EVALUATION OF BT COWPEA INTERCROP PATTERN WITH MAIZE AND INSECTICIDE SPRAY REGIME IN THE MANAGEMENT OF FLOWERING AND POST FLOWERING PESTS OF COWPEA AT SAMARU, ZARIA

BY

Iheakachi Peace EHILEGBU

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

MARCH, 2021

EVALUATION OFBT COWPEA INTERCROPPATTERN WITH MAIZE AND INSECTICIDE SPRAY REGIMEIN THE MANAGEMENT OF FLOWERING AND POST FLOWERING PESTS OF COWPEA AT SAMARU, ZARIA

BY

Iheakachi Peace EHILEGBU

(B.Sc. ZOOLOGY A.B.U 2014)

(P16AGCP8006)

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 IN CROP PROTECTION

DEPARTMENT OF CROP PROTECTION,

FACULTY OF AGRICULTURE,

AHMADU BELLO UNIVERSITY,

ZARIA, NIGERIA

MARCH, 2021

DECLARATION

I declare that this Dissertation entitled "**Evaluation of Bt Cowpea Intercrop Pattern with Maize andInsecticide Spray Regime in the Management of Flowering and Post Flowering Pests ofCowpea at Samaru, Zaria."** was written by me under the supervision of Professor R.S. Adamu and Dr. B.T. Magaji in the Department of Crop Protection. It is a record of my research work and has not been presented for the award of any higher degree in any Institution. All cited references of published and unpublished literatures have been duly acknowledged.

Ehilegbu I. Peace	______________________	______________________
Name of student	Signature	Date

CERTIFICATION

This Dissertation entitled “Evaluation of Bt Cowpea Intercrop Pattern with Maize and Insecticide Spray Regimein the Management of Flowering and Post Flowering Pests of Cowpea at Samaru, Zaria.” By Ehilegbu Iheakachi Peace meets the regulation governing the award of the Degree of Masters of Science in Crop Protection, Ahmadu Bello University. Zaria and has been approved for its contribution to knowledge and literary presentation.

______________________________ _______________________

Professor R. S Adamu Date
Chairman, Supervisory Team.

______________________________ _______________________

Dr. B.T MagajiDate
Member, Supervisory Team.

______________________________ _______________________

Prof. I. J. BamaiyiDate
Head, Department of Crop Protection

______________________________ _______________________

Prof. Sani Abdullahi Date
Dean, School of Postgraduate Studies
Ahmadu Bello University, Zaria.

DEDICATION

Thisresearch dissertation is dedicated to my parents, late Mr. S. O Ehilegbu, may his soul continue to find rest in the bosom of God Almighty, my mum Mrs. Comfort Ehilegbuand to my Aunt Mrs. Blessing Ubakah.

ACKNOWLEDMENT

I want to appreciateGod Almighty for his grace and mercy to be alive and to be able to carry out this work in good health. My appreciation goes to my aunt Mrs. B Ubakah for her sponsorship and support. My profound gratitude goes to my Supervisors Professor R.S. Adamu (Chairman Supervisory Committee) and Dr. B.T Magaji (Member Supervisory Committee) for their insights, guidance, advice, constructive criticisms, valuable suggestions, support and encouragement that led to the success of this work. I am grateful to the Head of Department, of Crop Protection,my lecturers who taught me during the course of this programme andother staff of the Department who in one way or the other contributed to the success of this work. I am also grateful to Mr. Ishaku Musa of Insect Museum, Mallam Muazu of pesticide laboratory, Mallam Aliyu of Media laboratory, Mallam Hamza Musa of *Maruca* laboratory and his assistants Messrs. Anthony and Aminu,for their guidance and assistance in the course of the field work. I will not forget to mention Mr. Baba Ganiyu andMr. Abdulkarim for their assistance in analyzing my data. To my course mates, Mr. Sunday Atilukwu, Mallam Isah Bomo, Chiagozie Opara, Mufidat Rabiu and ZulaikhaAbdulsemiu, thank you being a source of encouragement to me in one way or the other during the course of the programme. I want to appreciate my Mummy and siblings for their moral support. To all,I say God bless you and continue to guide you through the journey of life.

