STUDIES ON ECONOMIC INJURY LEVEL OF LEGUME POD BORER (*Maruca vitrata* (G.) Fab.) ON COWPEA (*Vigna unguiculata* (L.) Walp) IN ZARIA, KADUNA STATE

BY

Nuradeen MUSA B. AGRIC (ABU 2010)
M.Sc./AGRIC/23375/2012-2013

A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE (M.Sc.) CROP PROTECTION

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

FEBRUARY, 2016

DECLARATION

I hereby declare that this dissertation titled **"**Studies on Economic Injury Level of Legume Pod Borer (*Maruca vitrata* (G.) Fab.) on Cowpea (*Vigna unguiculata* (L.) Walp) in Zaria, Kaduna State" was written by me and it is a record of my own research work. It has not been presented in any previous application for a higher degree. References made to published and unpublished literature have been duly acknowledged.

_____ _____

Nuradeen MUSA DATE

CERTIFICATION

This dissertation titled "STUDIES ON ECONOMIC INJURY LEVEL OF LEGUME POD BORER (*Maruca vitrata* (G.) Fab.) ON COWPEA (*Vigna unguiculata* (L.) Walp) IN ZARIA, KADUNA STATE" meets the regulations governing the award of the Master of Science in Crop Protection of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

_____ _____

Prof. R. S. Adamu — Date
Chairman, Supervisory Committee

_____ _____

Prof. A. M. Oparaeke — Date
Member, Supervisory Committee

_____ _____

Dr. L. J. Bamaiyi — Date
Member, Supervisory Committee,

_____ _____

Prof. A. B. Zarafi — Date
Head, Department of Crop Protection

_____ _____

Prof. Kabir Bala — Date
Dean, School of Postgraduate Studies

DEDICATION

This work is dedicated to my parents, Alh. Musa Abdullahi and Haj. Hindatu Musa, whose love and parental advice made it possible for me to acquire education

ACKNOWLEDGEMENTS

I wish to give ALLAH (SWT) all the glory, honour and thanks for sparing my life and for the privilege He granted me to successfully complete my second degree. My profound gratitude goes to Prof. R. S. Adamu, Chairman Supervisory Committee, Prof. A. M. Oparaeke and Dr. L. J. Bamaiyi members, Supervisory team for their advice, valuable suggestions, guidance, constructive criticisms and encouragement which were instrumental to the success of this work. My profound gratitude also goes to my parents Alh. Musa Fagacin Fatika and Haj. Hindatu Musa and my siblings Ibrahim, Zaharadeen, Hauwau and Salima Musa for their prayers and support. I appreciate the support, encouragement and understanding of my wife, Malama Shamsiyya Ibrahim Fatika and my son, Abdurrahman and daughter Amina, (Hassana).

My sincere thanks and appreciation go to the Head of Department, Crop Protection, Prof. A. B. Zarafi, Dr. B. T. Magaji, Dr. S. E. Alao, Mr. K. J. Adobe, Dr. I. M. Utonu, Alh. Iro Sule Faskari, for their advice, I say thank you all. I specifically appreciate the following technical staff: Mal. Hamza Adamu, Mal. Musa U. Akpa, Mr. Bala J. Adamu and Ishaku Musa of the Department of Crop Protection for assisting me in my research work. I would like to especially appreciate my friends Alh. Umar Provision Store Fatika, Ishaq Lawal, Abubakar Rabiu (JAWA), Mal. Aliyu Uwais, Alh. Isah (Driver), Kabir Lawal Mil-Goma, Dr Shuaibu Muhammad and Hamisu U. Fatika for their prayers. My appreciation will not be complete without saying thank you to my course mates in the persons of Abdulbasit Shiyanbola, Mustapha U. Abdullahi, Abdulkadir Dalhatu, Jummai A. Ibrahim, Halima Badamasi, Olatunde Gbenga, and my senior colleagues Mal. Buhari Muhammad, Ismail Yakubu, Abdulkarim Abdullahi, Mustapha Ojonuba, Inusa J. Ajene and Agaat C. Chindo; may

Allah (SWT) bless you all. I also appreciate the support of my Director, School of Agricultural Technology Dr. Damina Ayuba and my Head of Department, Mrs. Cecelia Shekari of School of Agricultural Technology Nuhu Bamalli Polythechnic Samaru, Kataf Campus for their encouragement and support.

ABSRACT

Trials were carried out in both screen house and field during 2014 cropping season at Samaru, Zaria to study the Economic Injury Levels (EIL) and to evaluate some cowpea varieties for field resistance to legume pod borer (*Maruca vitrata* (G.) Fab). First instar larvae of *M. vitrata* at levels 0 (no larvae were released), 5, 10, 15, 20, 25 and 0, 25, 50, 75, 100, and 125 were used to infest (SAMPEA 7) cowpea at flower bud initiation, 50 % flowering and 50 % podding in both screen house and field cages, respectively. The treatments were arranged in a Complete Randomized Design (CRD) and Randomized Complete Block Design (RCBD) replicated four times for screen house and field trials, respectively. Parameters assessed include, number of pods produced, damaged pods, weight of grains and the rate of association between larval density and grain weight. The result obtained showed decreased yield in cowpea with increase in number of larvae infested in both screen house and field cages. Infestation with 5 and 25 larvae per cage, caused decrease in yield from 549.75 kg ha^{-1} and 843.50 kg ha^{-1} in screen house while infestation with 25 and 125 larvae caused a decrease of 486.25 kg ha^{-1} and 222.50 kg ha^{-1} in field cages. The estimated Economic Injury Levels (EIL) in the screen house was 0.13, 0.14, 0.14, 0.13 and 0.15 when Cypermethrin, Dimethoate, Chlorpyriphos, Cypermethrin plus Dimethoate and Imidachloprid, respectively were sprayed to control *Maruca.* The corresponding values for field cages were 0.14, 0.15, 0.14, 0.14 and 0.16, for the respective insecticides. Twelve cowpea varieties were also assessed for resistance to *Maruca vitrata* using three sowing dates at two weeks interval. The experiments were laid out in Randomized Complete Block Design (RCBD) replicated three times. Based on the percentage pod damage, damage score for each variety was given resistance rating 1-5. The results showed that the first sowing date (early August) had less infestation by *M. vitrata* and differed significantly ($p<0.05$) from those sown in late August to early September. All the varieties sown early August to late August had less *Maruca* infestation and produced higher grain yields than those sown early September. Wild cowpea (*Vigna dekendtiana)* was highly resistant and differed significantly ($P< 0.05$) from the cultivated varieties, while SAMPEA 1, 4, 6, 9 and 10 were the most susceptible varieties with higher pod and seed damage and lower grain yields. SAMPEA 7, 8, 11, 12, 14, and15 were moderately resistant. None of the variety was resistant or highly susceptible to the *Maruca vitrata* attack. Therefore, highly resistant and moderately resistant varieties can be utilized by the farmers and in breeding programme for the management of pod borer as a component of IPM.

TABLE OF CONTENTS

Title page i
Declaration ii
Certification iii
Dedication iv
Acknowledgement v
Abstract vii
Table of Contents viii
List of Tables xi
List of Figures xii

CHAPTER ONE:
1.0 INTRODUCTION 1
1.1 Justification 3
1.2 Objectives 4

CHAPTER TWO:
2.0 LITERATURE REVIEW 5
2.1 Origin and Distribution of Cowpea 5
2.2 Importance and Uses of Cowpea 6
2.3 Constraints of Cowpea Production 7
2.4 Insect Pests of Cowpea 8
2.5 Legume Pod Borer, *Maruca vitrata* (G.) Fab. 9
2.5.1 Nature of damage of *Maruca vitrata* 9
2.5.2 Host range and suitability 10
2.5.3 Life cycle 10
2.6 Economic Injury Levels (EIL) 11
2.7 Management of *Maruca vitrata* on Cowpea 12
2.7.1 Cultural practices: 12
2.7.2 Insect resistant cowpea varieties: 13
2.7.3 Use of biopesticides 13
2.7.4 Use of synthetic insecticides 14

CHAPTER THREE

3.0 MATERIALS AND METHOD 16

3.1 Study Area 16

3.2. Mass Rearing of *Maruca vitrata* for Field and Screen House Infestation 16

3.3 Experiment I: Determination of Economic Injury Level in the Field 17

3.3.1 Field establishment of crop 17

3.3.2 *Maruca* larvae infestation 19

3.3.3 Damage assessment and data collection 19

3.4.0 Experiment II: Determination of Economic Injury Level under the Screen House Condition 20

3.4.1 Colony establishment 21

3.4.2 Calculation of economic injury levels 21

3.5.0 Experiment III: Field Evaluation of Cowpea Varieties for Resistance to *M. vitrata* 21

3.5.1 Field establishment and experimental layout 22

3.5.2 Data collection 22

3.5.3 Data analysis 23

CHAPTER FOUR

4.0 RESULTS 25

4.1.1 Effect of *M. vitrata* larvae infestation on number of pods produced, pods damaged, percentage pods damage and grain yield per cage in 2014 at Samaru 25

4.1.2 Effect of *M. vitrata* larvae infestation on Healthy grain, damaged grains, percentage grain damage and 100 seeds per cage of cowpea in 2014 at Samaru. 25

4.2.1 Effect of *M. vitrata* larvae infestation on produced flowers, damaged flowers, produced pods and damaged pods per cage of cowpea under screen house 28

4.2.2 Effect of *M. vitrata* larvae infestation on percentage pods damage, Grains yield, damaged grain weight and percentage grain damage per cage of cowpea under screen house……30

4.3 Economic Injury Levels (EILs)……30

4.4.0 Evaluation of some cowpea varieties for resistance to *Maruca vitrata* infestation ……..32

4.4.1 The effect of *M. vitrata* larval population and pods produced at three sowing date……32

4.4.2 Effect of *M. vitrata* infestation on damaged pods number and total grain weight (g) at three sowing dates of cowpea…….….39

4.4.3 Effect of *M. vitrata* infestation on weight of grains damaged and 100 seed weight of cowpea per plot. ……..41

4.4.4 Effect of *M. vitrata* infestation on percentage grains damage and grain weight (kg ha^{-1}) at three sowing dates of cowpea. ……..……43

4.4.5 Effect of *M. vitrata* infestation on percentage pods damage at three sowing dates of cowpea ……...…….43

CHAPTER FIVE

5.0 DISCUSSION……...47

5.1 Evaluation of some Cowpea Varieties for Resistance to *Maruca* Pod Borer……51

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS…….58

6.1 Summary……58

6.2 Conclusion…….58

6.3 Recommendations…….60

REFERENCES……61

APPENDICES……72

LIST OF TABLES

Table1: Showing the composition of synthetic rearing diet of *M. vitrata* in the laboratory 18

Table 2: Scale for rating *Maruca vitrata* damage to cowpea…….24

Table 3: Effect of *M. vitrata* larvae infestation on number of pods, damaged pods, percentage pods damage and grain yield of caged cowpea in 2014 at Samaru……..……..……..26

Table 4: Effect of *M. vitrata* larvae infestation on healthy grain and damaged grain, percentage grain damage and 100 seed weight per cage of cowpea in 2014 at Samaru……27

Table 5: Effect of *M. vitrata* larvae infestation on number of produced flowers and damaged flowers, produced pods and damaged pods of cowpea under screen house…….....29

Table 6: Effect of *M. vitrata* larvae infestation on percentage pods damage and grain yield, damaged grain weight and percentage grain damage of cowpea per cage under screen house……...31

Table 7: Economic Injury Levels (EILS) of *M. vitrata* larvae based on regression of yield loss (Y) on the number of larvae controlled with different insecticides in 2014 cropping season……..……37

Table 8: Effect of *M. vitrata* Infestation population and Number of pods produced at three sowing dates of cowpea per plot at Samaru in 2014 38

Table 9: Effect of *M. vitrata* infestation on damaged pods number and total grain weight per plot at three sowing dates of cowpea at Samaru in 2014 40

Table 10: Effect of *M. vitrata* infestation on damaged grain weight and 100 seed weight per plot at three sowing dates of cowpea at Samaru in 2014 42

Table 11: Effect of *M. vitrata* infestation on percentage grain damage and grain weight (kg ha^{-1}) at three sowing dates of cowpea at Samaru in 2014 44

Table 12: Relationship between percentage pods damage and resistance rating of twelve cowpea varieties against *Maruca* pod borer at Samaru in 2014. 46

LIST OF FIGURES

Figure 1: Relationship between larval density and yield reduction per caged cowpea plant in screen house at Samaru in 2014 33

Figure 2: Relationship between larval density and grain weight per caged cowpea plant in the screen house at Samaru in 2014 34

Figure 3: Relationship between larval density and grain weight per caged cowpea plant in the field at Samaru in 2014 35

Figure 4: Relationship between larval density and yield reduction pre caged cowpea plant in the field at Samaru in 2014 36

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). More than 14.5 million hectares of land is planted to cowpea worldwide each year. Its global production as dried cowpea in 2013 was 6.2 million metric tonne, of which 94 % is in Africa (Diouf, 2011; FAOSTAT, 2014). Nigeria is the world largest cowpea producer where about 2.9 million metric tonnes are produced per annum, followed by 1.3 and 0.2 million metric tones of Niger and Mali, respectively (FAOSTAT, 2014). The major areas of production in Africa are Nigeria, Niger, Mali, and Senegal in West Africa, Cameroon and Democratic Republic of Congo in central Africa and Kenya, Sudan, Tanzania, Uganda and Somalia in East Africa (FAOSTAT, 2014).

Under sole cropping, the grain yield potential of the crop ranges from 1.5-3.0 tonnes per hectare but can be realized mainly when insecticides are applied (Olufajo and Singh, 2002). In Nigeria the highest production of cowpea comes from the northern states of Nigeria where about 1.7 million tonnes from 4 million hectares have been reported (Anonymous, 2009). However, some appreciable quantities are also produced in the rainforest belt particularly in the South East of Nigeria (Oparaeke, 2004). Cowpea can be regarded as vegetable meat due to the high amount (20-30 %) of protein in the grain. It is thus a source of cheap plant protein to people who hardly can afford animal protein derived from meat, fish, milk and eggs (Olakoja *at al*., 2007, FAOSTAT, 2011). It is rich in minerals, fats, oils and vitamins and is consumed in different forms, with many local variations in their preparation (Gungula and Garjila, 2005).

According to statistics, 52 % of Africa's production is used for food, 13 % as animal feed, 10 % for seed, 9 % for other uses and 16 % is wasted (FAOSTAT, 2011). Most frequently, they are cooked together with vegetables, spices and often palm oil to produce a thick bean soup, which accompanies the basic staple foods, such as cassava, yams and plantain (Valenzuela and Smith, 2002). They are also ground into flour and mixed with sliced onion, spices and made into cakes, which are either deep-fried (*akara balls*), or steamed (*moi-moi*) in Nigeria (USAID, 2008). 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; Singh, 2000). In Nigeria, farmers who cut cowpea fodder and store for sale during the peak of the dry season can obtain as much as 25 % of their annual income by this means (FAOSTAT, 2011).

Insect pests are considered to be responsible for reduction in yield. Sometimes total yield loss and crop failure occur due to the activities of a wide spectrum of insect pests which ravage the crop in the field at different growth stages (Singh and Ajeigbe, 2002). Insects attack cowpea and cause economic damage at all stages of plant growth starting from seedlings to harvest and in storage. The major insect pests which severely damage cowpea at all growth stages are the cowpea aphid (*Aphis craccivora* Koch), foliage beetle (*Ootheca mutabilis* Sahlb), the flower bud thrips (*Megalurothrips sjostedti* Trybom), the legume pod borer (*Maruca vitrata* Fabricius) and the sucking bug complex, of which *Clavigralla tomentosicollis* Stal, Giant pod bug (*Anoplocnemis curvipes* F,) and Shield bug (*Aspavia armigera* L,) are prevalent and the most important. *M. vitrata* is a major pest of cowpea which causes economic damage at the lowest population density (Sharma, 1998).

Jackai (1982) observed that infestation starts from the shoot of cowpea 21 days after planting and spread to productive parts. Intensity of larvae is usually highest on flowers followed by flower buds, terminal shoots and pods. *M. vitrata* can be controlled primarily through the use of chemical insecticides (Akinfenwa, 1975; Dina and Medaigedu, 1988). However, continous use of chemicals may lead to problems such as development of pest resistance, outbreak of secondary insect pests and pesticide residues in the produce and environmental degradation. Where the insect resistance develops the use of insect resistant genotypes is an important and compatible component of integrated pest management (IPM).

Pedigo (2004) reported that IPM modules can be used as an effective, cheap, and environmentally safe method of reducing the menace of this pest. Reasonable grain yield cannot be obtained without proper management strategy (Jackai and Daoust, 1986; Amatobi, 2007). According to Stern *et al*. (1959), economic injury level (EIL) is the level at which damage can no longer be tolerated and therefore at that point or before reaching that levels deliberate control operation should be initiated.

1.1 Justification

Cowpea production in Sub- Sahara Africa accounts for more than 94 % of the world production (FAOSTAT, 2011). Tropical infestation by *M. vitrata* alone can cause yield loss reduction of 20-80 % (Singh *et al*., 1990; Sharma, 1998). Depending on the region and management practices, the year to year crop losses and challenges in effective field control have led to the identification of this pest as a major threat to economic and well-being of people in the developing nations. In West Africa, *M. vitrata* is one of the major pests of cowpea, especially in Nigeria, Niger and Mali, which are the major cowpea producing

areas. A seasonal variation in yield losses that was obtained from Nigeria ranged from 48-86 % (IITA, 1986, Dryer *et al*., 1994). The high population of *Maruca* encountered on cowpea leads to expensive control measures. Their typical feeding habit makes control of the larvae so difficult with pesticides and their natural enemies. Farmers usually spray insecticides to protect the cowpea crop from *Maruca* and other pests. Cost of chemicals, added to the production cost, thus reducing the farmer's profit. The development of cowpea resistant to *Maruca* and other insect pests would benefit the most resource poor African farmers who grow the crop.

