	Root MSE	s3 Mean
0.384346	25.76432	2.662313	10.33333

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	15.0476190	7.5238095	1.06	0.3605
TRT	13	100.0000000	7.6923077	1.09	0.4119

The ANOVA Procedure

Dependent Variable: s4

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	54.45238095	3.63015873	2.49	0.0201
Error	26	37.95238095	1.45970696		
Corrected Total	41	92.40476190			

R-Square	Coeff Var	Root MSE	s4 Mean
0.589281	64.23253	1.208183	1.880952

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	8.04761905	4.02380952	2.76	0.0821
TRT	13	46.40476190	3.56959707	2.45	0.0253

The SAS System 11:51 Thursday, December 30,

Analysis for Grain Yield in Wase

The ANOVA Procedure

Dependent Variable: GRAIN

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	3.97935952	0.26529063	1.84	0.0828
Error	26	3.73928095	0.14381850		
Corrected Total	41	7.71864048			

R-Square	Coeff Var	Root MSE	GRAIN Mean
0.515552	28.32622	0.379234	1.338810

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	1.75951905	0.87975952	6.12	0.0066
TRT	13	2.21984048	0.17075696	1.19	0.3411

The SAS System 11:51 Thursday, December 30, 2012 48