ABSTRACT

Two field trials were conducted in the confined fields of the Institute for Agricultural Research, Samaru, Zaria during the cropping season of 2018 to evaluate Bt cowpea/maizeintercrop patternand insecticide spray regimes in the management of flowering and post flowering insect pests of cowpea.Experiment I involvedevaluating two spray regimes on an intercropped Bt Cowpea (IT97KT) with Maize (SAMAZ 27) in a ratio of 2:2, 2:4 Maize/cowpea intercrop and a sole crop of cowpea. The experiment was laid out in split plot design. The number of Cypermethrin sprays were assigned to the main plots while the intercrop pattern was assigned to the sub-plot and the experiment, replicated three times. No significant (p=0.05) difference was observed in the population of insect pests at flowering and post flowering stages of the cowpea forplots of the individual cropping pattern sprayed once at 50% podding and plots that were sprayed twice (at 50% podding and 100% podding), One spray of Cypermethrin reduced insect pest damage and increased grain yield (1,690.9kgha^{-1}) equivalent to two sprays (1,804.5kgha^{-1}).There was no significant difference between the intercrop and sole crop in insect pest population and damage level caused by *Megalurothrips sjostedti* and *Maruca vitrata*.In experiment II theyield advantage of Bt cowpea (IT97KT) over SAMPEA 15 under two spray regimes of neem seed oil using Imidacloprid as check was evaluated. The experiment was laid out in a Completely Randomized block design with three replications. It was observed that SAMPEA 15 suffered significantly ($p \leq 0.05$) higher *Maruca*and pod sucking bug damage than the Bt cowpea variety, thus had a lower insignificantly grain yield (1,108.6kgha^{-1}) than IT97KT (1,523.8kgha^{-1}). Significantly lower seed damage index was recorded on IT97KT (9.79) compared to SAMPEA 15 (16.68).It was also observed that two sprays of Imidacloprid carriedout at 50% flowering and 50% podding significantly reduced pod damage by pod sucking

bugs by 16.8% when compared to untreated control.Grain yield was higher in plots that received two sprays of Imidacloprid (1,817.8kgha^{-1}) although it was not significantly different from other treatments (one spray of Imidacloprid (1,444.4kgha^{-1}), one spray of neem oil (989.8kgha^{-1}) and two sprays of neem oil (1,218.6kgha^{-1}).

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATE

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

Cowpea (*Vigna unguiculata*(L.) Walp) is an important grain legume in the developing countries (Timko and Singh, 2008)which is mainly cultivated in the tropics with West Africa producing 4.5 million tons of dry grain in 2014 alone (FAOSTAT, 2016) and Nigeria is the largest cowpea-producing country (Jacob *et al*., 2016). Cowpea is adapted to the savannah region because of its drought tolerance and is grown by resource-poor farmers for multiple uses including food and fodder (Boukar *et al*.,2013, Murdock *etal*., 2008; and Nkongolo *et al*., 2009). Cowpea production is constrained by diseases and pests, with insect pests causing significant economic losses as the crop is severely attacked at every stage of its growth (Gianess, 2013)

Maruca vitrata (Lepidoptera; Crambidae), also known as the legume pod borer, is one of the major pestsof cowpea that causes large losses in cowpea yields (Jackai 1995; Tamo *et al*., 2003). It is found within the tropical and sub-tropical regions, but it is most devastating in sub-Saharan Africa (Margam *et al*., 2011). This insect pest is responsible for up to 80% yield losses if no control measures are employed(Mohammed *etal*.,2014).The larva is the most destructive stage of this pest and feeds on flower parts, green pods and seeds of cowpea and several other leguminous crops(Mohammed *etal*.,2014).

Farmers usually spray insecticides between 5 – 8 times per season (African Agricultural Technological Foundation, 2012)to protect the cowpea crop from *Maruca* and other pests.Purchasing chemicals, however, adds to the production cost, thus reducing the farmers' profit.

Insecticide application on a large scale causes a number of problems including environmental pollution, destruction of natural enemies of pests, pest resistance and resurgence and health risk to the farmers, applicators and livestock. Over the years,*M. vitrata* larvae have shown some resistance to different classes of insecticides (Ekesi, 1999) and coupled with the current economic hardship in Africa due to withdrawal of various subsidies previously enjoyed by farmers and the demand for pesticide-free foods research interest has now shifted to non-synthetic insecticide management alternativethat would become a component of socio-economically sustainable and environmentally friendly crop protection strategies (Jackai and Oyediran, 1991).

Well-timed insecticide applications starting at flower bud initiation control these late season pests and 2-3 sprays of insecticide are sufficient to produce good high cowpea grain yields when improved varieties are used(Ajeigbe and Singh. 2006).“Cowpea production cannot be successful without insecticide application.”(Dugje*et al.*, 2009, andKamara*et al*., 2010)

This work seeks to add scientific knowledge to the number of works being done in Nigeria on the Bt cowpea to ascertain its resistant quality conferred by the gene from the soil bacterium *Bacillus thuringiensis* and also to compare its performance with that of a non-transgenic variety, to evaluate different spray regimes of neem seed oil and Imidacloprid in the management of *M. vitrata* and pod sucking bugs on non-Bt and Btcowpea.Furthermore, to evaluate the effect of intercropping maize with Bt cowpea on the management of post flowering insect pest using different spray regimes of Cypermethrin in the management process.