The basic biology of *M. vitrata* has been studied extensively (Jackai 1982; Akinfenwa, 1975; Singh *et al.*,1990), but there is still inadequate information on the level at which they caused damage on cowpea in Nigeria and this could hinder the development of effective integrated pest management strategies against the pest in the country. Economic injury level is prerequisites of IPM and basic criterion to knowing the need and time to apply economic control measures (Smith, 1968). Transgenic plants and traditional plant breeding for insect resistant varieties are potentially effective methods for managing pests of cowpea, a better understanding of pest populations is needed in order to integrate these, and other pest control options into an overall integrated pest management (IPM) plan to maximize cowpea production in the field.

1.2 Objectives

The present research work was undertaken to:

i. Determine the economic injury levels of *Maruca vitrata* on cowpea

ii. Evaluate some cowpea varieties for resistance to the *Maruca* pod borer.

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 *Fabaceae*, order *Leguminosae* and genus *Vigna* (Singh, 1997). The genus consists of over one hundred different species widely found in the tropical and subtropical regions and has a great morphological and ecological diversity (Paino D urzo *et al*., 1990). The common name includes black eye bean, southern peas, cowpea or beans in Nigeria. The crop can be grown on many soil types but does best on well drained fertile, sandy loamy soils. Cowpea production is considered suitable in areas with annual rainfall of 750-1500 mm (Anthonio, 1979). Cowpea varieties could be prostrate, semi-erect, erect or climbing, pod could be coiled, round, crescent or linear (Singh, 2000). The centre of origin of cowpea was reported to be sub-humid and semi-arid region of West Africa (Steele, 1965). Regardless of its centre of origin, cowpea is extensively cultivated in Africa, Asia, Brazil, India and U.S.A. Other producers are Haiti, Sri Lanka and Egypt (FAO, 2008).

The major areas of production in central Africa and West Africa are Nigeria, Niger, Mali, Cameroon, Senegal Burkina Faso, which account for 94 % of world production (FAOSTAT, 2011). The Food and Agricultural Organization (FAO) estimated the production of more than 6.2 million metric tonnes of dry cowpea grains worldwide in the year 2014 (FAO STAT, 2014),which showed that cowpea production in Nigeria accounts for 58 % of the total world output, making Nigeria the largest producer and consumer of cowpea with an output of 2.9 million metric tonnes. However, some appreciable quantities

are grown in the south west of Nigeria but still the production is highest in the North East (803.13 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), the main producing states in Nigeria are Kaduna, Kano Nasarawa, Sokoto, Katsina, Niger, Kebbi, Borno, Yobe, Jigawa, Zamfara, Bauchi, Gombe, Borno Adamawa and Taraba where most cowpeas are traditionally grown as intercrops with cereals such as maize and sorghum (Anonymous, 2009).

2.2 Importance and Uses of Cowpea

Cowpea is an important food crop in both tropical and subtropical regions of the world as it provides not only high quality protein but also constitutes the cheapest source of dietary protein for the low income sector of the population (Rachie, 1985; USAID, 2008). All part of the plant used as food are nutritious providing protein and vitamin, immature pods and peas are used as vegetables (Islam *et al*., 2006). The grain contains 26.61 % protein, 3.99 % lipids, 56.24 % carbohydrate, 8.61 % moisture, 3.84 % ash, 1.38 % crude fiber, 1.51 % gross energy and 54.85 % nitrogen free extract (Owolabi *et al.*, 2012). It is also a good source of calcium, iron, vitamin B and carotene. Many researchers include (Giller, 2001) have show that daily consumption of dry bean reduce serum cholesterols levels by 20 % thereby, reducing the risk of coronary disease (Anderson, 1985).

Besides the usefulness of cowpea in human diet, it is also an important fodder crop in different parts of Africa. The haulm contains about 20 % protein which is a highly valued livestock feed and sold for almost the same price as cowpea grain on dry weight bases (Alghali, 1993). In developing countries, the seeds are an important source of protein for the rural and urban poor whereas the green parts of the plant that are used as vegetables

supply roughage and minerals (FAO, 2002). Cowpea can improve the productivity of cereal crop by increasing the amount of nitrogen available for uptake (Giller, 2001).

2.3 Constraints of Cowpea Production

In Nigeria, cowpea yield is very low, grain yield range between 100 and 300 kg/ha, this is due to several constraints such as weather, parasitic weeds, insect pests and diseases (Amusa and Adegbite, 2006). Tomo *et al.* (1993), reported that the reasons for low yield involves a combination of limiting factors, such as low plant density, shading by cereal crops, abiotic factors (droughts, poor soil fertility) and biotic factors (e.g Arthropod pests, birds, rodents) factors (Singh *et al.*,1997).

In most parts of West Africa insect pests are the most important constraints to cowpea production (Singh and Jackai 1985; Karungi, 2000). Insects attack cowpea from seedlings to harvest and can cause economic damage at all stages of plant growth and in storage, to increase hectarage of this food crop, researchers and farmers must minimize the damage caused by insect pests. The most damaging of all the insects are the flowering and post flowering insect pests, which include flower bud thrips (*Megalurothrips sjostedti* Tryb), Cowpea pod borer (*Maruca vitrata*) and cowpea pod sucking bugs out of which *Clavigralla tomentosicollis* is the dominant species, the most important diseases are cowpea wilt *fusarium oxysporium*,Scab *Sphaceloma* sp, Brown blotch *Collectotricum capsici*, Septoria leaf spot *Septoria* sp. Complete crop failure may occur especially in improved varieties when management strategies are not applied (Jackai *et al.*, 2001). Oparaeke *et al*. (2000) reported a yield loss of cowpea about 80% due to insect pests in Nigerian farms.

One of the requirements for developing an effective pest management programme is to understand the relationship between insect pests' population and resulting losses (Luckmann and Metcalf, 1994; Buntin, 2001). In developing countries, cowpea fields are small and farmers have limited access to synthetic insecticides because of economic constraints (Amatobi, *et al*., 2005). Thus, knowledge of when to apply a treatment to achieve maximum benefit is essential. Jackai (1991) reported that more than 70 % of total loss in cowpea seed yield caused by insect results from damage that occurs during the flower and pod formation stages. This underlines the importance of understanding the plant's response to injury to these reproductive parts. Larval stages of the pod borer *M. vitrata,* which attack cowpea flowers in Africa resulting in flower abscission also attack pods and together with pod sucking bugs, such as *Clavigralla tomentosicollis* cause loss of young pods (Jackai and Daoust 1986; Tayo, 1988).

2.4 Insect Pests of Cowpea

Cowpea is a hardy crop but it hosts many insects that attack vegetative parts, these includes leaf miners, whiteflies *Bemisia tabaci*, leafhoppers *Empoasca*, mites *Tetranychus* spp, thrips *Megalurothrips* s*jostedti*, Cowpea beetle *Ootheca* spp, Pod sucking bugs *Clavigralla* spp. Legume pod borer *Maruca* spp, Aphids *Aphis craccivora*. There are numerous important insect pests of cowpea worldwide and most locations have 2-4 species being key pest. The major pests of cowpea in the field in Nigeria, Niger, and Burkina Faso are the legume pod borer, *M. vitrata*, (Lepidoptera: Pyralidae) flower bud thrips *Megalurothrips sjostedti* Tryb. (Thysanoptera: Thripidae) and the pod sucking bugs complex of which *Clavigralla* spp. Stal. (Hemiptera: Coreidae), Giant pod bug *Anoplocnemis curvipes* Fab. (Hemiptera: Coreidae) and Shield bug *Aspavia armigera* are

the most damaging (Jackai and Daoust, 1986; Malgwi and Onu, 2004). Attack by these insects is often so severe that farmers obtain no yield, especially when improved cowpea varieties are used without insecticides protection (Tanzubil, 2000).

2.5 Legume Pod Borer, *Maruca vitrata* (G.) Fab.

The legume pod borer *M. vitrata* (Lepidoptera: Pyralidae) have a characteristics dark spot on each segment forming longitudinal dorsal and ventral rows. Adult have a wingspan of 16-27 mm (Amatobi, 2007). The forewing is light brown with white spots markings and the hind wings are grayish-whites with brown markings on the margins; the wingspan is 16-27 mm (Hill and Waller, 1990). The eggs are oval and yellow, and the larvae are about 16 mm long, whitish in colour with a black head. Normally, larvae feed on anthers filaments, styles, stigma and ovaries of flowers (Singh and Allen, 1980).

2.5.1 Nature of damage of *Maruca vitrata*

Jackai, (1981) observed the infestation to start from terminal and then spreading to reproductive parts, the intensity is highest on flowers followed by flower buds, terminal shoots and pods. Sharma, (1998) observed young larvae boring the stems of black gram from leaf-axils of branches causing wilting, the larva damages leaves by rolling, webbing and continued feeding inside the rolled leaves. Indicators of larvae in a plant include webbing of flowers, leaves and pods, frass on shoot tips and pods.

Young larvae bore into flower buds and flower feeding inside, causing flowers and flower bud to drop. Young stems, terminal shoots and young flower buds are also damaged (Amatobi, 2007). *Maruca* Moths prefer to oviposit at the flower bud stage and move from one flower to another, and each may consume 4-6 flowers before larval development is completed (Jackai, 1991). Third to fifth- instar larvae is capable of boring into peduncles

and stems the moths and larvae are nocturnal (Singh, 2000). Singh and Allen (1980) estimated that loss cause by *M. vitrata* ranged from 20 to 60% in cowpea. The young larvae bore into the flower buds, and cause flower shedding by destroying the young flower parts enclosed in the sepals. The successful establishment of this pest at the flower bud stage is significant in relation to subsequent damage, reduction in grain yield, and efficiency of control (Singh, 2000).

2.5.2 Host range and suitability

Studies on the importance of alternative host plants for the population dynamics of *M. vitrata* have revealed that this insect is oligophagous, feeding and reproducing on a number of cultivated and wild host plants of which belong to the *fabaceae* (Luckmann and Metcalf, 1994, Arodokun *et al*., 2006). The alternation of the flowering pattern of these plants on a south-north gradient has been found to influence the migration of *M. vitrata* from the coast to dry savanna of West Africa (Luckmann and Metcalf, 1994). During this migration, the population of *M. vitrata* fined the condition favorable and multiplies rapidly on the different host plant thereby increasing the size of each new generation. It has been reported to feed on several host plants and occur throughout the tropics and sub-tropics. The most frequent host plants are Beans and peas mainly, but other host includes groundnut, castor, tobacco, rice, Hibiscus species and other legumes (Sharma *et al*., 1999; Arodokoun *et al*., 2006; Amatobi, 2007).

2.5.3 Life cycle

Eggs are laid on terminal shoots, flower buds and flower, leaves and pod in batches of 2-16. Female lay up to 174-194 eggs (Akinfenwa, 1975). The eggs hatch in 2-3 days and the larvae undergo through five larvae stages in 8-14 days in cowpea, depending on climatic

conditions and availability of food (Okeyo-Owuor and Ochien, 1981; Amatobi, 2007). The larvae and adult are active at night and during the day they hide in or among the flowers, pods or on the soil around the plant. There is prepupal stage of about two days without feeding; pupation is in the pod or in cocoon on plant debris beneath the plant and also in the soil, pupal stages last 5-15 days (Akinfenwa, 1975).

2.6 Economic Injury Levels (EILs)

Economic threshold perhaps is the best known term and most widely used index in making pest management decision. The knowledge of economic threshold (ET) helps to determine whether an insect is to be classified as a pest or not, (Pedigo, 1996). ET is the pest density at which control measures should be applied to prevent an increasing pest population reaching the Economic Injury Level (EIL). Control measures are taken at this stage so that this pest does not exceed the EIL. The idea expressed by Pierce (1934) with regards to assessment of insect damage and initiation of control measures become an incentive for the development of the concept of EIL. Stern *et al*. (1959) formally proposed the concept of ET as the number of insect (density and intensity) when management action should be taken to prevent the increasing pest population from reaching EIL.

Economic injury levels is defined as the lowest number of insect that will cause economic damage, or minimum number of insect that would reduce yield equal to gain threshold (Pedigo, 2004). EIL is really a level of injury because injury is usually difficult to measure in a field situation, number of insect are used as an index of that injury (Pedigo, 2004).The relationship between the EIL and ET demonstrate that action taken when population levels exceed the ET forces down the population before it reached the EIL. Pests are recognized according to several factors including the abundance, damage caused (Amatobi, 2007).

The concept of economic threshold based on population level of organisms or level of incident of pest, is still the most acceptable in categorizing pest. Singh (2005) showed that this concept is based on the fact that organisms over a long period of time and in a relatively undisturbed environment reach a state of equilibrium. The economic injury level and economic threshold are usually above the average population level. Economic damage is the amount of injury which will justify the cost of artificial measures. Injury is the effect of pest activities on host physiology that is usually deleterious. Damage is the measurable loss to host utilities which includes yield quality, quantity and or aesthetics. Economic damage begins to occur when money required for suppressing insect injury is equal to potential monetary loss from a pest population (Pedigo, 2004)

2.7 Management of *Maruca vitrata* on Cowpea

M. vitrata is one of the major biotic constraints to increasing the productivity of most grain legume in West Africa and effective control measures depend primarily on making the environment unfavorable for its development (Ogah and Ogah, 2012). Various methods have been and are currently being tested for the control of *M. vitrata*.

2.7.1 Cultural practices

Pod borer population tends to build up over the season, thus infestation increases on the late sown crop (Alghali, 1993). Simultaneous planting of maize and cowpea increase pod borer infestations in cowpea (Ezuch, 1982), whereas sowing cowpea 12 weeks after maize reduces the pod borer damage. Pod borer damage in a monocrop is greater than the maize-cowpea-sorghum inter-mixed crop (Omolo *et al.*, 1993). Inter cropping maize with bean is considered useful as a cultural method for controlling pod borer in common bean (Alghali, 1993).

2.7.2 Insect resistant cowpea varieties

Wild relatives of cowpea species are often sources of genes for disease and insect resistance, increased yield, improved product quality, earliness and wide adaptation (Stalker, 1989). Wild forms and closely related species of cowpea, therefore, have great potential as an additional source of useful germplasm for cowpea improvement (Padulosi and Ng, 1990). A number of wild cowpea species (*Vigna* spp.) in Africa contribute directly to food security through consumption of their fruits and seeds (www.biodiveersityinternational.org). Members of the var. *pubescens* have been known to confer some degree of insect resistance on cowpea owing to the presence of hairs (hence the name *pubescens*) on the plants (Fatokun and Singh, 2001).

Cowpea variable source of resistance have been identified in cultivated or wild *vigna* spp for practically all major pests. Resistance cultivars have been developed for a number of important pests (Jackai *et al*., 2001). Although, high level of resistance to post flowering pest have not yet been found among cultivated cowpea, the available level of resistance can certainly be used in combination with other intervention to substantially reduce pest infestation and damage in cowpea. Among cultivated land race, a number of cowpea cultivars have been identified with low to moderate level of resistance to the pod borer (Jackai, 1982, 1991).

2.7.3 Use of biopesticides

Biopesticides are pesticides derived from animals, plants, microorganisms, and minerals; they are less harmful to human and have fewer environmental effects than conventional pesticides (Pedigo, 2004). This resuscitated the idea of botanical insecticides as a promising alternative to pest control (Oyewale and Bamaiyi, 2013). Often their

effectiveness does not last longer compared to those of synthetic pesticides, and over 2000 species of plant are known to possess insecticidal activities, in spite of this, only a few plants have been scientifically evaluated (Isman, 2006). They are biodegradable and harmless to the environment. Neem seed powder and neem kernel extract are effective against legume pod borer (Singh *et al.*, 1990); but less effective compared to Fenvalerate and Monocrotophos. Neem products have shown efficacy against *Maruca* pod borer, *Clavigralla tomentosicollis* and other insect pests (Jackai and Oyediran 1991; Jackai *et al*., 1992).

Cashew, Clove and African nutmeg extracts have also shown insecticidal properties against some flowering pests of cowpea (Oparaeke, 2007).The use of Cashew nut shell liquid has been gaining more attention due to its possession of the active phenolic compounds, Anacardic and Cardol, which also have corrosive and abrasive properties (Olotuah and Ofuya, 2010). Cobbinah and Osei-Owusu (1988) reported that defatted neem seed powder applied as dust on soil around the plant reduced the incidence of *M. vitrata* and increased pod yield. Degaonkar *et al.* (1988) obtained the highest benefit cost ratio with 5 % neem leaf extract. Ivbijaro and Bolaji (1990) also observed that pod borer damage was reduced by four sprays of *A. indica* or *Piper guineense* extracts.

2.7.4 Use of 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 and Medaigedu, 1988). Chemical control is the only method employed at present on a large scale for the management of insect pest of cowpea in Nigeria especially those infesting the flower and pods (Oyewale, 2014). Because of the persistent nature of organochlorine

insecticides, the organophosphate group is an alternative and Monocrotophos prove quite effective in spite its high mammalian toxicity, synthetic Pyrethroids are promising in *Maruca* control (Sharma, 1998).

The advantage of Pyrethroids includes high potency to insect pest, low mammalian toxicity and short resistance, they caused minimum disturbance to the environment and make possible the production of crops devoid of residues. Lal *et al*. (1988) reported that two sprays of Dimethoate 0.05% and Monocroptophos 0.05% are effective against *M. vitrata*. According to Rahman and Rahman (1988), four sprays of Cypermethrin 0.008 percent (1^{st} at flower initiation, 2^{nd} at 50 percent flowering, 3^{rd} at 100 percent flowering and the 4^{th} at 100 percent pod set) are effective against *Maruca* with the highest benefit cost ratio of 6.23 in pigeon pea.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

Two fields and screen house experiments were conducted during the 2014 cropping season at the Institute for Agricultural Research (IAR) Farm at Samaru, Zaria (11^{o} 11, 7^{o}38 E) in the northern Guinea Savanna of Northern Nigeria.