1.1 Justification

Cowpea production is constrained by diseases and pests, with insect pests causing up to 100% yield losses if not controlled.The production of this crop in the tropics and Nigeria is generally low due to insect pest like *M. vitrata.M. vitrata* is the most widespread cowpea pest, with the larvae causing damage on the plants in the field, particularly during the reproductive stage, through feeding on young succulent shoots, flowers, pods, and seeds. This pest can cause significant grain yield reduction, by 20% to 80% if not controlled.

Genes conferring resistance against *Maruca* and other pests have been isolated from *Bacillusthuriengensis* and introduced into cowpea which provides protection against the pod borer (AATF, 2012) resulting in increased yield and reduced insecticide applications (Qaim, 2009).

The development of cowpea varieties with resistance to *Marucavitrata*and other insect pests would benefit the resource-poor African farmers who grow the crop. The expected yield improvement will impact positively on food security and the country's economic status (AATF, 2012).Intercropping, the growing of two or more crops in proximity to promote interaction between themcan play a significant role in integrated pest management.One common feature of most studies on intercropping irrespective of the associated crop or intercropping pattern is the lack of response by the pod borer, *Maruca vitrata* (Matteson 1982, and Ibeawuchi, 2007).

There are limited information on the use ofBt cowpeaintercrop patternwith other crops and insecticidespray regimes in the management of insect pests of cowpea in the study area. The information obtained from this work will be useful in knowing the level of resistance of the Bt cowpea (IT97KT) to *M. vitrata* for which it has been bred for especially in the study area, its relative advantage over a non-transgenic variety, and the number of sprays of Cypermethrin, Imidacloprid and neem seed oil required for managing the insect pests of the cowpea varieties used.

1.2 Objectives of the Study.

1. To determine the effect ofinsecticide spray regimes andBt cowpea/maize intercrop pattern in the managementof insect pestsof Bt cowpea (IT97KT)

2. To determine the relative yield advantage of transgenic over non-transgenic cowpea variety

3. To determine the number of synthetic and non-synthetic insecticidal sprays that will effectively manage the insect pests on Bt and non Bt cowpea varieties.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Importance of Cowpea

Cowpea (*Vigna unguiculata* L. Walp.) is an annual herbaceous legume from the genus *Vigna*. Cowpea originated and was domesticated in Southern Africa and later spread to East and West Africa and Asia (Davis *et al*., 1991).It is considered one of the most important food grain legume in the dry savannah of tropical Africa (NGICA, 2002) and the most important indigenous African legume for both home use and cash crop (Kushwaha *et al*., 2004).It is the most important grain legume crop in sub-Saharan Africa. Cowpea is mostly grown by smallholders in the hot, drought-prone savannas and very arid Sahel agro-ecological zones. It is often intercropped with pearl millet and sorghum (IITA, 2011). Cowpea is a protein-rich grain that complements staple cereal and starchy tuber crops. It also provides fodder for livestock, improves the soil fertility by fixing nitrogen, and benefits households as it brings in income. The sale of cowpea stalks for animal feed during the dry season add to household income (IITA, 2011).The crop can be harvested at three stages: when the pods are young and green, when the pods are mature and green, and when the pods are dry. The young leaves, immature pods, immature seeds, and the mature dried seeds are all used as food. The stems, leaves, and vines serve as animal feed and are often stored for use during the dry season. In Nigeria, farmers who cut and store cowpea fodder for sale at the peak of the dry season increase their annual income upto 25%. Women prepare and sell snacks made from cowpea, and are also mainly involved in the sale of green pods(NGICA, 2002).Fifty-two percent of Africa's cowpea production is used for food, 13% as animal feed, 10% for seed, 9% for other uses, and 16% is wasted.Cowpeas are of vital importance to the livelihood of several millions ofpeople in West and Central Africa (Abate *et* *al.*, 2012). It is also used as a green manure crop, a nitrogen fixer in the soil, and for erosion control

2.1.1 Cowpea production and consumption

Most cowpeas are grown on the African continent, particularly in Nigeria and Niger, which account for 66% of world cowpea production (FAOSTAT, 2012). The Sahel region also covers part of other countries such as Burkina Faso, Ghana, Senegal, and Mali. Exact figures for cowpea production are hard to come by as it is not a major export crop. Estimating world cowpeahectarage is rather difficult as it is usually grown in mixtures with other crops (Singh *et al*., 1997). Outside Africa, major production countries are Asia, Central America and South America. Brazil is the world's second-leading producer of cowpea seed, accounting for 17% of annual cowpea production, although most is consumed within the country (Rangel *et al.*, 2003).