3.2 Mass Rearing of *Maruca vitrata* for Field and Screen House Infestation

Pupae of *M. vitrata* were obtained from a stock culture in the *Maruca* rearing laboratory at the Department of Crop Protection, Ahmadu Bello University (ABU) Zaria, for mass rearing. They were placed in open Petri dishes that were incubated in (30 x 30 x 30 cm) wire mesh cage with cloth sleeves at the rate of 200 pupae per cage, having sides of fine screen and a glass top and kept at room temperatures 21 to 25°C and ±70-80% relative humidity. The adults that emerged inside the cage were fed using filter paper moistened with 10 % glucose solution.

Four day old pairs of male and female moths of *Maruca* were transferred in groups of five individuals to transparent plastic cup (3 cm diameter x 35 cm height) and kept for 24 hours to allow for mating and oviposition which occurred on the inner surface of the cups. Ovipositing females were fed with 10 % glucose solution moistened with water; the filter paper was replaced every 24 hours. Cups carrying eggs were kept under the same experimental conditions until the eggs hatched. Larvae were transferred using camel brush to large cylindrical plastic containers (9 cm diameter x 12 cm height) provided with artificial diet (Table 1) prepared according to Jackai and Raulston, (1988) and allowed to develop through five instars until pupation. Pupae were collected and placed in a

laboratory rearing cage for emergence of adult. The same procedure was used for the mass production of larvae used for the subsequent field infestation.

3.3 Experiment I: Determination of Economic Injury Level in the Field

3.3.1 Field establishment of crop

The fields were sprayed with Glyphosate herbicides to get rid of weeds. The fields were disc harrowed and ridged. Single Super Phosphate fertilizer was applied prior to planting at 31.5 kg P_2O_5 ha^{-1} for proper root development. SAMPEA 7 variety characterized by large, light brown to dark brown seed, rough seed coat texture, adapted to Savanna and forest zone, medium maturing (90-100 days), with estimated yield of 1.5-2.5 tonnes per ha, Semi-upright, susceptible to scab, Bacteria Blight, Septoria leaf Spot, susceptible to beetles, thrips, *Maruca* pod borer, pod sucking bugs (Anonymous, 2015) was used. The area marked out for the experiment consisted of four replications (blocks) and each replication consisted of six plots each measuring 3 m× 3 rows = 9 m^2. Plots were separated by a 1.5 m wide border margin.

The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. Three seeds were sown per hole at the spacing of 75cm by 20cm. Seedlings were thinned to two plants per stand at 2 weeks after sowing (WAS). The plants on one meter length ridge were covered with screen mesh cages of size 1.0 m x 0.5 m x1.0 m as adopted from Egwurube (2004) for each treatment before flower bud initiation to avoid natural infestation. The cages were designed in such a way that they did not interfere with ventilation and aeration of the growing plants within the mesh. The bottom edges of the cages were inserted into the soil in all sides to check the escape or entry of other insects.

Table1: Composition of synthetic rearing diet for *M. vitrata* in the laboratory

Ingredients	Quantity for 4-litre diet
Sterile Water	4L
Agar-agar	59.2 g
Cowpea flour	400 g
Wheat germ	127.2 g
Bog Wesson salt	38 g
Sorbic acid	3.5 g
Methyl P-hydroxide	5.7 g
Acetic acid (Glucidal)	45 g
Ascorbic acid	25 g
Aureomycin	3.88 g
Potassium Hydroxide	19 ml
Formaldehyde	26 ml
Research Sugar	46 g

(Source: Jackai and Raulston, 1988).

3.3.2 *Maruca* larvae infestation

Different levels of larval populations were used in artificial infestation to determine the economic injury levels (E.I.L) of *M. vitrata* according to Pedigo and Hagley (1992). During field infestation, *Maruca* at the first instars stage were placed directly on the flower buds at between 6.00 and 7.00 a.m. A camel hairbrush was used to transfer the larvae from a holding container to the flower bud of cowpea; different larval densities (0, 25, 50, 75, 100 and 125 larvae per plant) were released at flower bud initiation stage, 50 % flowering and 50 % podding to maintain constant population till the maturation stage of the pod.

3.3.3 Damage assessment and data collection

The total number of pods produced, number of damaged pods was recorded, and the presence of hole or larvae was used as index of *Maruca* damage in the pods. At maturity 65-90 days pods were harvested with hand into labelled polythene bags, sundried, shelled and weighed. Weight of grains from all the covered plants in each cage was determined. Relationship between the larval density and grain yield were determined by regression analysis. Yield data were extrapolated to kg ha^{-1} and yield losses due to different larval rate were derived by deducting the yield of respective larval rate from the yield of untreated control (where no larvae were released). The monetary values of yield losses were determined according to the prevailing market price of cowpea grains at Zaria just after harvest. Three spray applications of Cypermethrin, Dimethoate, Chlorpyriphos, Cypermethrin plus Dimethoate and Imidachloprid at 0.5 l/ha according to Oyewale, (2014) were considered for calculating the cost of insecticidal applications.

The economic injury level for pod borer larvae were calculated by regression equation

$$Y = a + bx,$$

Where,

$Y_=$ yield per cage,

a = a constant (the y intercept),

b = yield loss per larva,

x = number of larvae per cage.

$$EIL = \frac{\text{Gain threshold}}{\text{Yield reduction per larva}}$$

$$\text{Gain threshold} = \frac{\text{Management cost ha}^{-1}}{\text{Market value of grain kg}^{-1}}$$

For calculating management cost, the cost of application of three insecticides spray and application cost including labour charges were considered. The costs of insecticides were determined and three applications were used for one hectare.

3.4.0 Experiment II: Determination of Economic Injury Levels under Screen House Condition

To determine the economic injury levels, seed of cowpea variety SAMPEA 7 was sown under screen house condition at IAR, Samaru, Zaria. The cowpea seed was sown in pots (measuring 18 cm diameter and height of 19 cm) at the rate of three seeds per pot using sterilized soil. Seedlings were thinned to two plants per stand at 2 WAS. Single Super Phosphate fertilizer (18% P_2O_5) was applied prior to sowing at the rate of 31.5 kg P_2O_5 ha^{-1} to promote proper development of root.

3.4.1 Colony establishment

A culture of *Maruca* larvae was established by collecting the first instar larvae of *Maruca* from the insect rearing laboratory of Department of Crop Protection, A.B.U. Zaria and this was used to infest the plants inside the wooden cages. The cage consisted of a wooden frame measuring 50 cm× 50 cm × 50 cm covered with screen mesh, the base were made of solid wood plank to prevent the escape and entry to prevent infestation from outside. The plants were infested with six different density levels of 5, 10, 15, 20 and 25 first instar larvae of *M. vitrata* per plant at flower bud initiation stage, 50% flowering and 50% podding. The experiments were laid out in Complete Randomized Design (CRD) with four repetitions. Infestations were done between 6.00 and 7.00 a.m. First instar larvae were harvested from the container using camel hairbrush to transfer the larvae to the flower buds of cowpea.

3.4.2 Calculation of economic injury levels

The EIL was computed based on the procedure given by (Pedigo and Hagley, 1992) as described earlier under No 3.3.3 of Experiment I.

3.5 Experiment III: Evaluation of Cowpea Varieties for Resistance to *Maruca vitrata*

A total of twelve Cowpea Varieties obtained from cowpea breeders of the Institute for Agricultural Research Samaru, Zaria were evaluated for resistance to *M. vitrata* SAMPEA 8, 9, 10, 11, 12, 14 and 15, are early varieties maturing in 65-90 days. SAMPEA 1, 4 and 7, are medium varieties that mature in 90-100 days, while SAMPEA 6 and Wild variety which are late varieties that mature in 90- 110 days.

3.5.1 Field establishment and experimental layout

The field was disc harrowed and ridged at 75 cm apart single super phosphate fertilizer was applied prior to planting at the rate of 31.5 kg P_2O_5 ha^{-1} to boost the growth and proper root development. The varieties were sown at three different sowing dates on 7th, 21st August and 4th September 2014, respectively. The experiments were laid out in Randomized Complete Block Design (RCBD) with three replications. The plots were sprayed with Glyphosate herbicides to get rid of weeds. The varieties were sown in two rows per plot each measuring 3 m in length with spacing of 20 cm x 75 cm. Each plot of two rows was separated by 1.5 m border margin. Similarly, the replicates were separated by 1.5 m as unplanted path. Two seeds of these cowpea varieties were sown per hole. Two hand weeding was carried out manually with hoe at three weeks intervals beginning at 3 WAS. No insecticide was applied as the studies were under natural infestation conditions.

3.5.2 Data collection

Determination of the levels of resistance of the varieties to incidences of *M. vitrata* on cowpea were based on pods damage, seed damage, larval population in flowers and grain yield at harvest. Infestation of cowpea flowers by *Maruca vitrata* larvae was assessed at 45 days after planting. Twenty flowers were randomly selected from the two inner cowpea rows. The flowers were carefully opened and examined on the spot for *Maruca* damage at 6-7 a.m. Presence of holes, frass or larvae in a flower was used as index of *Maruca* infestation. Observation on pod damage was done three times, at 5 days intervals beginning at 8 WAS. The mean score for the 20 flowers was calculated and recorded.

At maturity, 65-90 days after sowing, pods from each plot were harvested, sundried for three days and shelled. The dry grains in each plot were weighed with a weighing balance

and the weight recorded. The yield per plot was extrapolated to kg ha^{-1}. Data collected on total grain yield per variety from each plot were recorded. Based on the percent pods damage, the damage score for each variety was given resistance rating by Jackai and Singh (1988) as modified in Table 2.

3.5.3 Data analysis

Damage percentage was subjected to arcsine transformation before analysis of variance. All data were analyzed using Analysis of Variance (ANOVA) and means were separated using Student Newman's Keuls (SNK) ($P<0.05$) test.

Table 2: Scale for rating *Maruca vitrata* damage to cowpea

	Pod damage	Resistance Score (%)
1-	Highly Resistant (HR)	0.0 - 20.0
2-	Resistant (R)	20.1 - 40.0
3-	Moderately resistant (MR)	40.1 - 60.0
4-	Susceptible (S)	60.1 - 80.0
5-	Highly susceptible (HS)	80.1 - 100.0

Modified Jackai and Singh (1988)

CHAPTER FOUR

4.0 RESULTS

4.1 Infestation of *M. vitrata* larvae on cowpea production under field screen cage

4.1.1 Effect of *M. vitrata* larvae infestation on pods number produced, damaged pods, percentage pods damage and grain yield per cage in 2014 at Samaru.

There were significant differences on number of pods produce ($p \leq 0.05$) among cowpea plants infested with 25, 50, 75 larvae and untreated control (Table 3). However, 25, 50 and 75 larvae statistically recorded similar number of pods which were at par with 100 larvae per meter row length. A lower number of pods were produced from 125 larvae per row but was also statistically similar with 100 larvae. However, there was significant difference ($p \leq 0.05$) between larval densities and untreated (control) but no significant differences existed among the larvae treatments on number of pods damaged.

On the other hand, cowpea plants caged with 100 and 125 larvae recorded the highest percentage pods damage. The 50 and 75 larvae populations statistically gave similar percentage pods damage. The least percentage pods damage was recorded with untreated control. Grain weight was highest in untreated control cage which was statistically ($p \leq 0.05$) different from cage infested with 25 larvae. However, the plants infested with 75 and 100 larvae per cage statistically produced similar grain weight; the lowest grain weight per cage was recorded with 125 and 100 larval densities per cage (Table 3).

4.1.2 Effect of *M. vitrata* larvae infestation on healthy grains, damaged grain weight, percentage grain damage and 100 seeds weight per cage of cowpea in 2014 at Samaru

The result showed that there were significant differences ($P \leq 0.05$) between untreated control and 25 larval densities (Table 4).

Table 3: Effect of *M. vitrata* larvae infestation on number of pods, damaged pods, percentage pods damage and grain yield of caged cowpea in 2014 at Samaru

Density of larvae/cage	Pod number /cage	Damaged pods /cage	Damaged pods/cage (%)	Grain yield (kg ha^{-1})
0	79.00[a]	1.00[b]	1.00[e]	153[a]
25	51.25[b]	14.50[a]	29.00[d]	844[b]
50	45.25[b]	19.75[a]	50.25[c]	664[c]
75	36.75[bc]	19.75[a]	66.50[bc]	389[d]
100	34.50[cd]	19.00[a]	82.00[ab]	297[de]
125	15.50[d]	12.50[a]	97.50[a]	223[e]
Mean	42.04	14.42	54.38	659
S.E±	4.68	1.70	5.49	34.2

Means within the same column followed by different letter(s) are significantly different at $p \leq 0.05$ of Student Newman's Keuls (SNK) test.

Table 4: Effect of *M. vitrata* larvae infestation on healthy and damaged grain weight, percentage grain damage and 100 seed weight of caged cowpea in 2014 at Samaru

Density of larvae /cage	Healthy grain (g/cage)	Damaged grain weight(g/cage)	Damaged grains (%)	100 seed weight (g)
0	114.63[a]	1.00[b]	1.00[c]	19.53[a]
25	55.63[b]	7.63[a]	12.00[bc]	18.67[a]
50	44.70[c]	5.13[a]	10.00[bc]	15.63[bc]
75	24.48[d]	5.45[a]	18.75[b]	13.95[cd]
100	15.43[e]	6.80[a]	32.00[a]	11.56[d]
125	9.75[e]	6.95[a]	41.75[a]	11.08[d]
Mean	44.10	5.49	19.25	14.90
S.E±	2.14	1.07	3.48	1.06

Means within the same column followed by different letters are significantly different at $p \leq 0.05$ of Student Newman's Keuls (SNK) test.

Similarly, among the larval treatments, significant difference was observed between 50 and 75 larval density. The least weight of healthy grain was recorded with 100 and 125 larvae per caged. On the other hand, there were significant differences ($p \leq 0.05$) between larval treatments and untreated control on the weight of damaged grain, but no significant difference among the larval treatments.

Cowpea plants caged with 100 and 125 *Maruca* larvae had higher ($P \leq 0.05$) percentage grain damage than 75 larval densities. However, there was no significant difference among the 25, 50 and75 larval densities and untreated control. On weight of 100 grains, 25 larvae of *Maruca* and untreated control had significantly higher ($P \leq 0.05$) grain weight compared with 50 larval densities. However, the least grain yield was recorded on plants caged with 100 and 125 larvae.

4.2.0 Infestation of *M. vitrata* larvae on cowpea under screen house condition in 2014 at Samaru

4.2.1 Effect of *M. vitrata* larvae infestation on flowers production, damaged flowers, pods produced and damaged pods per cage of cowpea under screen house

There was no significant difference among the larval treatments and untreated control in the number of flowers produced per cage (Table 5). With respect to flowers damaged, there was a significant difference ($P \leq 0.05$) between the larval densities. The 15, 20 and 25 number of larvae released per cage had higher number of damaged flowers compared with 5 and 10 larval densities.

There was significant difference ($P \leq 0.05$) between untreated control and 5 larval densities. Infestation by 5 and 10 larvae statistically had similar number of pods and the least number of pods was recorded on plants caged with 15, 20, and 25 larval densities.

Table 5: Effect of *M. vitrata* larvae infestation on produced flowers and damaged flowers, produced pods and damaged pods of cowpea under screen house

Density of larvae/ cage	Produced flowers /cage	Damaged flowers/cage	produced pods /cage	damaged pods /cage
0	11.00	1.00[c]	7.25[a]	1.00[c]
5	10.00	3.25[b]	5.25[b]	4.74[a]
10	9.00	4.00[b]	4.75[bc]	3.73[ab]
15	6.25	5.75[a]	3.50[c]	2.50[bc]
20	7.00	6.00[a]	3.50[c]	2.50[bc]
25	7.75	6.25[a]	1.50[c]	1.15[b]
Mean	8.25	4.79	3.79	2.67
S.E±	1.88	0.56	0.66	0.58

Means within the same column followed by different letters are significantly different at $p \leq 0.05$ of Student Newman's Keuls (SNK) test.

On the other hand, number of pods damaged was higher ($p \leq 0.05$) on plants infested with 5 and 10 larvae but was statistically similar to that of 15, 20 and 25 larvae. The least number of pods damaged was recorded with the untreated control.

4.2.2 Effect of *M. vitrata* larvae infestation on percentage pods damage, grain yield and damaged grain weights and percentage grain damage per cage of cowpea under screen house

The result showed that there were no significant differences among the larval densities, but untreated control had least percentage pods damaged than all the larval densities. Similarly, there was significant difference ($p \leq 0.05$) between larval densities and untreated control, but no significant difference among the larval treatment on grain weight kg per hectare (Table 6).

There was significant difference ($p \leq 0.05$) among the larval densities. 25 larval densities had higher weight of damaged grain compared with untreated control, but no significant difference was recorded from the other larval densities. On the other hand, there was significant difference ($p <\leq 0.05$) between larval densities and untreated (control) on percentage grain damaged, but no significant differences among the larval densities.

4.3 Economic Injury Levels (EILs)

To calculate the EIL it was necessary to know not only the rate of yield reduction in question but also the cost of controlling the insect and market price of the crop. In the year under review one litre of Cypermethrin cost ₦ 900.00. The field was sprayed three times at rate of $^1/_2$ litre / spray. For spraying half litre three times (₦900.00 ÷ 2 = N450.00 × 3 = ₦1, 350.00). Application cost and labour for the three applications = ₦1, 200.00 + ₦1, 350.00 = ₦2, 550.00

Table 6: Effect of *M. vitrata* larvae infestation on percentage pods damage, grain yield, and damaged grain weight and percentage grain damage of cowpea per cage under screen house

Density of larvae /cage	Damaged pods/cage (%)	Grain yield (kg ha^{-1})	Damaged grain(g/cage)	Damaged grain /cage (%)
0	1.00[b]	120[a]	1.00[b]	7.75[b]
5	81.00[a]	549[b]	1.58[ab]	40.38[a]
10	100.00[a]	543[b]	1.25[ab]	31.18[a]
15	93.00[a]	456[b]	1.50[ab]	49.78[a]
20	87.00[a]	516[b]	2.05[ab]	53.93[a]
25	100.00[a]	486[b]	2.25[a]	63.43[a]
Mean	77.21	625	1.60	44.40
S.E±	6.35	18.0	0.27	8.26

Means within the same column followed by different letters are significantly different at $p<0.005$ of Student Newman's Keuls (SNK) test.