Table 1.2017 Cowpeas dry production quantity (metric-tonne)- for all countries

Rank	Country	Quantity(metric-tonne)
0	World	7,407,924
1	Nigeria	3,409,992
2	Niger	1,959,082
3	Burkina Faso	603,966
4	Tanzania	200,940
5	Cameroon	198,201
6	Burma	178,582
7	Kenya	146, 342
8	Mali	145,018
9	Sudan	129,856
10	Mozambique	87,723
11	Congo	72,580
12	Senegal	59,157
13	Malawi	48,168
14	Haiti	28,920
15	Peru	20,341
16	United states	28,920
17	Serbia	20,341
18	China	19,822
19	Madagascar	15,968
20	Uganda	15,626
21	Sri Lanka	13,000
22	Macedonia	12,015
23	Mauritania	8,576
24	Egypt	7,974
25	South Africa	7,104
26	Croatia	4,938
27	Australia	2,347
28	Guinea Bissau	2,314
29	Philippines	646
30	Bosnia/Herzegovina	508
31	Trinidad/Tobago	505
32	Jamaica	330
33	Zimbabwe	218
34	Cyprus	191
35	Guyana	158
36	Palestinian	148
37	Slovenia	146
38	Iraq	68
39	Japan	15
40	Hungary	7

Source: FAOSTAT 2016

2.1.2 Transgenic cowpea

Transgenic cowpeas are those genetically engineered with Cry1Ab gene for protection against the Lepidopteran pest,*M. vitrata* that could inflict up to 80% yield loss in severe infestation (Mohammed *et. al.*, 2014).The *Bt* cowpea have been tested in the Commonwealth Scientific and industrial research organization (CSIRO) laboratory in Australia and found to be effectively protected against the larvae of another Lepidoptera, *Helicoverpa armigera*. The *Bt* gene in cowpea was expected to be effective against *M. vitrata*, but needs to be tested in an environment where *Maruca* thrives (Fatokun, 2009).

Cowpea variety was transformed with a *cry1Ab* gene by Higgins (CSIRO Australia), and lines were tested in over 15 independent Confined Field Trials (CFTs) inPuertoRico, Nigeria, Burkina Faso and Ghana. Highlevels of control was achieved in all CFTs. (AATF, 2016)

Laboratory studies have shown that the Cry1Ab transgene derived from the *Bacillus thuriengiensis* Bt gene confers resistance on cowpea to the pod borer (Fatokun, 2009; and Higgins, 2007) and the transfer of the Cry1Ab transgene into improved cowpea varieties, will reduce the need for insecticide sprays in cowpea: and smallholder farmers can substantially increase their yields and greatly enhance their nutritional and economic status (AATF, 2016).

The development of cowpea varieties with resistance to *Maruca* and other insect pests would benefit the most resource-poor African farmers who grow the crop (Fatokun,2009).With this development, farmers will have access to improved cowpea varieties that will lead to increase in yield. These varieties are expected to reduce grain yield losses caused by the Pod borer, as well as, reduce the need for insecticide application. Recently, a *cry* transgene has been used to generate many cowpea lines expressing Cry 1Ab protein and one line was selected as a breeding parent following several years of field trials against *Maruca* in the field in West Africa (Higgins *et al.*,2010).Mohammed *et. al*., (2014) performed a confined field trial,where two transgenic events TCL-709 and TCL-711 were crossed to three non-transgenic lines IT97K-499-35, IT93K-693-2 and IT86D-1010 to generate six set of F_1 hybrids. The study was designed and conducted to evaluate the performance of transgenic cowpeas and hybrids derived from them under natural field conditions.The results revealed that the cowpea lines containing the cry1Abgene produced enough toxin to kill and inhibit the feeding of *Maruca* on cowpea plants.

2.1.3 Cultivation of cowpea

Climatic requirements for cowpea- During growing season the temperature range for cowpea is between 28^0C-30^0C, its rainfall range is from 500-1200mm/year but some variety can thrive in areas with less than 500mm. This means that cowpea will still survive in areas with low rainfall, although the crop requires enough moisture during the germinating period (IITA, 2021a).

Time of planting: Savannah zone: For medium/late maturing varieties (70–86 days), plant from late July to mid-August. For early maturing varieties (55–69 days), commencing sowing from mid-August to the end of August. Forest zone: For medium/late maturing varieties, planting should commence from mid- August to early September, depending on the onset of late season rains.(IITA, 2021a)

Seed rate and plant population:Seed rate: approximately 25–30 kg/ha (good and viable seeds). Spacing: 20 x 75 cm for erect varieties and 50 x 75 cm for spread types. 2 seeds/hole, 4–5cm deep.