The market price of cowpea in December/January 2014 was ₦400.00 per *tiya* (a *tiya* is a local measure which weighed about 2.5 kg). Therefore, the market price of cowpea per kg was ₦ 400.00 ÷ 2.5 = ₦160.00 EIL = $\frac{Gain\ threshold}{Yield\ reduction\ per\ larva}$

Gain threshold = $\frac{\text{management cost } \square ha^{-1})}{\text{Market value of grain } \square kg^{-1})} = \frac{2{,}550\ \square ha^{-1})}{160\ \square kg^{-1})}$ = 15.94 kg ha^{-1}

The yield infestation relationship was obtained by regression equation (Y= a+ bx) (Figures 1, 2, 3, and 4) and this was based on the ability of different *Maruca* larval densities to cause grain weight loss (Y) on cowpea both in screen house and field cages, and cost of protection of cowpea with five different insecticides sprays applied three times. Cost of protection (insect management per hectare) using five different insecticides and corresponding gain threshold were substituted in the regression equation to obtained EIL value presented in Table 7. EIL for screen house were 0.13, 0.14, 0.14, 0.13, and 0.15 per cage, when Cypermethrin, Dimethoate, Chlorpyriphos, Imidacloprid and Cypermethrin + Dimethoate respectively were sprayed. In the field cage the EIL value were 0.14, 0.15, 0.14, 0.14 and 0.16, respectively.

4.4.0 Evaluation of Some Cowpea Varieties for Resistance to *M. vitrata* Infestation

4.4.1 The effect of *M. vitrata* larval population and pods produced at three sowing dates

The result showed that there were no significant differences among the improved cowpea varieties, between improved cowpea varieties and wild variety on mean number of *Maruca* larvae per plant at first sowing date (Table 8). However, at the second sowing date SAMPEA 6 and SAMPEA 7 had significantly higher ($p \leq 0.05$) mean number of *M. vitrata* larval per plant when compared with wild cowpea variety (*Vigna dekendtiana*).

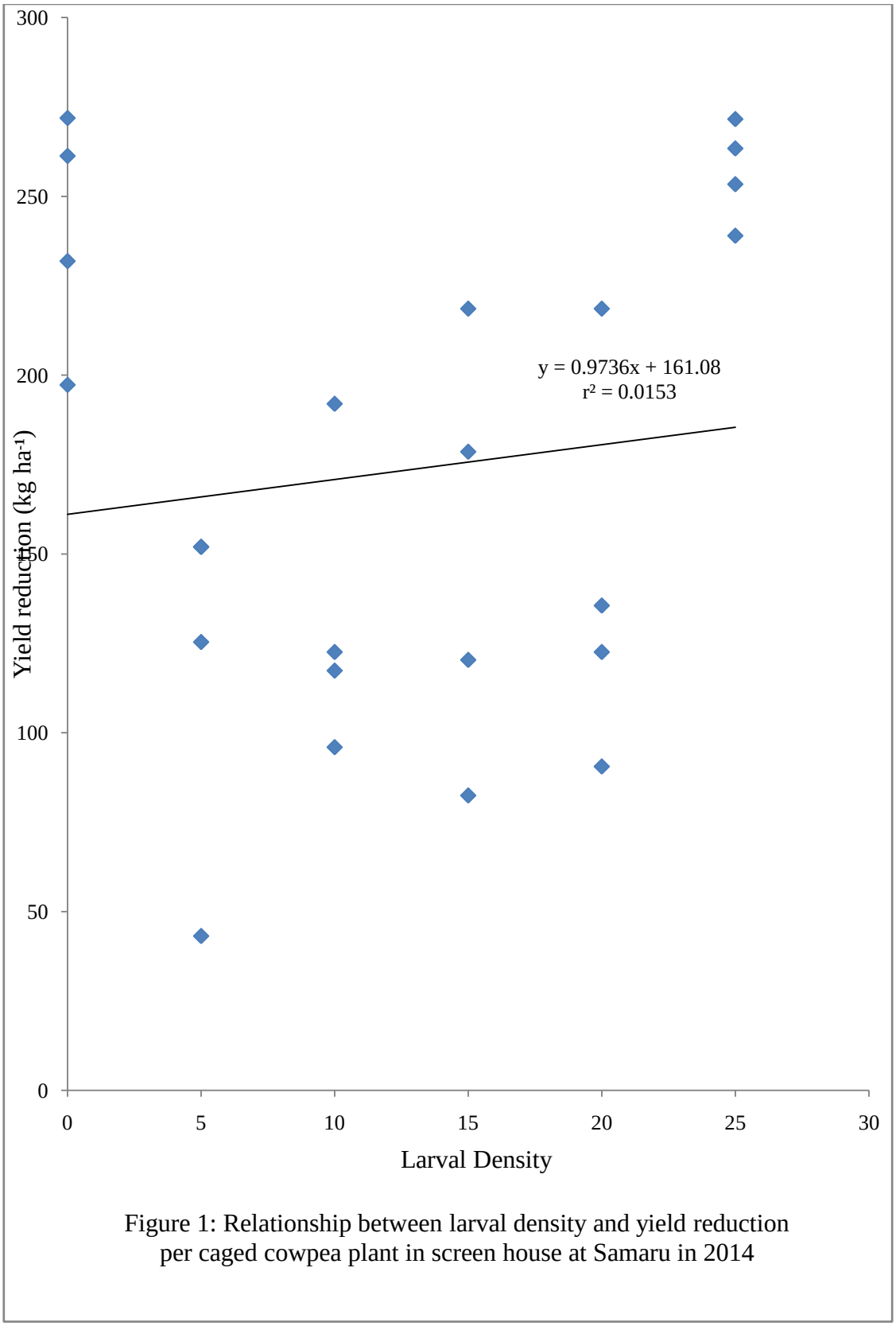


Figure 1: Relationship between larval density and yield reduction per caged cowpea plant in screen house at Samaru in 2014

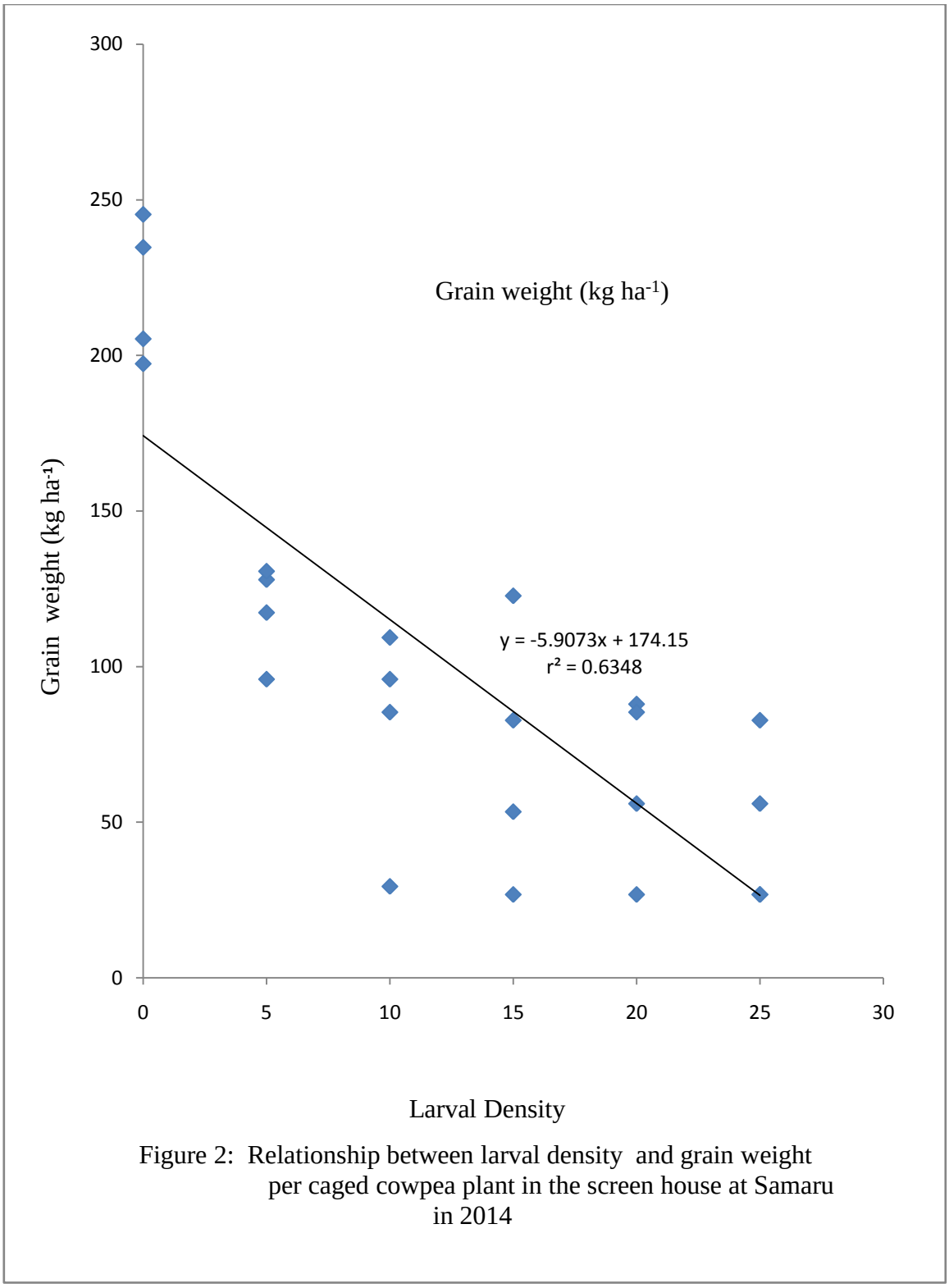


Figure 2: Relationship between larval density and grain weight per caged cowpea plant in the screen house at Samaru in 2014

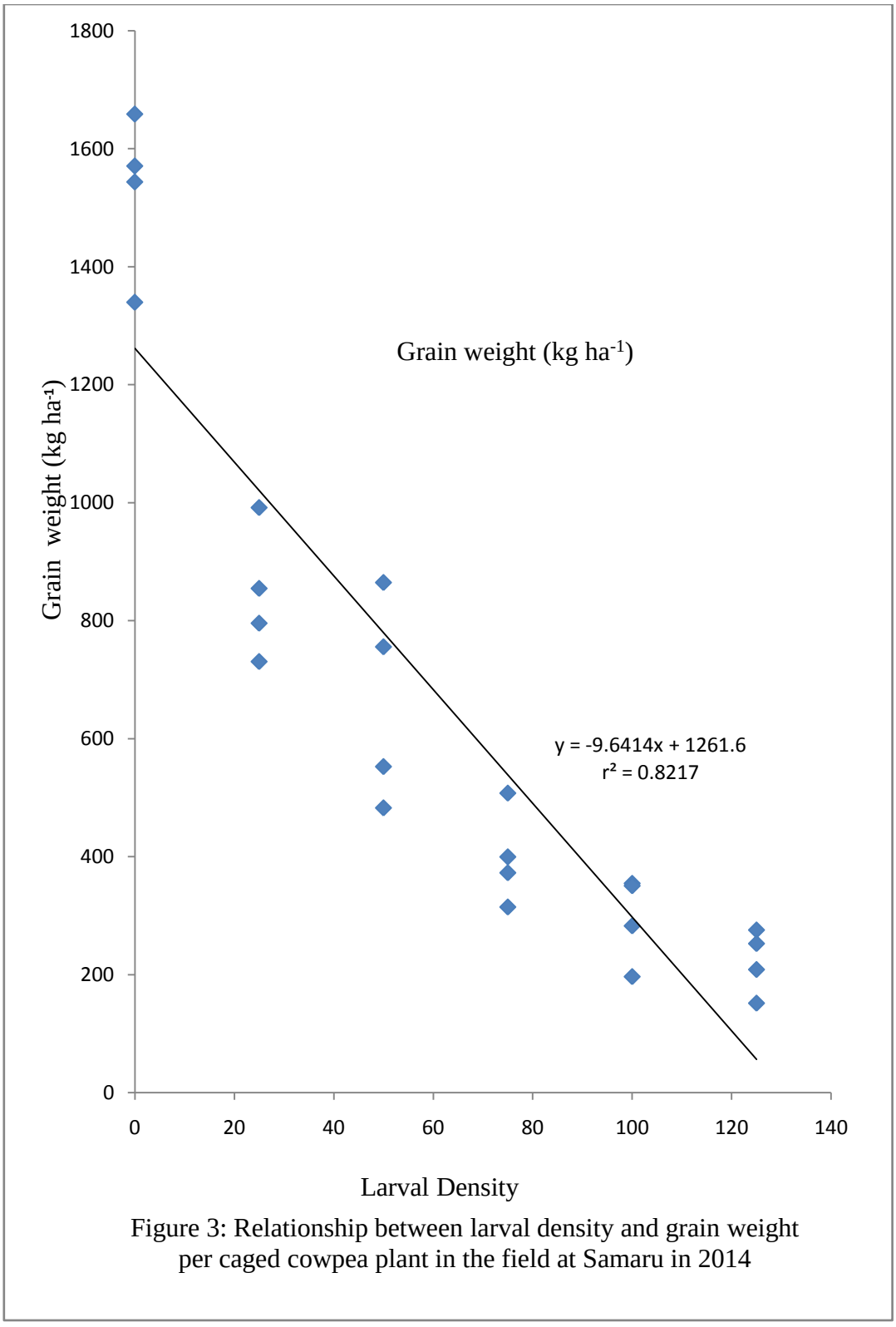


Figure 3: Relationship between larval density and grain weight per caged cowpea plant in the field at Samaru in 2014

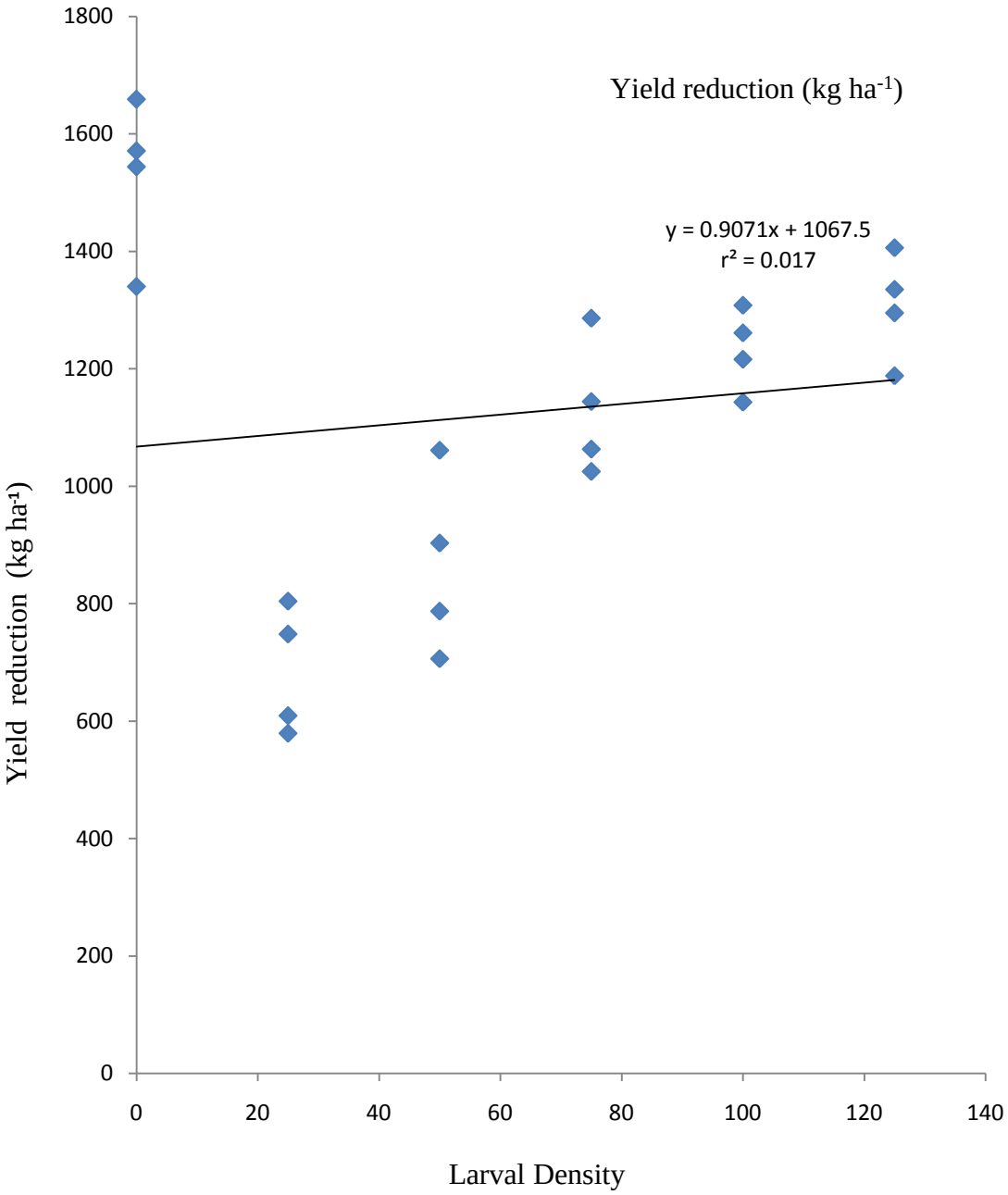


Figure 4: Relationship between larval density and yield reduction per caged cowpea plant in the field at Samaru 2014

Table 7: Economic injury levels (EILS) of *M. vitrata* larvae based on regression of yield loss (Y) on the number of larvae controlled with different insecticides at Samaru in 2014