Fertilization: cowpea does not require too much nitrogen fertilizer because they fix their own nitrogen from the air using the nodules in the roots. Cowpea requires more phosphorus than nitrogen in the form of single super phosphate**.** Savannah zone: Use 50–100 kg/ha (1–2 bags) of single superphosphate depending on the level of P-deficiency or 100 kg/ha (2 bags) of NPK 15:15:15. Forest zone: Use 50 kg/ha (1 bag) of single superphosphate on land under continuous cropping. Broadcast the fertilizer and harrow it before planting. Alternatively, apply 150kg/ha of NPK 15:15:15 in the same way(IITA, 2021a)

Weed control: Hand weeding:Give minimum of 2 hoe-weedingthe first 3 weeks after sowing and the second 4–5 weeks after sowingand leave them in the field to dry. (IITA, 2021a)

2.2Insect Pests of Cowpea

There are numerous important insect pests of cowpeas worldwide and most locations have 2 – 4 species being key pests. The insect pests are classified into three feeding guilds as pre-flowering (vegetative) insects, flowering (reproductive) insects, and post-flowering (podding) insects. The crop is severely attacked at every stage of crop growth by these insects. Pre- flowering cowpea pests are *Ootheca mutabilis* and *Zonocerus variegatus*. The flowering and the post-flowering insects are the most damaging (Olatunde*et al.*, 1991;Alghali, 1993).

The most damaging flowering pestsare flower bud thrips, *Megalurothrips sjostedti* Tryb. (Thysanoptera: Thripidae), the legume pod borer, *Maruca vitrata* Fab. (Lepidoptera: Pyralidae) which are the reproductive insect pest. The post-flowering pests are the pod sucking bug (PSB) complex of which *Clavigralla*spp. Stal. (Hemiptera: Coreidae), *Anoplocnemiscurvipes* Fab. (Hemiptera: Coreidae), *Riptortusdentipes* Fab. (Hemiptera: Alydidae) and *Aspavia armigera* are the most damaging and prevalent ones at podding.

In Nigeria, major field insect pests of cowpea include aphids (*Aphiscraccivora* Koch.), thrips (*Megalurothrips sjostedti* Trybom), legume pod borer (*Maruca vitrata*), spiny brown bug (*Clavigralla tormentosicollis* Stal.), flowerbeetle (*Mylabris* species), leaf-footed plant bug

(*Leptoglossus australis* F.) and foliage beetle (*Oothacea mutabilis* Salhib)(Malgwi and Onu, 2004).

2.2.1 *Maruca vitrata*and distribution

Several authors have identified *M. vitrata*to be widely distributed, most especially in sub-Saharan Africa with wide-ranging host plant (Legumes) and favorable climatic condition (Shanower*et al*., 1999, Sharma*et al*., 1999). According to recent studies, the geographical range of *M. vitrata*has extended to some parts of Europe probably by means of pod transportation.About 39 host species of this pest were identified feeding on flowers, pods, leaves and shoots.Despitehaving such a wide range of alternative hosts in West Africa, *M. vitrata*appears to be migratory along the coastal areas tothe dry savanna parts (Arodokoun *et al.*,2006).

2.2.2 Life cycle of *Maruca vitrata*

Eggs are normally deposited on flower buds and flowers although ovi-position on leaves, leaf axils, terminal shoots and pods has also been recorded (Taylor, 1967). A female lay between 6 and 189 eggs although 200-300 ova have been observed per female. Eggs are translucent and have faint reticulate sculpturing on the delicate chorion, and measure 0.45 to 0.65mm. Eggs are usually deposited singly or in batches of 2 to 16 andhatch in about five days. There are five larval instars, total larval developmental stage is completed in 8-14 days (Das and Islam 1985). The larvae are translucent and shinning and have six rows of black spots on the larva. It is also called a spotted caterpillar; the head is dark brown. The larvaeare very active and tend to fall off the webbed flowers and pods with the slightest disturbance by spinning a silken thread. The prepupal period lasts for two days. Pupation occurs in a silken cocoon amongst webbed leaves, pods or in soil. The life cycle is completed in 18 to 35 days (Taylor 1967, Akinfenwa 1975, Sharma in press). Adults are brown to black with a white patch on the wings. In their normal resting posture, the moths hold wings in a horizontal position unlike other moths which rest with folded wings.

2.2.3Nature of damage of insect pest of cowpea.

Aphiscraccivora; feeds by piercing the plant tissue and sucking sap from the under surface of young leaves and stem tissues, and on the pods of mature plants. The cowpea aphid causes economic losses directly by sucking sap and indirectly through the transmission of viral disease.

Megalurothripssjostedti: The adults are tiny black slender insects with two pairs of feathery wings. The pest feeds on flower buds and flowers. Severely infested plant does not flower. Yield loses estimated between 20% and 100%. The current management of thrips relies on chemical control with insecticides or the use of tolerant variety Omoigui *et.al*., (2020).

The importance of *M. vitrata* as a pest on grain legumes results from its early establishment onthe crop. The larvae web the leaves and inflorescenceand feed inside flowers, flower buds, and pods. This typical feeding habit protect the larvae from natural enemies and other adverse factors, including insecticides. The flower bud stage is preferred most for ovi-position, and it is at this stage that the young larvae cause substantial damage, and reduce the crop potential for flowering and fruit setting. 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.

The nymphs and adults of several different species of pod-sucking bugs suck the sap of the young pods causing them to shrivel and dry prematurely, or become deformed and have reduced grain yields. The shriveling and drying symptoms can be confused with other stresses such as drought and disease; however, the feeding puncture wounds are a sign of pod-sucking bugs (Ericah,2014). The insects can often be found on the pods or under the leaves of cowpeas and other host plants. Pod-sucking bugs feed on a wide range of legumes and are very mobile, which makes it difficult to control them. Monitor crops regularly to look for pod-sucking bugs and symptoms such as shriveling and prematurely dried out pods(Ericah,2014).

2.2.4Economic importance of insect pests of cowpea

Several findings have described *M. vitrata* as the most devastatinginsect pest causing poor yield and considerable losses of cowpea worldwide. The larval stage is the damaging stage and it does so by entering the flower buds and pods. The damaged pod is completely or partially eaten up and its entrance hole allows water into the pod which stains the seeds. The buds, flowers and leaves are also damage (Huang *et al*. 2003) which may be consumed and or bound together by the larvae. The young larvae usually feed on and damage the flower while the older ones feed most often on the pod (Sharma 1999). In severe infestation, yield losses of between 70% and 80% have been reported (Prince, 2010). Various workers have reported that losses in cowpea grain yield due to insect pests vary from 20% to almost complete crop failure (Alghali, 1992; and Tanzubil, 2000). Alghali (1992) also reported that in Nigeria, yield loss was up to 75% when insects attacked the crop during the flower budding and flowering stages of the crop. Studies by Tanzubil (2000) concluded that in Northern Ghana, complete crop failure often resulted when improved cowpea varieties were grown without insecticide sprays.

2.2.5Control of cowpea insect pests

Various legume insect pest management strategies have been successfully used. They include biological control (Cox *et al*., 2006; Ugine *et al*., 2007), botanical pesticide mixtures such as aqueous neem and eucalyptus leaf extracts (Oparaeke *et al*., 2006), cultural control (Nampala *et al*., 2002) and chemical control (Heitholt *et al*., 2006; and Seal *et al*., 2006). The tendency, however, has been to rely heavily upon chemicals for control of such diseases and insect pests. This is because fungicides and insecticides are considered to be reliable because of their quick and effective action (Adejumo, 2005; and Seal *et al*., 2006). Various chemicals have been evaluated and reported to be effective against major crop diseases and insect pests. Although the use of chemicals as a control measure is advisable, various problems have arisen. Other than the prohibitive costs of pesticides, high applications have dangerous effect on the environment and on human health besides the risk of development of resistance (Ekesi, 1999).The neem products and other plant extracts are cost effective crop alternative protectants compared to synthetic insecticides which are expensive to farmers and detrimental to the ecosystems (Mensah *et al.*, 2017).

2.3Imidacloprid

Imidacloprid is a systemic insecticide that acts as an insectneurotoxin and belongs to a class of chemicals called the neonicotinoids which act on the central nervous system of insects. The chemical acts by interfering with the transmission of stimuli in the insect nervous system. Specifically, it causes a blockage of the nicotinergic neuronal pathway. By blocking nicotinic acetylcholine receptors, imidacloprid prevents acetylcholine from transmitting impulses between nerves, resulting in the insect's paralysis and eventual death. It is effective on contact and via stomach action (Pesticide Information Profile) Because imidacloprid binds much more strongly to insect neuron receptors than to mammal neuron receptors, this insecticide is more toxic to insects than to mammals (Gervaise*et al*., 2010).

2.3.1Uses of imidacloprid

Imidacloprid is the most widely used insecticide in the world. Its major uses include:

Agriculture –for control of aphids, cane beetles, thrips,stink bugs, locusts, and a variety of other insects that damage crops(Federoff *et al*., 2008).

Arboriculture - for control of the emerald ash borer, hemlock woolly adelgid, (Preston, 2007) and other insects that attack trees including hemlock, maple, oak, and birch(Herms *et al*., 2009).

Home Protection –for control of termites, carpenter ants, cockroaches, and moisture-loving insects. (Preston 2007, Federoff *et al*., 2008).

Domestic animals – for control of fleas applied to the neck (Preston, 2007).