	Screen House Yield reduction by larvae	Field Yield reduction by larvae
Regression equation	Y = 0.973X + 161.0	Y = 0.907X+1067.5
Coefficient of Determination	r^2 =0.015	r^2 =0.017
Insecticides		
Cypermethrin		
Mgt cost ₦ ha^{-1}	2,550	2, 550
Gain threshold (kg ha^{-1})	15.9	15.9
EIL	**0.13**	**0.14**
Dimethoate		
Mgt. cost ₦ ha^{-1}	2,700	2,700
Gain threshold (kg ha^{-1})	16.9	16.9
EIL	**0.14**	**0.15**
Chlorpyriphos		
Mgt. cost ₦ ha^{-1}	2,700	2, 700
Gain threshold (kg ha^{-1})	16.9	16.9
EIL	**0.14**	**0.14**
Imidachloprid		
Mgt. cost ₦ ha^{-1}	2,550	2,550
Gain threshold (kg ha^{-1})	15.9	15.9
EIL	**0.13**	**0.14**
Cypermethrin plus Dimethoate		
Mgt. cost ₦ ha^{-1}	3,000	3,000
Gain threshold (kg ha^{-1})	18.8	18.8
EIL	**0.15**	**0.16**

Price of cowpea grain = ₦160.00/kg, Insecticide 0.5l/ha was used and labour =₦1200.00
Source: Chemicals used and recommended rate, were from Unpublished M.Sc. dissertation by Oyewale, Rasheed Olakitan, (2014). Department of Crop Protection, Ahmadu Bello University, Zaria

Table 8: Effect of *M. vitrata* infestation population and number of pods produced at three sowing dates of cowpea per plot at Samaru in 2014

	Mean No. of *M. vitrata* larvae/plot			Number of pods produced/plot		
Cowpea varieties	1st	2nd	3rd	1st	2nd	3rd sowing
SAMPEA 1	3.33	4.33^{ab}	4.67^{cde}	136^{c}	112^{b}	88.3
SAMPEA 4	5.33	6.33^{ab}	2.00^{e}	136^{c}	128^{b}	105.3
SAMPEA 6	5.33	8.33^{a}	11.33^{a}	192^{cb}	184^{b}	94.0
SAMPEA 7	4.33	8.00^{a}	9.67^{abc}	143^{c}	202^{b}	155.6
SAMPEA 8	3.67	3.33^{ab}	6.67^{a-e}	179^{cb}	147^{b}	100.0
SAMPEA 9	4.00	5.67^{ab}	6.67^{a-e}	197^{cb}	172^{b}	107.6
SAMPEA 10	4.33	6.67^{ab}	8.00^{a-d}	152^{cb}	141^{b}	137.0
SAMPEA 11	1.67	4.33^{ab}	5.33^{b-e}	278^{cb}	201^{b}	97.3
SAMPEA 12	6.67	4.00^{ab}	3.67^{de}	232^{cb}	177^{b}	107.3
SAMPEA 14	4.33	3.00^{ab}	4.00^{de}	289^{b}	164^{b}	131.6
SAMPEA 15	5.00	7.00^{ab}	10.33^{ab}	178^{cb}	177^{b}	126.3
Wild Cowpea	1.00	1.33^{b}	1.33^{e}	533^{a}	463^{a}	100.0
Mean	4.08	5.19	6.14	220	189	112.4
S.E±	1.29	1.20	1.19	29.9	38	14.2

Means within the same column followed by different letters are significantly different at P<0.05 of Student Newman's Keuls (SNK) test.

1st sowing - 7th August, 2014
2nd sowing - 21st August, 2014
3rd sowing - 4th September, 2014

At the third sowing date, the varieties differed significantly and SAMPEA 6 had higher ($P \leq 0.05$) mean number of larvae than SAMPEA 6, SAMPEA 7 and SAMPEA 15 but was statistically similar with SAMPEA 8, SAMPEA 9, and SAMPEA 10. SAMPEA 1, 11 and 14 have significantly similar mean number of *Maruca* larvae. The least mean number of *Maruca* larvae was recorded on wild cowpea variety and SAMPEA 4.

Wild cowpea had significantly higher ($P \leq 0.05$) number of pods compared with all others. All other cowpea varieties statistically produced similar number of pods but the least number of pods was recorded on SAMPEA 1, SAMPEA 4, and SAMPEA 7 at first sowing. However at the second sowing date, there was significant difference ($P \leq 0.05$) between the improve cowpea varieties and wild cowpea but no significant difference was recorded among the improved varieties. At the third sowing there was no significant difference among the improved cowpea varieties and between the improved cowpea varieties and wild cowpea.

4.4.2 Effect of *M. vitrata* infestation on number of pods damaged and total grain weight at three sowing dates of cowpea

At first sowing date there was significant difference ($P \leq 0.05$) between improved cowpea varieties and wild cowpea variety on the number of pod damage Table 9, but no significant difference was recorded among the improved cowpea varieties. At the second sowing date, wild cowpea variety had significantly lower number of pods damage than all the improved cowpea varieties but no significant difference among the improved cowpea varieties. However, SAMPEA 6, 7, 9, and 15 had higher number of pods damage compared with wild cowpea variety, no significant difference was recorded among the improved cowpea varieties at third sowing date.

Table 9: Effect of *M. vitrata* infestation on damaged pods and total grain weight (g) per plot at three sowing dates of cowpea at Samaru in 2014

	Number of pods damaged/plot			Total grain weight (g)/plot		
Cowpea varieties	1st	2nd	3rd	1st	2nd	3rd sowing
SAMPEA 1	15.33[a]	23.67[a]	22.00[ab]	912.30[a]	867.00[a]	574.60[b]
SAMPEA 4	20.67[a]	19.33[a]	20.67[ab]	912.60[a]	756.10[a]	482.90[b]
SAMPEA 6	18.33[a]	25.33[a]	34.67[a]	694.40[a]	807.46[a]	471.50[b]
SAMPEA 7	15.33[a]	20.00[a]	32.33[a]	718.00[a]	635.50[a]	443.60[b]
SAMPEA 8	10.00[ab]	16.33[a]	17.00[ab]	940.90[a]	786.90[a]	553.20[b]
SAMPEA 9	21.00[a]	20.33[a]	30.67[a]	882.20[a]	927.10[a]	507.20[b]
SAMPEA 10	20.00[a]	23.33[a]	23.33[ab]	945.80[a]	710.00[a]	497.20[b]
SAMPEA 11	16.33[a]	15.67[a]	21.67[ab]	735.90[a]	768.20[a]	539.70[b]
SAMPEA 12	19.33[a]	23.67[a]	21.33[ab]	994.70[a]	785.30[a]	434.36[b]
SAMPEA 14	16.33[a]	11.33[ab]	19.00[ab]	885.20[a]	777.90[a]	643.40[b]
SAMPEA 15	18.00[a]	21.33[a]	33.33[a]	770.20[a]	753.40[a]	892.30[a]
Wild Cowpea	2.67[b]	4.00[b]	5.33[b]	56.70[b]	55.10[b]	38.70[c]
Mean	16.11	18.69	23.44	787.55	719.15	505.91
S.E ±	3.10	3.11	3.92	96.36	83.91	81.12

Means within the same column followed by different letters are significantly different at P≤0.05 of Student Newman's Keuls (SNK) test.

1st sowing- 7th August, 2014
2nd sowing- 21st August, 2014
3rd sowing- 4th September, 2014

At first and second sowing dates, there was significant difference (P≤ 0.05) between improved cowpea varieties and wild cowpea variety on grain weight but no significant difference was recorded among the improved cowpea varieties, the same trend were observed at third sowing except SAMPEA 15 significantly produced highest grain weight compared with other improved cowpea varieties.

4.4.3 Effect of *M. vitrata* infestation on weight of grains damaged by *Maruca* and weight of 100 grains per plot

At the first sowing date, SAMPEA 7 showed significantly higher grain weight damage by *Maruca* compared with SAMPEA 10 and SAMPEA 15 but no significant difference among other improved varieties (Table 10). At second sowing SAMPEA 10 had higher (P≤0.05) grain damaged caused by *Maruca* than SAMPEA 4, 6, 8 and SAMPEA 14. Wild cowpea recorded the least grain weight damage by *Maruca*. Similarly, at the third sowing, there was significant difference (p≤0.05) among the improved cowpea varieties with SAMPEA 7 differing significantly from SAMPEA 4, 6 and SAMPEA 8, but no significant difference among the other improved cowpea varieties. Wild cowpea recorded the least grain weight damage.

The weight of 100 grain, differed significantly (p≤0.05) between the wild cowpea variety and improved cowpea varieties, but no significant difference among the improved cowpea varieties at first and second sowing dates. However, at third sowing date, varieties differed significantly SAMPEA 1 had the highest weight of 100 grains compared with SAMPEA 7, 9, 10, 11 and 15but no significant differences was recorded among other improved varieties. Wild cowpea had least 100 grain weight.

Table10: Effect of *M. vitrata* infestation on damaged grain weight and 100 seed weight per plot at three sowing dates of cowpea at Samaru in 2014

	Damaged grain weight (g)/plot			100 seed weight (g)/plot		
Cowpea varieties	1st	2nd	3rd	1st	2nd	3rd sowing
SAMPEA 1	11.03^{ab}	18.03^{ab}	35.33^{ab}	18.70^{a}	18.10^{a}	9.43^{a}
SAMPEA 4	10.37^{ab}	12.27^{b}	22.80^{b}	19.23^{a}	15.53^{a}	17.27^{ab}
SAMPEA 6	10.97^{ab}	13.27^{b}	23.77^{b}	17.60^{a}	16.30^{a}	15.53^{ab}
SAMPEA 7	16.73^{a}	17.97^{ab}	42.80^{a}	14.70^{a}	13.23^{a}	10.33^{b}
SAMPEA 8	10.03^{ab}	12.70^{b}	20.20^{b}	17.70^{a}	15.47^{a}	14.13^{ab}
SAMPEA 9	9.97^{ab}	18.23^{ab}	35.97^{ab}	18.03^{a}	14.20^{a}	9.43^{b}
SAMPEA 10	6.73^{b}	24.93^{a}	30.20^{ab}	16.17^{a}	18.37^{a}	11.50^{b}
SAMPEA 11	11.17^{ab}	21.27^{ab}	38.33^{ab}	14.97^{a}	12.53^{a}	11.77^{b}
SAMPEA 12	10.83^{ab}	21.87^{ab}	35.20^{ab}	18.50^{a}	17.43^{a}	15.53^{ab}
SAMPEA 14	10.63^{ab}	18.07^{ab}	36.90^{ab}	17.53^{a}	19.10^{a}	12.37^{ab}
SAMPEA 15	8.57^{b}	12.13^{b}	29.37^{ab}	16.63^{a}	15.17^{a}	11.20^{b}
Wild cowpea	1.00^{c}	1.27^{c}	1.57^{c}	3.37^{b}	3.30^{b}	3.40^{c}
Mean	9.84	16.00	29.37	16.18	14.89	12.66
S.E ±	1.40	2.15	3.72	1.15	1.46	1.65

Means within same column followed by the same letters are significantly different at P<0.05 of Student Newman's Keuls (SNK) test.

1st sowing - 7th August, 2014
2nd sowing- 21st August, 2014
3rd sowing - 4th September, 2014

4.4.4 Effect of *M. vitrata* infestation on percentage grains damage and grain yield in kg ha^{-1} at three sowing dates of cowpea in 2014 at Samaru

At first sowing date, there was no significant difference on the percentage grain damage by *Maruca* among the improved cowpea varieties and between the improved cowpea varieties and wild cowpea variety Table 11. However, at second sowing date, SAMPEA 10 had significantly higher ($p \leq 0.05$) percentage grain damage than SAMPEA 4, SAMPEA 6, SAMPEA 8 and SAMPEA 14, but no significant difference was observed among other improved cowpea varieties and Wild cowpea variety. Similarly, SAMPEA 7 had higher ($p \leq 0.05$) percentage grain damage which was significantly different from SAMPEA 8 and SAMPEA15. No statistical difference among other improved cowpea varieties and wild cowpea variety.

There was significant difference ($p \leq 0.05$) between improved cowpea varieties and wild cowpea on the grain yield per hectare, but no significant difference recorded among the improved cowpea varieties at first and second sowing dates (Table 11). However, at third sowing date SAMPEA 15 had significantly higher ($p \leq 0.05$) grain yield compared with other improved cowpea varieties and the least grain yield was recorded on the wild cowpea.

4.4.5 Effect of *M. vitrata* infestation on percentage pods damage at three sowing dates of cowpea

The result showed that among the twelve cowpea varieties SAMPEA 1, SAMPEA 4, SAMPEA 6, SAMPEA 9, SAMPEA 10, and SAMPEA 15 recorded significantly higher pod damage across the three sowing dates compared to SAMPEA 7, SAMPEA 8, SAMPEA 11, SAMPEA 12 and SAMPEA 14 which were at par with each other.

Table 11: Effect of *M. vitrata* infestation on percentage grain damage and grain weight at three sowing dates of cowpea at Samaru in 2014

	Percentage grain damage/plot			Grain yield kg ha^{-1}		
Cowpea varieties	1st	2nd	3rd	1st	2nd	3rd sowing
SAMPEA 1	1.23	2.13^{ab}	6.60^{ab}	3048^{a}	2890^{a}	1915^{b}
SAMPEA 4	1.17	1.63^{b}	5.33^{ab}	3042^{a}	1744^{a}	1601^{b}
SAMPEA 6	3.97	1.63^{b}	5.57^{ab}	2315^{a}	2691^{a}	1572^{b}
SAMPEA 7	2.37	2.87^{ab}	10.47^{a}	2390^{a}	2119^{a}	1368^{b}
SAMPEA 8	1.27	1.67^{b}	3.73^{b}	3136^{a}	2623^{a}	1844^{b}
SAMPEA 9	1.27	2.17^{ab}	7.33^{ab}	2943^{a}	3091^{a}	1691^{b}
SAMPEA 10	1.07	3.63^{a}	6.97^{ab}	3160^{a}	2367^{a}	1658^{b}
SAMPEA 11	1.27	2.77^{ab}	7.60^{ab}	2453^{a}	2561^{a}	1766^{b}
SAMPEA 12	1.20	2.80^{ab}	8.80^{ab}	3316^{a}	2618^{a}	1448^{b}
SAMPEA 14	1.20	2.40^{b}	5.80^{ab}	2951^{a}	2593^{a}	2145^{b}
SAMPEA 15	1.17	1.63^{ab}	3.40^{b}	2568^{a}	2511^{a}	2974^{a}
Wild cowpea	2.33	2.27^{ab}	5.60^{ab}	1906^{b}	184^{b}	129^{c}
Mean	1.63	2.30	6.43	2626	2333	1676
S.E ±	0.76	0.38	1.33	321.	356	265

Means within the same column followed by different letters are significantly different at P≤0.05 of Student Newman's Keuls (SNK) test.

1st sowing- 7th August, 2014
2nd sowing- 21st August, 2014
3rd sowing- 4th September, 2014

The lowest pod damage was recorded in wild cowpea. Based on the pod damage, the cowpea varieties were given the resistance rating 1-5. The varieties SAMPEA 1, SAMPEA 4, SAMPEA 6, SAMPEA 9, SAMPEA 10, and SAMPEA 15 were categorized as susceptible varieties. SAMPEA 7, SAMPEA 8, SAMPEA 11, and SAMPEA 14 were categorized as moderately resistant and wild cowpea was rated as highly resistant. None of the cowpea varieties was highly susceptible to the *Maruca* pest attack as shown in Table 12.

Table 12 Relationship between percentage pods damage and resistance rating of twelve cowpea varieties against *Maruca* pod borer at Samaru in 2014

Cowpea varieties	Percentage pod damage	Resistance rating
SAMPEA1	19.44[ab]	Susceptible
SAMPEA 4	18.51[abc]	Susceptible
SAMPEA 6	20.09[a]	Susceptible
SAMPEA 7	14.63[bcd]	Moderately resistance
SAMPEA 8	11.29[d]	Moderately resistance
SAMPEA 9	17.14[abc]	Susceptible
SAMPEA 10	16.39[abc]	Susceptible
SAMPEA 11	13.30[cd]	Moderately resistance
SAMPEA 12	14.41[bcd]	Moderately resistance
SAMPEA 14	10.49[d]	Moderately resistance
SAMPEA 15	16.99[abc]	Susceptible
Wild cowpea	3.06[e]	Highly resistance
Mean	14.65	
SE±	1.79	

CHAPTER FIVE

5.0 DISCUSSION

The knowledge of economic threshold (ET) is used to determine whether an insect is to be classified as a pest or not (Pedigo, 1996). ET is the pest density at which control measures should be applied to prevent an increasing pest population reaching the Economic Injury Level (EIL). Economic Injury Level is the lowest number of insect that will cause economic damage. EIL were and are fundamental for a holistic approach to pest management (Adamu *et al.*, 2006). According to Ogunlana and Pedigo (1974), EIL is the amount of yield loss that constitutes minimum economic damage. The concept has been described as the pest population level, which causes damage equals to the gain threshold which is the ratio of protection cost and price of produce (Zahid *et al*., 2008). EIL was based on a significant linear regression equation model. In the present study the values of coefficient of determination (r^2) were high for both screen house and field cages and this offered a more reliable explanation for the nature of the association. This also implied that the *Maruca* larval damage significantly influenced grain yield with the increasing number of larvae.

The linear relationship indicates a yield reduction proportional to infestation and lack of compensation following the larval attack. In this study, gain threshold was worked out, based on the ratio of cost of pest control to the market price of produce. Thus, the concept of EIL was developed largely as a means for more rational use of insecticides (Adamu *et al*., 2005). Economically and ecologically, sound use of insecticides is essential in the current integrated pest management (Adamu *et al*., 2006). The results of this study showed that number of pods per plant at field cages ranged from 15.50 to 79.00 and

screen house cages ranged from 1.50 to 7.25. In both the field cages and screen house cages the difference among the various treatments were found significant indicating the effect of larval density on the pod formation.

Zahid *at al*. (2008) reported that there was no significant effect of *Maruca* density on chick pea. The percentage pod damage increased with increase in larval density. This corroborated with the reports of Reddy *et al.* (2001) who observed proportionate increase in damage of chickpea pods with increase in the larval population levels of *M. vitrata*. The regression between the number of larvae per plant and grain weight was negative and significant (r^2= 0.634 and r^2= 0.821) in screen house and field cages, respectively. Statistical analysis showed that the regression between the larval population and reduction in grain weight per plant was positive and significant (r^2=0.015 and r^2= 0.017) in both screen house and field cages, respectively.