Gardening - Control of aphids and other pests

2.4 Neem as an Ideal Source of Bio-Pesticide:

Bio-pesticides defines compounds that are used to manage agricultural pests by means of being specific rather than the broader chemical pesticides. They are derived from natural materials such as animals, plants, bacteria or certain minerals.Of the several plant species screened so far as sources of bio-pesticides in tropical Africa, neem (*Azadirachta indica* A, Juss) is, perhaps, the most promising becauseit possesses all the characteristic of an ideal bio-pesticidal agent. It has been recommended that plant species containing bio-pesticidal agentsshould ideally possess the following characteristics(i) Be easy togrow, requiring little space, labour,water and fertilizer (ii)Recover quickly each time the pest control material is harvested from it. (iii) Be perennial, eliminating the need for periodic replanting. (iv) Not become a weed or a host to plant pathogens or insects. (v) Possess complementary uses. (vi) Effectively control either a specific pest or a broad range of pests. (vii) Pose no hazard to non-target organism, wildlife, humans or the environment and (viii) Be easy to harvest, formulate and use with simple village-level technology (Lale, 2002). Neem, is therefore, one of the few sources of botanical pesticides currently attracting much research interest world -wide. It is a hardy tree that thrives in marginal tropical and subtropical areas under little care and inputs. More than 12 to 15 complex constituents (triterpenoids) having repellant, anti-feedant, insect growth regulatory and pesticidal properties have been identified in aqueous and organic solvent extracts of its leaves, bark,stem, seed and other parts. These have been used to control more than 250 species of insects, mites and nematodes, as well as some fungal, bacterial and viral diseases. They have also been found to be safe for humans and friendly to the environment. Neem products are characterized by low mammalian toxicity, lack of mutagenicity and a high rate of biodegradability (Lale, 2002).

2.4.1 Neem oil

Neem oil is a naturally occurring pesticide pressed out of the seeds obtained from neem trees *Azadirachta indica* A. Juss. It is yellow to brown, has a bitter taste and a garlic sulfur smell (Bond *et al.*, 2012). It is composed mainly of triglyceridesand contains many triterpenoid compounds, which are responsible for the bitter taste. It is hydrophobic in nature; in order to emulsify it in water for application purposes, it is formulated with surfactants.*Azadirachtin* is the most well-known and studied triterpenoid in neem oil. Neem oil also contains several sterols, including campesterol, beta-sitosterol, and stigmasterol.It is used for preparing cosmetics such as soaps, hair products and hand creams (Puri, 1999). The ingestion of neem oil, even in small doses is severely toxic and can induce metabolic acidosis, seizures, renal failure and severe brain ischemia. Formulations made of neem oil also find wide usage as a bio-pesticide for organic farming, as it repels a wide variety of pest including mealy bug, beet army worm, aphids, thrips, whiteflies, mites, fungus gnats, leaf miners, locust, nematodes etc. (Isman 2006, and Mishra *et al.*, 1995).It can also be used as a household pesticide for ants, bedbug, cockroaches, housefly, sand fly, snail, termite and mosquitoes both as repellant and larvicide (Puri, 1999).

2.4.2 Extraction of neem seed oil

There are two main methods used for the extraction of oil from neem seeds and these comprise extraction using organic solvents and extraction by the traditional kneading methods (Lale, 2002)

(1) **Extraction by kneading**. In this method, a known quantity of the neem powder is put into a bowl and pre-boiled water is added gradually, a little at a time, preferably from a kettle and mixed into the powder. This procedure should be repeated until a dough-like material is formed. The oil is then pressed out manually into a collecting container. The entire process should be repeated until oil in the dough is pressed out. The oily material collected should be heated to remove any traces of water and the final product (pure neem seed oil) should be stored in an appropriate container at room temperature. Unlike

the neem seed powder, neem seed oil stores well without loss of efficacy. The oil is not volatile and this product can be extracted in large quantities and stored for future use. This is particularly important because storage of oil is more economical of space than storing decorticated seeds. (Lale, 2002)

(2) Extraction using organic solvents. The most commonly used solvents include acetone, chloroform, ethanol, methanol, and petroleum ether. The choice of the solvent is very crucial as the solubility of the active constituents of neem and hence the efficacy of the extracts vary with the solvent used. Oil obtained by extraction with acetone seems to be more potent against pests of stored commodities. (Lale, 2002) Two common method are used for the extraction of oil from neem seeds using organic solvents these include hot extraction involving the use of Soxhlet extractor, and cold extraction. For the Soxhlet extractor method, 40g of the powder should be wrapped in a double layer of Whatman No. 1 filter papers. The filter papers should be stapled at the seams to prevent leakage of powder. Each pack should then be extracted in 200ml of grade acetone for 1.5 hours at the boiling point temperature of the solvent (56^{o} C for acetone). The procedure should be repeated until the required quantity of oils obtained (Lale, 2002). For the cold extraction method, 40g of the neem powder should be put into a 250 ml volumetric flask or similar glassware and 200ml of analytical grade of any available organic solvent should be added. Larger quantities of the powder can be extracted in glassware of larger capacities provided that the ratio of 40g of neem seed powder to 200ml of solvent is maintained. The mixture should be filtered through a double layer of cheese cloth or Whatman No. 1 filter papers. The resulting filtrate should be collected and heated over an electric heater or other source of heat to evapourate off all traces of the solvent. In both methods of extraction, the oil collected, as in the kneading method, should be stored in a cool dry place at room temperature (Lale, 2002).