Mallikarjunappa and Rajagopal (1991) reported linear relationship between the number of *Adisura atkinsoni* larvae and the per cent pod damage in field bean. In the present study the yield reduction per larva was 0.973 and 0.907 g per plant for both screen house and field cages respectively. These findings are also in conformity with that of Amarnath (2000) who reported a yield reduction of 1.61 g per plant for every increase in the larval number of *M. vitrata*. The EIL of the study was found to be 0.15 and 0.16 for both screen house and field cages, respectively. Zahid *et al*. (2008) had also reported a linear relationship between *Maruca* larval density and percentage grain yield in Mungbean and added that the EIL during 2006 and 2007 was 1.45 and 1.34, respectively when Cypermethrin was sprayed. The authors concluded that the mean two years of EIL value of the borer was 1.08 larvae per meters row respectively.

The cost involvement of pest control using Cypermethrin, Dimethoate, Chlorpyriphos, Cypermethrin+ Dimethoate at 0.5 liter/ha (3 sprays) was relatively moderate ₦2,550.00, ₦2,700.00, ₦2,700.00 and ₦3,000.00 including labour charges, respectively. The relationship between EIL and market value (price) was inversely related such that as market value increased EIL decreased and vice versa. EIL calculation should be based on current market value of crop (Adamu *et al.,* 2006). However, the market value of cowpea grain at Samaru, Zaria was ₦ 160.00/kg during 2014. Sharma and Lopez (1989) and Egwurube (2004) showed that EIL differed across season, stage of crop development cultivars and efficacy of insecticides used.

In this study the values of EIL in the screen house and field cages were found to range from 0.13 - 0.15 and 0.14 - 0.16, respectively using different insecticides. This was in conformity with Venkataiah *et al*. (1994) who reported EIL for *Helicoverpa armigera* Hub. in pigeon pea as 0.6 larvae/plant. Odak and Thakur (1975) reported that more than four larvae of *M. vitrata* per meter square in Chick pea at flowering stage caused economic injury. Ogunlana and Pedigo (1974) showed that when a young plant of soybeans in their trifoliate leaf stage was infested with *Empoasca fabae* one nymph per plant was economically injurious in terms of seed yield. Nath and Rai (1995) found EIL of green gram (*Vigna radiata* L.) pod borer, *Helicoverpa armigera* under natural condition to be 1.77 to 2.00 larvae per metre row length. In the present study, relatively lower values of EIL were estimated for *Maruca* larvae infestation for both screen house and field cages using different insecticides. It is evident that economic injury level being dynamic mainly depends on the market price of the produce and cost of plant protection, which vary from time to time, crop to crop and locality to locality.

Among the insecticides used in controlling *Maruca* larvae, the minimum and maximum EIL for both screen house and field cages were 0.13 and 0.16 attained when Cypermethrin, Dimethoate, Cypermethrin plus Dimethoate, Chlorpyriphos, Imidacloprid were sprayed, respectively. There seems to be no differences among the insecticides and between screen house and field cages. These findings are in agreement with that of Reddy *et al*. (2001) that reported EIL of *M. vitrata* in pigeon pea 0.78 to 0.80 larvae per plant. Prabhakar *et al.* (1998) found EIL of chick pea pod borer to be 0.9 and1.23 larvae per metre for unirrigated and irrigated crops respectively. However, Adamu *et al*. (2006) found that the EIL of ovipositing and feeding adults of head bug *Eurystylus oldi* on sorghum was 0.08 and 5.9 using, Cypermethrin respectively.

Similarly, Sharma and Lopez (1989) reported an EIL of 0.2 to 0.4 for CHS 1 using two to five sprays of Carbaryl against head bugs. In this study, the field cages had higher observed EIL estimates than screen house cages. This might be associated with the lower damage potential in field cages compared to screen house cages and higher management costs incurred in controlling field cages. Thus, EIL value increased with increase in the cost of protection.

The use of EIL to define the level of resistance of a newly released crop cultivar is critical. Insect resistant cultivars decreased insect pest abundance or delayed the time required by the insect to attain EIL or increased the EIL, depending on the mechanism of resistance and the criterion on which the EIL is based (Sharma *et al.,* 1999). If the EIL is based on damage, then the EIL would be the same for insect resistant cultivars and for susceptible cultivars (Sharma and Fronzamann, 2000). If it is based on larval damage

alone and the mechanism of resistance is antibiosis then the time taken by the insect to attain EIL will be prolonged by insect resistant cultivars (Sharma and Lopez, 1989). Ganapathy and Durairaj (1994) enumerated an EIL of 3.0 larvae per plant and combined threshold of 2 pairs each of *M. testulalis* and *Exelastis atomosa* per plant at 50 % flowering stages when both occurred together on pigeon pea. The pest population reduced grain yield at 5 and 25 levels of *Maruca* larvae per plant; it therefore appears that it is important to minimize serious insect pest damage to cowpea when the plants are at flowering and podding stage.

The cost of protection with five different insecticides and gain threshold value were substituted in the regression equation to obtain the EIL values. The value of EIL in the screen house was 0.15 larvae /plant; while in field cages was 0.16 larvae /plant. The result signified that even at very low population level the damage caused by *Maruca* larvae is economically significant. The EIL values presented in the present study may be due to high damage potential of *Maruca* larvae on this (SAMPEA 7) variety contrary to Afun *et al*. (1991) who reported that calendar based sprays resulted in less borer infestation than when sprays were based on economic threshold. Economic and ecologically sound use of insecticides is essential in current integrated pest management (Kamaru *et al*. 2010). Thus, the economic injury concept was developed largely as a means for more rational use of insecticides. It was designed to be most applicable in situation with discreet curative control measures (Pedigo, 2004).

5.1 Evaluation of some cowpea varieties for resistance to pod borer, *Maruca vitrata*

The present study was conducted to evaluate some cowpea varieties for resistance to *M. vitrata*. Significant differences were observed among cowpea varieties on some

parameters such as different sowing dates used for evaluating resistance to *Maruca*. The result of larval population on flower was a reflection of the distribution of *Maruca* in the field. In the present study there was no significant difference in the population of *M. vitrata* infestation at the first sowing date this could be attributed to the lower population of the *M. vitrata* early in August, which subsequently built-up as the season progressed (Ogah and Ogah, 2012). Result from this finding also indicated that the farmers should plant cowpea early to mid August to avoid late sowing which coincided with the peak period of *M. vitrata* infestation in the field (Alghali, 1993; Sharma and Franzamann, 2000). Similar results have been reported on cowpea in Uganda by Karungi *et al.* (2000). Other studies have also indicated that early planting reduced pest population of some crops, for example early season planted groundnut was shown to have low *Aphis craccivora* infestations, and consequently, little or no groundnut rosette disease (Naidu *et al.,* 1998).

Some cowpeas are less preferred for feeding, ovipositing and damage than others. SAMPEA 6 and SAMPEA 7 in the present study attracted the highest population of *Maruca* larvae on flowers and pods. This was attributed to insect pest preference or non preference for some cowpea genotypes which may possess characters that affect the behavior and selection pressure of the insect during search for food, shelter, and oviposition (Onyishi *et al*., 2013). This finding is supported by Stadler (1977) that reported biochemical factors tends to a large extent affect the behavior and metabolic process of pest while morphological factors mostly influence the mechanism of locomotion, feeding, oviposition, ingestion and digestion of pest. According to Painter 1951, Onyishi *et al.* (2013) heritable characteristics of some crops, race, species, clone or

individual may reduce the probability of successful utilization of that plant as a host by an insect species, race, and biotype.

Wild cowpea (*Vigna dekendtiana*), SAMPEA 1, SAMPEA 12, SAMPEA 14 had the least number of *Maruca* count recorded among cowpea varieties having cream to purplish flower that are less attractive to *Maruca* larvae. Similar findings have been reported by Ntonifor *et al*. (1996) on cowpea with purple flowers and soybeans with small yellow flowers. Fatokun and Singh (2001), reported that wild cowpea variety subsp. *dekindtiana* var. *pubescens* have been known to confer some degree of insect resistance on cowpea owing to the presence of hairs (hence the name *pubescens*) on the plants. Oghiakhe (1995) observed high levels of resistance to *Maruca* in some wild cowpea cultivars such as Tvu N 72 and Tvu N 73 using preference ratio. However, Koona *et al*. (2002) and Dabire- Binso *et al*. (2007) suggested that purple colour character was not responsible for the non preference mechanism in some varieties it might be due to presence of trichome on the pod surface providing a physical barrier to the insects. Result from this study indicated that early sown cowpea remains an important strategy for suppressing cowpea insect pests particularly legume pod borer in the field, if properly managed.

Pest control tactics that involve manipulating the insect environment are well known among traditional farmers. Several of these agronomic practices are used in different parts of the tropics, especially in Africa (Okigbo and Greenland, 1976). Improved crop cultivars and alteration in planting dates of crops have been reported as an effective strategy in reducing pest damage by a number of researchers (Karungi *et al*., 2000; Asante *et al*., 2001). *M. vitrata* needs denser canopy formation as hiding places for the larvae against predators (Oghiakhe *et al*., 1993). However, first sown cowpea varieties

probably may have passed the flowering and podding stage before the peak infestation of *M. vitrata* that occurs from early- September through November in northern Nigeria (Asante *et al*., 2001). This is supported by Fenemore (1982) who showed that resistant varieties may have high tolerance to pest damage.

The present study had shown that SAMPEA 4, SAMPEA 6, SAMPEA 7, SAMPEA 9, SAMPEA 10 and SAMPEA 15 had significantly higher number of pod damage compared to other varieties. This could be attributed to their susceptibility to the insect pest infestation. Wooley and Evans (1979) suggested that pod damage and ratio of grain yield could be used as selection criterion to evaluate cowpea genotype for resistance to pod borer. The discrepancy obtained among the genotype in pod number per plant indicated that the significant difference observed on pod damage may be due to differences in the genetic constitution of the cowpea varieties.

Onyishi *et al*. (2013) also reported that reasonable silicate deposits in leaves and pod of maize and cowpea crops make them unattractive to leaf feeding insect pests as it slows down the rate of digestion of the pest. This corroborates the finding of Flint (1990) who stated that resistant varieties may inhibit pest attack through physic- toxic or repellant compound or through physical factors such as colour or toughness. The result of this study indicated that higher number of pod damage was recorded across the three sowing dates, due to the fact that some of the varieties were suitable for the growth and development of pod borer, as a result of their nutritional or antibiotic factors (Macfoy *et al*., 1983). This supports Ofuya (1993) that reported Aphids as a major economic pest of cowpea, through its feeding which removes sap from the leaves, pods, seed, and other aerial plant parts causing damage to the plant and yield reduction.

Result from this study has shown that wild cowpea (*V. dekendtiana*) variety appendix 43 had least pod damage compared with other cowpea varieties. Singh (2005) reported that resistance of some wild cowpea varieties such as TVu 946 and TVu4557 is due to long peduncles, pod held over the plant canopy and at wider angle than the normal. Sunitha *et al*. (2008) observed that highly resistant pigeon pea holds the pod above the foliage and the time required to complete flowering and pod maturity was comparatively short which results in less preference of the genotypes for feeding and less weight gain by the larvae. SAMPEA 1, SAMPEA 4, SAMPEA 6, SAMPEA 9, SAMPEA 10 and SAMPEA 15 had high percentage pod damage across the three sowing dates compared to other varieties except wild cowpea variety which showed low level of percentage pod damage. Sharma *et al*. (1999) reported that percentage pod damage and larval infestation in flower were positively correlated with relative humidity and negatively with temperature. This means that increase in temperature may increase the damage percentage.

The result of grain weight showed that the high grain yield was recorded from all the varieties except the wild cowpea and last sowing date which produced least grain weight. The variation in yield loss in the third sowing may attributed to the fact that flowering and podding stages of cowpea planted in the third sowing, coincided with the peak population densities of *M. vitrata* resulting in considerable reduction in grain yields, or that first sown cowpea crop may have matured before peak infestation of the pest. This was also in agreement with Asante *et al*. (2001) who reported that cowpea planted early escaped severe *M. vitrata* infestation, while those planted late coinciding with peak population density of the major post flowering pests resulted in considerable reduction of grain yield.

Cowpea yield depends on cowpea cultivars and planting dates. Similar findings have also been reported by Karungi *et al.* (2000) in Uganda and for pod sucking bug in Nigeria, Akesi *et al.* (1996). The variation in yield loss in the third sowing may also be attributed to the low amount of rainfall and other environmental condition (Appendix 44) such as sunshine temperatures and relative humidity (Onyishi *et al*., 2013; Ogah and Ogah, 2012). The fact that the highest resistant variety did not give the highest grain yield may be attributed to the genetic differences among the varieties. Low grain yield output obtained from third sowing date could be attributed to their susceptibility to insect pest infestation. The higher grain yield recorded in SAMPEA 15 at the third sowing date compared with other improved varieties may be due to the genetic difference of the varieties. This is corroborated with the report of Dreyer *et al*. (1994) who observed low seed damage despite heavy flower infestation in cowpea. However, according to Saxena *et al*. (1998) grain yield was significantly greater in *Maruca* resistant cultivars than the susceptible one. This suggests that some genotype recovered quickly following *Maruca* damage (Tolerance).

Most of the yield components such as number of pods per plot, pod damaged, weight of damaged grains and percentage grain damaged from different varieties had values which suggest that varieties and planting dates had effects on yield output of the cowpea. Although, number of pods per plant and grain yield per hectare was low, the relatively low yield was due to rainfall and other environmental conditions as shown in Appendix 44. *Maruca* infestation at flowering podding stage are significant limiting factors to increased and sustainable cowpea grain production. Proper planting time in association with resistant varieties could offer effective control measures for cowpea pod borer

thereby ensuring optimum grain yield. This is corroborated with Ameh and Okezie (2005), reported that insect pests were responsible for significant reduction in yield of cowpea. Result from the present study, showed that none of the cowpea variety was categorized as resistant and/ or highly susceptible to the *Maruca* attack. This is agreed with the Sunitha *et al.* (2008) reported that none of the pigeon pea genotype screened was highly susceptible or resistance to the *Maruca* attack.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

Trials were carried out in both the screen house and field in Samaru, Zaria to study the economic injury levels of legume pod borer and to evaluate some cowpea varieties for field resistance to pod borer. The result showed that the yield of cowpea decreased from 549.75 kg ha^{-1} and 843.50 kg ha^{-1} when 5 and 25 larvae were released for both screen house and field cages to 486.25 kg ha^{-1} and 222.50 kg ha^{-1} when 25 and 125 larvae were released, respectively. Yield of cowpea decreased with increasing number of larvae. Five insecticides with application cost were chosen and a range of estimated values workout in order to provide alternative management protection strategies for the farmers in case of particular insecticide was not available. The infestation at 15, 20, 25 larvae and 75, 100 and 125 larvae for both screen house and field caged plant, respectively had the most pronounce effect on grain yield. There seem to be no differences among the insecticides used and between screen house and field cages.

Twelve cowpea varieties were evaluated for resistance to *M. vitrata* under field condition during 2014 cropping season using three dates of sowing 7^{TH}, 21^{ST} August and 4^{th} September, respectively. SAMPEA 1, SAMPEA 4, SAMPEA 9, SAMPEA 11, SAMPEA 12, SAMPEA 14, SAMPEA 15 and wild cowpea had the lowest significant number of *Maruca* count on flower per plot. Based on the percentage pod damage SAMPEA 1, SAMPEA 4, SAMPEA 6, SAMPEA 7, SAMPEA 9, SAMPEA 10 and SAMPEA 15 were categorized as susceptible varieties. SAMPEA 8, SAMPEA 11, SAMPEA 12, and SAMPEA14 were grouped as moderately resistant and wild cowpea as highly resistant,

none of the varieties were resistant and or highly susceptible to the *Maruca* pest attack. SAMPEA 4, SAMPEA 8, SAMPEA 15 and wild cowpea had lowest significant grain damage across the three sowing dates.

6.2 Conclusion

From the economic injury levels values obtained in this study the infestation of *Maruca* at low population level can cause significant yield loss. The numbers of larvae per plant have attained, the EIL should serve as basis on which cowpea farmers should base their decision to spray against *Maruca* larvae attack, and this would ensure judicious and sound use of insecticides.

Early maturing cowpea varieties sown early to mid August had low *Maruca* populations per plot. These varieties are important to farmers in that the plants would have passed the vulnerable stage before the build-up of the *Maruca* larvae. Among the varieties studies SAMPEA 7, 12, 10 and 11 recorded with high grain damaged by *M. vitrata*. SAMPEA 1, 4, 7, 8, 11, 12, 14, and SAMPEA 15 had high grain yield per hectare and low population of *Maruca* per plot and so could be considered resistant to the *Maruca* attack. Wild cowpea varieties found to be resistant and none of the cowpea varieties were highly susceptible to *Maruca* pest attack.

6.3 Recommendations

- Control measures should be initiated when the *M. vitrata* larvae population reaches at least one larva per caged plant and one larva per metre row length in cowpea plant.
- Farmers should plant improved cowpea varieties early to mid August to avoid peak period of *M. vitrata* infestation in the field.
- SAMPEA 1, SAMPEA 7, SAMPEA 8, SAMPEA 11, SAMPEA 12, SAMPEA 15 varieties can be utilized by the famers and in breeding programme for the management of *M. vitrata* as a component of IPM package for cowpea pod borer control.
- More research should be carried out on the resistance of cowpea to pod borer, on high yielding and medium maturing varieties need to be developed to assess their susceptibility to *Maruca* pod borer under no-choice conditions before susceptible/resistance status can be fully determined.

REFERENCES

Adamu, R. S. (2005). Economic injury levels and control of *Eurystalis oldi* Pop. on *Sorghum biocolor* L. Moench Ph. D. Thesis, Department of Crop Protection. Ahmadu Bello University, Zaria, Nigeria. 243 pp.

Adamu. R. S., Onu, I. and Ogunlana, M. O. (2006). Economic injury levels of ovipositing and feeding adults of the headbug *Eurystalis oldi* pop. On *Sorghum biocolor* L. Moench. *Journal of Tropical Bioscience,* 6*:*50-54.

African Agricultural Technology Foundation (AATF) (2012). *Maruca*- Resistant cowpea frequently asked question. Nairobi, Kenya www.aatf-africa.org July, 2013.

Afun, J. V. K., Jackai, L. E. N. and Hodgson, C. J. (1991). Calendar and monitor insecticide application for the control of cowpea pest. *Crop Protection,* 10: 363-370.

Akesi, S., Dike, M. C. and Ogunlana, M. O. (1996). Relationship between planting dates and damage by the legume pod-borer, *Maruca testulalis* (Geyer) (Lepidotera; Pyralidae) on cowpea *Vigna unguiculata* L. Walp) in Nigeria. *International Journal of Pest Management,* 42: 315 - 316.

Akinfenwa, S. (1975). Biological study of *Maruca testulalis* Geyer in the Zaria area of northern Nigeria. M. Sc. Thesis. Department of Crop Protection. Ahmadu Bello University, Zaria, Nigeria. 41 pp.

Alghali, A. M. (1993). The effects of some agrometereological factors on fluctuation of the legume pod borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae), on two cowpea varieties in Nigeria. *Insect Science and its Application,* 14:55-59.

Amarnath, K. (2000). Management of soybean pod borer *Cydia ptychora* (Meyrick) (Tortricidae: Lepidoptera). M.Sc. (Agric.) Thesis, University of Agricultural Science, Dharwad (India). 142 pp.

Amatobi, C. I. (2007). *Arthropod pests of crops in Nigeria; General biology, natural enemies and control*. P. A. Ndahi printing. Zaria, Nigeria. 124 pp.

Amatobi, C. I., Dike, M. C. and Oparaeke, A. M. (2005). Integrated pest management of thrips and Maruca on Cowpea at Samaru. Cropping Scheme Meeting Report on Legume and Oil seed Research Programme, I. A. R., Ahmadu Bello University, Zaria, Nigeria. 23 – 24.

Ameh, G. I. and Okezie, C. E. A. (2005). Pests and diseases of African Yam Beans. *Bio Research,* 3 (1): 14-20.

Amusa, N. A. and Adegbite, A. A. (2006). The major economic field disease of cowpea in the humid. Agro Ecologist of South Western Nigeria. *World Applied Journal*, 1(1): 12-18.

Anderson, J. W. (1985). Cholesterol lowering effect of canned beans for hyper cholesterol M. C. *Medical Clinical Resource*, 3314: 871-75.

Anonymous. (2015). Institute for Agricultural Research (IAR), *Released Variety Descriptors*, Institute for Agricultural Research Samaru. Ndahi press, Zaria, Nigeria; pp52-73.

Anonymous. (2009). Annual agricultural performance survey report of Nigeria national research council 2000. The future Role of pesticides in US Agriculture Washington, DC: Natl. Press. 301pp.

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

Arodokoun, D.Y., Tamo, M., Cloutier, C. and Brodeur, J. (2006). Larval parasitoids occurring on *Maruca vitrata* Fabricius (Lepidoptera: Pyralidae) in Benin, West Africa. *Agriculture, Ecosystems and Environment*, 113:320–325.

Asante, S. K., Tamo, M. and Jackai, L. E. N. (2001). Integrated management of cowpea insect pests using elite cultivars date of planting and minimum insecticide applications. *African Crop Science Journal*, 9(4):655 – 665.

Blade, S. F., Shetty, S. V. R., Terao, T. and Singh, B. B. (1997). Recent developments in cowpea cropping systems research. **In:** Singh, B. B., Mohan Raj, D. R., Dashiell, K. E., Jackai, L. E. N. (eds.) Advances Cowpea Research Co. publication of IITA and JIRCAS, IITA, Ibadan Nigeria.89-97p.

Buntin, G. D. (2001). Techniques for evaluating yield loss from insects, pp. 23–41. ***In:*** Peterson, R. K. D. and Higley, L. G. (eds). Biotic stress and yield loss. CRC Press, New York, 261 pp.

Cobbinah, J. R. and Osei-Owusu, K. (1988). Effects of neem seed extracts on insect pests of egg plant, Okra and cowpea. *Insect Science and its Application,* 9**:** 601-607.

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

Dabire-Binso, L. C., Niango-Malick, B. A., Sanon, A., Drabo, I. and Foubi, K. (2007). Resistance mechanism to the pod sucking bug, *Clavigralla tomentosicollis* Stal (Hemiptera; Coreidae) in the cowpea IT 86-716 Variety.

Degaonkar, A. M., Kurtadikar, J. S. and Rekawar, P. V. (1988). Economical control measures against pod borer complex in Marathwada region. *Pesticides,* 22**:** 15-16.

Dina, S. O. and Medaigedu, J. A. (1988). Field test with insecticide to control *Maruca vitrata* and other pod boring insect of cowpea in southern Nigeria. *Journal of Economic Entomology*, 69:173-177.

Diouf, D. (2011) recent advance in cowpea (*Vigna unguiculata* L. Walp) "Omcs" Research for genetic improvement, *Africa Journal of Biotechnology*, 10(15): 2803-2810.

Dreyer, H., Baumgartner, J. and Tamo, M. (1994). Seed damaging field pests of cowpea (*Vigna unguiculata*) (Walp) in Benin: Occurrence and pest status. *International Journal of Tropical Pest Management*, 40: 252-260.

Egwurube, E. A. (2004). Bioeconomics of *Empoasca dolichi* Paoli (Homoptera; Cicadellidae) on groundnut in northwestern Nigeria. M. Sc Thesis, Department of Crop Protection, Ahmadu Bello University Zaria. 142 pp.

Ezuch, M. I. (1982). Effect of planting date on pest infestation, yield and harvest quality of cowpea (*Vigna unguiculata*). *Experimental Agriculture,* 18: 311-318.

FAO, (2002). World Agriculture toward 2015-2030, Summary report. Rome.

FAO, (2008). Agricultural production status worldwide web sites pages, http:www.fao.org/faostat.

FAO. STAT; Bulletin of Tropical Legumes, (2011); http//.www.Icrisat.org/tropical legumes11.

FAO. STAT; Bulletin of Tropical Legumes, (2014); http//.www.Icrisat.org/tropical legumes.

Fatokun, C. A. and Singh, B. B. (2001). Improving cowpea-cereal systems in the dry Savanna. Annual Report, IITA, Ibadan, Nigeria. 79pp.

Fenemore, P. G. (1982). *Plant pests and their control*. Butterworth, Wellington, New Zealand pp: 271.

Flint, M. L. (1990). *Pests of the Garden and Small Farm*. University of California

Ganapathy, N. and Durairaj, C. (1994). Chemical control schedule for red gram pod borers and pod fly. *Madras Agricultural Journal*, 81**:** 698-699.

Giller, K. E. (2001). *Nitrogen fixation in the Tropical System* 2nd edition; CABI, Wallington ford, U. K pp 150-300.

Gungula, D. T. and Garjila, Y. (2005). The effect of phosphorous application on growth and yield of cowpea in Yola. *Journal of Sustainable Development in Agricultural Environment*, 18:323-313.

Hill, D. S. and Waller, J. M. (1990). *Pests and diseases of tropical crops*, volume 2, Field handbook, Person Education Limited pp: 25-37.

IITA, (1986). *Annual Report*. International Institiute of Tropical Agriculture (IITA) Ibadan, Nigeria.

Islam. S., Cowmen, R. C. and Ganer, J. O. (2006). Screening for tolerance to stress temperature during germination of twenty five cowpea *Vigna ungucuilata* L. Walp. Cultivars. *Journal of food Agriculture and Environment*, 4(2): 189-191.

Isman, M. B. (2006). Botanical insecticide, deterrent, and repellent in modern agriculture and an increasingly regulated world. *Annual Review of Entomology,* 51: 45-46.

Ivbijaro, M. F. and Bolaji, O. O. (1990). Effects of cypermethrin + dimethoate and extracts of *Piper guinense* and *Azadirachta indica* on the pests and yield of cowpea, *Vigna unguiculata*. *Journal of Agricultural Science*, 115**:** 227-231.

Jackai, L. E. N. (1991). Laboratory and screen house assays for evaluating cowpea resistance to the legume pod borer. *Crop Protection*, 10: 48-52.

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. and Daoust, R. A. (1986). Insect Pest of Cowpea. *Annual Review of Entomology,* 31: 9-119.

Jackai, L. E. N., Nokoe, S., Tayo, B. O. and Koona, P. (2001) Inferences on pod wall and seed defences against the brown cowpea coreid bug, *Clavigralla tomentosicollis* Stal. (Hemiptera : Coreidae) in wild and cultivated *Vigna* species. *Journal of Applied Entomology,* 125: 277-286.

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

Jackai, L. E. N. (1981) Relationship between cowpea crop phenology and field infestation by legume pod borer, *Maruca testulalis*. *Annual Entomology Society*, 74**:** 402-408.

Jackai, L. E. N. (1982) A field screening technique for resistance of cowpea *(Vigna unguiculata*) to pod borer, *Maruca testulalis* (Geyer). *Bulletin of Entomological Res*earch, 72*:* 145- 156.

Jackai, L. E. N. and Oyediran, I. O. (1991). The potential of neem (*Azadirachta indica A. Juss.*) for controlling post flowering pests of cowpea, *Vigna unguiculata* Walp. L. the pod-borer, *Maruca testulalis*. *Insect Science Applic*ation, 12*:* 103-109.

Jackai, L. E. N. and Raulston, J. R. (1988). Rearing of legume pod borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae) on artificial diet. *Tropical Pest Management*, 34**:**168-172.

Jackai, L. E. N., Oghiakhe, S. and Makanjuola, W. A. (1992). Cowpea plant architecture in relation to infestation and damage by the legume pod borer, *Maruca testulalis* (Geyer) ii Effect of canopy structure and pod position. *Insect Science Application*, 12:193-199.

Kamaru, A. Y., Ekeleme, F., Omoiguia, L. O., Abdoulayea, T., Amaza, P., Chikoye, D. and Dugje, I. Y. (2010). Integrating planting date with insecticide spraying regimes to manage insect pests of cowpea in North-Eastern Nigeria. *International Journal of Pest Management*, 56 (3): 243-253.

Karungi, J. Adipala, E., Ogenga-Latigo, M. W. and Kyamanywa, S. (2000). Pest management in Cowpea. Part 1. Influence of planting time and plant density on 18 cowpea field pest infestation in eastern Uganda. *Crop Protection,* 19: 231-236.

Koona, P., Osisanya, E. O., Lajide, L., Jackai, L. E. N. and Tamo, M. (2002). Assessment of chemical resistance of wild and cultivated *Vigna* species to the brown pod-bug *Clavigralla tomentosicollis* Stal (Hemiptera., Coreidae). *Journal of Applied Entomology,* 127: 293–298.

Lal, S. S., Yadava, C. P. and Dias, C. A. R. (1988). Major pest problems of pigeon pea in Uttar Pradesh. *International Pigeon pea Newsletter,* 1**:** 30-31.

Luckmann, W. H. and Metcalf, R. L. (1994). The pest-management concept, pp. 1–34. ***In:*** Metcalf, R. L. and Luckmann, W. H. (eds.), Introduction to insect pest management. John Wiley and Sons, New York, 650 pp.

Macfoy, C. A., Dabrowski, Z. T. and Okech, *S.* (I983). Studies on the legume pod borer, *Maruca testulalis* (Geyer) - 4. Cowpea resistance to oviposition and larval feeding. *Insect Science and its Application*, 4: 147-152.

Malgwi, A. M. and Onu, I. (2004). Insect pest of cowpea and groundnut in Girei local government area of Adamawa state. *Nigerian Journal of Entomology*, 21: 137-151.

Mallikarjunappa, S. and Rajagopal, D. (1991). Action thresholds for the management of pod borer, *Adisura atkinsoni* Moore (Lepidoptera : Noctuidae) on field bean, *Lablab purpureus* (L.) in India. *Tropical Pest Management*, 37: 431-435.

Naidu, R. A., Bottenberg, H., Subrahmanyam, P., Kimmins, F. M., Robinson, D. J. and Thresh, J. M. (1998). Epidemiology of groundnut rosette virus disease: current status and future research needs. *Journal of Applied Biology*,132:525-548.

Nath, P. and Rai, R. (1995). Study of the bio-ecology and economic injury levels of *Helicoverpa armigera* infesting gram crop. ***In****:* "Proceeding of National Seminar on International Pest Management (IPM) in Agriculture", 19-30 December, Nagpur. pp. 20-21.

Ntonifor, N. N., Jackai, L. E. N. and Ewete, F. K. (1996). Influence of host plant abundance and insect diet on the host selection behavior of *M. testulalis* Geyer (Lepidoptera: Pyralidae) and *Riptortus* dentipes Fab. (Hemiptera: Alydidae). *Agriculture, Ecosystem and Environment*, 60(1): 71-78.

Odak, S. K. and Thakur, B. S. (1975). Preliminary studies on the economic threshold of gram pod borer *Heliothis armigera* (Hubn.) on gram. ***In:*** "All India Workshops on Rabi Pulses". A.P.A.U., Hydrabad, pp. 29-30.

Ofuya, T. I. (1993). Evaluation of selected cowpea varieties for resistance to *Aphis craccivora* Koch at seedling and podding phases. *Journal of Applied Biology*, 123 (1): 19-23.

Ogah, E. O. and Ogah, F. E. (2012). Evaluating the effect of host plant resistance and planting dates on the incidence of legume pod borer (*Maruca vitrata*, Geyer) on African Yam Bean in Nigeria. *African Crop Science Journal*, 20(3): 163-170.

Oghiakhe, S., Jackai, L. E. N., Makanjuola, W. A. and Hodgson, C. J. (1993) Morphology, distribution, and the role of trichomes in cowpea (*Vigna unguiculata*) resistance to the legume pod borer, *Maruca testulalis* (Lepidoptera: Pyralidae). *Bulletin of Entomological Research*, 82 (4): 499–505.

Oghiakhe, S. (1995). Effect of pubescence in cowpea resistance to the legume pod borer, (*Maruca testulalis* Geyer). *Crop Protection*. 14(5): 379-387.

Ogunlana, M. O. and Pedigo, L. P. (1974). Economic injury levels of potato leaf hopper on soybeans in Iowa. *Journal of Economic Entomology*, 67: 29-32.

Okeyo-Owuor, J. B. and Ochieng, R. S. (1981). Studies on legume pod borer, *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae) in small farming system of western Kenya. *Insect Science and its Application*, 12**:** 35-42.

Okigbo, B. N. and Greenland, D. J. (1976). Intercropping system in tropical Africa. *American Society of Agronomy*. Wisconsin, USA. pp. 63 - 101.

Olakoja,S. A., Ayanwole, J. A. and Obasemola, V. I. (2007). Laboratory science of seed of some cowpea (*Vigna unguiculata*. Walp for tolerance to cowpea Bettle (*Callosubruchus maculatus*) in hot humid environment. *American-Eurasian Journal of Agriculture and Environmental Society*, 2(5): 528-533.

Olotuah, O. F and Ofuya, T. I. (2010). Comparative protection of cowpea, *Vigna unguiculata* (L.) Walp against field insect pest using cashew nut shell liquid and Cypermethrin (Cymbush). *Pakistan Journal of Nutrition* 9(2); 158-161.

Olufajo, O. O. and Singh, B. B. (2002). Advance in cowpea cropping systems research, http/www.iita.org/detail/cowpea August, 2015.

Omolo, E. O., Niyambo, S., Simbi, C. O. J. and Ollimo, P. **(**1993). The role of host plant resistance and intercropping in integrated pest management (IPM) with specific to Oyugis project. *International Journal of Tropical Pest Management*, 39:265-272.

Onyishi, G. C., Harriman, J. C., Ngwauta, A. A., Okporie, E. O. and Chukwu, S. C. (2013). Efficiency of some cowpea genotype against *Maruca* insect pest in southern agro-ecology of Nigeria. *Middle East Journal of Scientific Research*, 15(1): 114-121.

Oparaeke, A. M. (2007). Toxicity and spraying schedules of a biopesticide prepared from *Piper guineense* against two cowpea pests. *Plant Protection Sciences*, 43: 103-108.

Oparaeke, A. M. (2004). Studies of insecticidal potential of extract of *Gmelina arborea* product for control of field pest of cowpea *Vigna unguiculata* (L.) Walp. *Journal of Plant Protection Research*, 45*:* 68-73.

Oparaeke, A. M., Dike, M. C. and 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., Okonkwo, 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. and 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.

Oyewale, R. O. (2014). Evaluation of Four new insecticides formulation for the management of post flowering pest of cowpea. M.Sc. Thesis, Department of Crop Protection, Ahmadu Bello University, Zaria. Pp 87.

Oyewale, R. O. and Bamaiyi, L. J. (2013). Management of cowpea insect pests. *Scholar Academic Journal of Biosciences*, 1(5): 217-226.

Padulosi, S. and Ng, N. Q. (1990). Wild *Vigna* species in Africa. Their collection and potential utilization. ***In*:** Cowpea Genetic Resources. (eds. Ng, N. Q. and Monti, L. M.) International Institute of Tropical Agriculture, Ibadan, Nigeria: pp. 58-77.

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

Painter, R. H. (1951). *Resistance in crop plants: reference to African Agriculture*. Arnold Hodder Macmillan, New York, pp 520.

Pedigo, L. P. and Hagley, L. G. (1992). The economic enjury concept and environmental quality. A new perspective: *American Entomology, 38*: 12-21.

Pedigo, L. P. (1996). *Entomology and Pest Management*, Macmillan Publishing Company, New York. pp. 107-119.

Pedigo. L. P. (2004). *Entomology and pest management* (4th ed). Prentice Hall of India, New Delhi 1010001, pp 255-266.

Pierce, W. D. (1934). At what point does insect attack become damage? *Entomological News*, 45: 1-4.

Prabhakar, M., Singh, Y., Singh, V. S. and Singh, S. P. (1998). Economic injury levels of *Helicoverpa armigera* in chickpea as influenced by irrigation. *Indian Journal of Entomology*, 60*(2)*: 109-115.

Rachie, K. O. and Singh, S. R. (1985). *Cowpea Research Production and Utilization*. John Wiley and Sons. New York. Brisbane. pp 22-25.

Rahman, M. M. and Rahman, M. S. (1988). Timing and frequency of insecticide application against *Maruca testulalis* (Geyer) infesting short-duration pigeon pea in Bangladesh. *Legume Research*, 11**:** 173-179.

Reddy, C. N., Singh, Y. and Singh, V. S. (2001). Economic injury level of gram pod borer (*Helicoverpa armigera*) on pegionpea. *Indian Journal of Entomology*, 63(4): 381-387.

SAS (2003). SAS version 8 for Windows. SAS Institute, Cary, North Carolina, USA.

Saxena, K. B., Lateef, S. S., Ariyaratne, H. P., Fonseka, H. H. D. and Dharmasena, C. M. D. (1998). *Maruca testulalis* damage in determinate and indeterminate lines of pigeonpea. *International Pigeonpea Newsletter,* 3**:** 91-93.

Sharma, K. K., Yadava, H. S. and Chandra, A. (1999). Reaction of field bean varieties to pod borer complex. *Research Journal,* 33(1-2): 78-79.

Sharma, H. C. (1998). Bionomics, host plant resistance and management of legume pod borer, *Maruca vitrata- a* review. *Crop Protection,* 17: 373-386.

Sharma, H. C. and Franzamann, B. A. (2000). Biology of legume pod borer, *Maruca vitrata* (F.) and its damage to pigeon pea and adzuki bean. *Insect Science Application,* 20*:* 99-108.

Sharma, H. C. and Lopez, V. F. (1989). Assessment of avoidable losses and economic injury levels for the sorghum head bug *Calocaris angustatus* Leth.(Hemiptera: Miridae) in India. *Crop protection,* 8:429-439.

Singh, B. B. (2005). Cowpea (*Vigna unguiculata* (L.) Walp. ***In:*** Singh, R. J. and Jauhar, P. P. (eds) Genetic resources chromosome engineering and crop improvement., Vol. 1, CRC Press, Boca Raton FL USA pp 117 – 162.

Singh, B. B. and Ajeigbe, H. A. (2002). Improving cowpea-cereal based system in the dry savannah of West Africa. **In:** Fatokun, C. A., Tarawali, S. A., Singh, B. B., Kormawa, P. M., Tamo, M. (eds) Challenges and opportunities for enhancing sustainable cowpea production., proceedings of the World cowpea conference III held at IITA, Ibadan Nigeria, pp 278 – 286.

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. Pp 214

Singh, N. N. (1997). Economics and use of insecticides against pod fly and pod borer complex on pigeionpea. *Indian Journal of Entomology,* 59: 228-231

Singh, B. B. (2000). Breeding cowpea varieties for wide adaptation by minimizing genotype x environment interactions. Pages 173–181 **in:** Genotype × environment interactions analysis of IITA mandate crops in sub-Saharan Africa, edited by Ekanayake, I .J. and Ortiz, R. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Singh, S. R. and Jackai, L. E. N. (1985). Insect pests of cowpeas in Africa: their life cycle, economic importance and potential for control. Pages 217-231 **in:** cowpea research production and utilization, Singh, S. R. and Rachie, K. O. (ed). John Wiley and Sons, New York pp. 210

Singh, S. R., Jackai, L. E. N. J, Dos Santos, H. R. and Adalla, C. B. (1990). Insect pests of cowpeas. Pages 43–90 **in:** *Insect pests of tropical legumes*, Singh, S. R. (eds). John Wiley and Sons, Chichester, UK.

Singh, S. R. and Allen, D. J. (1980). Pests, diseases, resistance and protection of *Vigna unguiculata* (L.) Walp. Pp. 419-433. **In:** *Advances in Legume Science*. Summerfield R. J. and Bunting, A. H. (eds.) London Royal Garden, Kew and Ministry of Agriculture, Fisheries and Food, London.

Smith, R. F. (1968). Recent developments in integrated control. Proceeding 4th *British Insecticide and Fungicide conference*, 2: 464-471.

Stadler, E. (1977). Sensory aspects of insects plant appraisal interaction. *Proceeding XV. International Congregation of Entomology* 2: 59-99. Washington D.C, pp: 228-248.

Stalker, H. T. (1989). Utilization of wild cowpea species for crop improvement. *Advances in Agronomy* 33: 111-147.

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., Smith, R. F., Bosch, R. Vand, E. and Hagen, K. S. (1959). The integrated control concept. *Hilgardia* 29:81-101.

Sunitha, V., Vijaya, L. K. and Ranga Rao, G. V. (2008). Screening of pigeon pea genotype against *Maruca vitrata* (Geyer). *Journal of Food Legumes,* 21(3): 193-195.

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.

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.

Tayo, T. O. (1988). Flower and pod development in three cowpea (*Vigna unguiculata* (L) Walp.) varieties with varying susceptibility to the pod borer, *Maruca testulalis* (Geyer), *Insect Science Application,* 9: 249-253.

USAID (2008). A Study of cowpea value chain in Kano State from a poor and gender prospective; http://www.nigeriamarkets.org/files/GATE_cowpea_find%5B1%5D.pdf.

Valenzuela, H. and Smith, J. (2002). *Cowpea:* cooperative extension service, College of Tropical *Vigna unguiculata* (L.) Walp Production in Nigeria. *Insect Science and its Application*, 14 (1): 49-53.

Venkataiah, M., Sekhar, P. R., Rao, N. V., Singh, T. V. K. and Rajasri, M. (1994). Distribution patterns and sequential sampling of pod borer, *Helicoverpa armigera* (Hubner) in pigeon pea. *Indian Journal of Pulses Research*, 7: 158-161.

Wooley, J. N. and Evans, A. M. (1979). Screening for resistance to *Maruca testulalis* (Geyer) in Cowpea (*Vigna unguiculata* (L.) Walp.). *Journal of Agricultural Science*, 92: 417-425.

Zahid, M. A., Islam, M. M. and Begume, M. R. (2008). Determination of economic injury levels of *M. vitrata* in Mungbean. *Journal of Agricultural Rural Development*, 6(1 and 2): 91-97.

APPENDICES

Appendix 1 Analysis of variance for the infestation of *M. vitrata* larvae on number of pods produced per field cage of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	3	209.458	69.819	1.44	0.271
Treat	5	10509.708	2101.941	43.26	<.0001
Error	15	728.791	48.586		
Total	23	11447.958			

Appendix 2 Analysis of variance for the infestation of *M. vitrata* larvae on number of pods damaged per field cage of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	3	121.500	40.500	3.49	0.042
Treat	5	1046.333	209.266	18.04	<.0001
Error	15	174.000	11.600		
Total	23	1341.833			

Appendix 3 Analysis of variance for the infestation of *M. vitrata* larvae on percentage pods damaged per field cage of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	3	982.333	327.444	2.63	0.0884
Treat	5	25165.333	5033.066	40.38	<.0001
Error	15	1869.666	124.644		
Total	23	28017.333			

Appendix 4: Analysis of variance for the infestation of *M. vitrata* larvae on grain weight (kg/ha) per field cage of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	3	160	534	11.41	0.0004
Treat	5	471	943	201.35	<.0001
Error	15	703	468		

Total	23	494			

Appendix 5 Analysis of variance for the infestation of *M. vitrata* larvae on weight of healthy grain of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	3	23.575	7.858	1.70	0.208
Treat	5	114.803	22.960	4.98	0.006
Error	15	69.180	4.612		
Total	23	207.558			

Appendix 6 Analysis of variance for the infestation of *M. vitrata* larvae on weight of damaged grain of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	3	834.773	278.257	15.25	<.0001
Treat	5	29977.120	5995.424	328.52	<.0001
Error	15	273.746	8.249		
Total	23	31085.640			

Appendix 7 Analysis of variance for the infestation of *M. vitrata* larvae on percentage grain damaged of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	3	497.833	165.944	3.43	0.044
Treat	5	4561.000	912.200	18.86	<.0001
Error	15	725.666	48.377		
Total	23	5784.500			

Appendix 8 Analysis of variance for the infestation of *M. vitrata* larvae on weight of 100 grain of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	3	5.214	1.738	2.91	0.069
Treat	5	76.643	15.328	25.64	<.0001
Error	15	8.967	0.597		
Total	23	90.826			

Appendix 9 Analysis of variance for the infestation of *M. vitrata* larvae on number of flowers of cowpea under screen house

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treat	5	83.000	16.600	1.17	0.362
Error	18	255.500	14.194		
Total	23	338.500			

Appendix 10 Analysis of variance for the infestation of *M. vitrata* larvae on number of flower damage of cowpea under screen house

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treat	5	127.708	25.541	20.66	<.0001
Error	18	22.250	1.236		
Total	23	149.958			

Appendix 11 Analysis of variance for the infestation of *M. vitrata* larvae on number of pods of cowpea under screen house

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treat	5	90.708	18.141	10.45	<.0001
Error	18	31.250	1.736		
Total	23	121.958			

Appendix 12 Analysis of variance for the infestation of *M. vitrata* larvae on number of pods damage of cowpea under screen house

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treat	5	37.333	7.466	5.60	0.002
Error	18	24.000	1.333		
Total	23	61.333			

Appendix 13 Analysis of variance for the infestation of *M. vitrata* larvae on percentage pods damaged of cowpea per cage under screen house

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treat	5	289	5792.441	35.96	<.0001
Error	18	289	161.097		
Total	23	318			

Appendix 14 Analysis of variance for the infestation of *M. vitrata* larvae on grain weight (kg/ha) of cowpea per cage under screen house

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treat	5	173	347	20.94	<.0001
Error	18	298	166		
Total	23	203			

Appendix 15 Analysis of variance for the infestation of *M. vitrata* larvae on weight of damaged grain per cage under screen house

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treat	5	4.468	0.893	2.95	0.040
Error	18	5.450	0.302		
Total	23	9.918			

Appendix 16 Analysis of variance for the infestation of *M. vitrata* larvae on percentage grain damage per cage under screen house

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treat	5	3803.378	760.675	2.79	0.049
Error	18	4911.867	272.881		
Total	23	8715.246			

Appendix 17 Analysis of variance for the infestation of *M. vitrata* larvae on percentage grain damage per cage under Screen House

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treat	5	649	129	9.99	0.0001
Error	18	234	130		
Total	23	883			

Appendix 18 Analysis of variance for the *M. vitrata* infestation population at first sowing date of cowpea in 2014 at Samaru

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Rep	2	0.667	0.333	0.07	0.936
Treat	11	80.750	7.34	1.45	0.220
Error	22	111.333	5.061		
Total	35	192.750			

Appendix 19 Analysis of variance for the *M. vitrata* infestation population at second sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	6.222	3.111	0.72	0.498
Treat	11	152.306	13.845	3.20	0.009
Error	22	95.111	4.323		
Total	35	253.639			

Appendix 20 Analysis of variance for the *M. vitrata* infestation population at third sowing date of cowpea in 2014 at Samaru

Source	DF	SS	Mean Square	F Value	Pr > F
Rep	2	4.389	2.194	0.52	0.604
Treat	11	344.306	31.300	7.36	<.0001
Error	22	93.611	4.255		
Total	35	442.305			

Appendix 21 Analysis of variance for the M. *vitrata* infestation on pods produced at first sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	697.389	348.694	0.13	0.881
Treat	11	405566.972	36869.725	13.46	<.0001
Error	22	60249.944	2738.634		
Total	35	466514.306			

Appendix 22 Analysis of variance for the *M. vitrata* infestation on number of pods produced at second sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	3341.722	1670.861	0.38	0.687
Treat	11	270888.306	24626.209	5.64	0.0003
Error	22	96098.278	4368.104		
Total	35	370328.306			

Appendix 23 Analysis of variance for the *M. vitrata* infestation number of pods produced at third sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	1135.722	567.861	0.94	0.407
Treat	11	13809.639	1255.423	2.07	0.070
Error	22	13325.611	605.709		
Total	35	28270.972			

Appendix 24 Analysis of variance for the *M. vitrata* infestation on number of pods damage at first sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	76.222	38.111	1.32	0.287
Treat	11	894.222	81.292	2.82	0.019
Error	22	635.111	28.868		
Total	35	1605.556			

Appendix 25 Analysis of variance for the *M. vitrata* infestation on number of pods damage at second sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	3.722	1.861	0.06	0.938
Treat	11	1234.972	112.270	3.88	0.003
Error	22	636.944	28.952		
Total	35	1875.639			

Appendix 26 Analysis of variance for the *M. vitrata* infestation on number of pods damage at third sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	147.388	73.694	1.59	0.226
Treat	11	2284.889	207.717	4.49	0.001
Error	22	1018.611	46.305		
Total	35	3450.889			

Appendix 27 Analysis of variance for the *M. vitrata* infestation on grain weight (g) per plot at first sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	96559.549	48279.774	1.73	0.2000
Treat	11	2077684.756	188880.432	6.78	<.0001
Error	22	612762.964	27852.862		
Total	35	2787007.270			

Appendix 28 Analysis of variance for the *M. vitrata* infestation on grain weight (g) per plot at second sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	19260.287	9630.144	0.46	0.6397
Treat	11	1615016.870	146819.715	6.95	<.0001
Error	22	464703.613	21122.891		
Total	35	2098980.770			

Appendix 29 Analysis of variance for the *M. vitrata* infestation on grain weight (g) per plot at third sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	51936.821	23438.410	1.36	0.2764
Treat	11	1230076.170	110425.106	5.87	0.0002
Error	22	418866.853	19039.402		
Total	35	1700879.843			

Appendix 30 Analysis of variance for the *M. vitrata* infestation on grain weight damage at first sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	2.807	1.403	0.30	0.7434
Treat	11	403.776	36.706	7.86	<.0001
Error	22	102.726	4.669		
Total	35	509.309			

Appendix 31 Analysis of variance for the *M. vitrata* infestation on grain weight damage at second sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	2.771	1.385	0.10	0.905
Treat	11	1270.627	115.511	8.33	<.0001
Error	22	304.902	13.859		
Total	35	1578.300			

Appendix 32 Analysis of variance for the *M. vitrata* infestation on grain weight damage at third sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	71.661	35.830	0.86	0.435
Treat	11	4088.516	371.683	8.97	<.0001
Error	22	911.639	41.438		
Total	35	5071.816			

Appendix 33 Analysis of variance for the *M. vitrata* infestation on 100 seed weight at first sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	5.602	2.801	0.70	0.506
Treat	11	610.215	55.474	13.88	<.0001
Error	22	87.924	3.996		
Total	35	703.742			

Appendix 34 Analysis of variance for the *M. vitrata* infestation on 100 seed weight per plot at second sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	5.146	2.573	0.39	0.679
Treat	11	571.387	51.944	7.93	<.0001
Error	22	144.127	6.551		
Total	35	720.660			

Appendix 35 Analysis of variance for the *M. vitrata* infestation on 100 seed weight per plot at third sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	12.693	6.346	0.78	0.471
Treat	11	578.448	52.586	6.46	0.0001
Error	22	179.166	8.144		
Total	35	770.309			

Appendix 36 Analysis of variance for the *M. vitrata* infestation on percentage grain damage at first sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	3.651	1.825	1.04	0.371
Treat	11	24.743	2.249	1.28	0.298
Error	22	38.655	1.758		
Total	35	67.050			

Appendix 37 Analysis of variance for the *M. vitrata* infestation on percentage grain damaged by at second sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	0.071	0.035	0.08	0.921
Treat	11	13.073	1.188	2.73	0.022
Error	22	9.595	0.436		
Total	35	22.740			

Appendix 38 Analysis of variance for the *M. vitrata* infestation on percentage grain damaged at third sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	26.915	13.457	2.53	0.102
Treat	11	131.700	11.972	2.25	0.050
Error	22	116.845	5.311		
Total	35	275.460			

Appendix 39 Analysis of variance for the *M. vitrata* infestation on grain weight (kg/ha) at first sowing date of in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	108	540	1.74	0.198
Treat	11	231	210	6.79	<.0001
Error	22	680	309		
Total	35	309			

Appendix 40 Analysis of variance for the *M. vitrata* infestation on grain weight (Kg/ha) at second sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	283	141	0.37	0.694
Treat	11	190	172	4.53	0.001
Error	22	839	381		
Total	35	277			

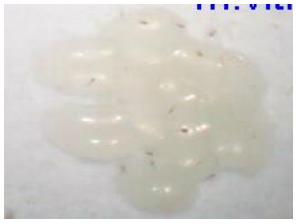
Appendix 41: Analysis of variance for the *M. vitrata* infestation on grain weight (Kg/ha) at third sowing date of cowpea in 2014 at Samaru

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Rep	2	577	288	1.36	0.2764
Treat	11	136	124	5.87	0.0002
Error	22	465	211		
Total	35	188			

Appendix 42: Meteorological data showing relative humidity, temperature sunshine and rainfall in 2014 at Samaru

	% Relative humidity		Temperature			
Month	Morning	Afternoon	Max	Min	Sunshine hours	Average rainfall
April	54.3	39.5	36.9	24.4	7.2	141.2
May	67.3	51.0	33.4	24.2	6.3	127.2
June	72.9	61.3	32.2	23.3	7.3	119.1
July	78.0	70.5	31.0	22.8	6.3	115.7
August	82.4	72.9	29.8	22.5	5.3	374.3
September	77.8	70.6	31.0	21.7	6.0	157.0
October	61.3	41.4	33.8	21.3	8.1	9.3

Source: I. A. R. Meteorological unit IAR/ABU Zaria



Egg



First Instar



Second Instar



Third instar



Fourth Instar



Fifth Instar



Maruca vitrata adult

Appendix 43: Eggs, Larvae and adult of *Maruca vitrata*



Appendix 44: Flowers and pods of *Vigna dekendtiana* (L.) Walp (I. A. R. Research Farm, Samaru, in 2014 wet season)