2.5 Maize

Maize (Zea mays L.) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. Maize is cultivated throughout the world (58°N latitude to 40°S latitude) in an area of 179.9 m hectares across 165 countries with a production of 1013.6 m.t and average productivity of 5.63 t/ha. It is largely grown in USA, China, Brazil, Argentina, Mexico etc. The highest productivity of 10.73 t/ha was achieved in United States, which was followed by China (5.81 t/ha) and Brazil (5.4 t/ha). India occupies 7th position in respect of area and production (United State Department of Agriculture, 2016). Africans depend on maize as the main staple food crop. All part of the crop can be used for food and non- food products. Maize accounts for 30-50% of low income household expenditures in Africa. Over 30% of the caloric intake of people in sub-Saharan Africa comes from maize. For these reasons, several African countries that depend on maize as a staple food crop, have adopted agricultural policies to maintain a steady supply of the crop (IITA,2021b)

2.6Intercropping

The availability of land for agriculture is shrinking every day as it is increasingly utilized for non-agricultural purposes. With increase in population, the demand for land has also increased, resulting in continuous land use with little or no fallow periods, hence the need for intercropping

(Weber *et al.,* 1996). Intercropping is a type of mixed cropping and defined as the agricultural practice of cultivating two or more crops in the same space at the same time. It increases productivity per unit of land via better utilization of resources. It minimizes the risks by insuring against crop failure, reduces weed competition and stabilizes the yield (Ananthi *et al*., 2017). Intercropping systems used the growth factors more efficiently because crops intercept greater solar radiation and make better use of available moisture and nutrients, reduce pests, disease incidence and suppress weeds (Addo-Ouaye *et al*., 2011) and favor soil-physical conditions, particularly in cereal/legume intercrop which tend to maintain and improve soil fertility (Akande *et al.,* 2006). Some studies have indicated that intercropping was more productive than sole cropping because of the complimentary effect of intercrops in systems involving Amaranth/cowpea, cucumber /cowpea (Bhatti *et al*., 2013), maize with cowpea (Mohammed *et al*., 2006) and cassava/cowpea intercrops (Gomez and Gomez, 1983). In tropical regions, corn has been considered as the best component in most intercropping system with cowpea (Susan and Mini 2005).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The research was conducted in the Confined Field Trial site (CFT) of the Institute for Agricultural Research, Samaru (11° 11‟ N, 7° 38‟ E).

3.2 Experimental Materials

SAMMAZ 27,Bt cowpea hybrid (IT97KT), and non-Bt cowpea variety (SAMPEA 15).

SAMMAZ 27 is an early maturing maize variety (75-80days) and the cowpeas are medium maturing cultivars (75-85). These were sourced from the Seed Production Unit and Plant Science Department of the Institute for Agricultural Research, Samaru.

SAMMAZ 27: (EV99DT-W-STR) was released in 2009. It is early maturing, drought tolerant and striga resistant (Nigerian seed portal 2021)

IT97KT (SAMPEA 20 T); is an early maturing variety (70-75 days) with semi-erect growth habit, insensitive to day length,and has medium large seeds. It is also resistant to Striga and Alectra (Issoufou 2019)

SAMPEA 15; original name IT99K-573-2-1, has outstanding characteristics which include; multiple disease resistance, drought tolerant, and resistance to Striga and Alectra. It is adapted for Northern Guinea Savannah. It was developed by IITA Ibadan and IAR Zaria. Its maximum yield is 2.5tonne/hectare (Nigerian Seed Portal 2021).

3.3 Land preparation

All debris, shrubs and stones were removed from the experimental field and sprayed with Glyphosate at 5l/hectare to control emerged weed before ploughing (Oyewale *et. al.*, 2014). The land was later ploughed, harrowed and ridges were made at 0.75m spacing

3.4 Experiment I: Effect of Intercropping and Insecticidal Spray Regime on Management of Post Flowering Insect Pest of Bt Cowpea.

SAMMAZ 27 was intercropped with Bt cowpea (IT97KT) in ratios of 2:2 and 2:4 with a sole plot of Bt cowpea as check. Each plot was 4m long with four ridges for 2:2 intercrop and sole plot and six ridges for 2:4 intercrop plot.Crest to crest spacing of the ridges was 0.75m, intra row spacing for maize was 30cm and 20cm for the cowpea. Three seeds were sowed per holes and later thinned to two seedlings per stand, at two weeks after sowing. Cypermethrin was sprayed to control the post flowering pest. Two spray regimes were evaluated with an untreated check. A total of nine treatments were laid out in a split plot design, spray regime was assigned to main plots and the cropping pattern to subplot. One Spray regime wasapplied only at 50% podding (8weeks after sowing) while, two Sprays regimes were applied at 50% podding and 100% podding.

Table 2. Experiment I Layout

4m long **REP I**

1 Spray regime	1.0m alley	2 Spray regimes	1.0m alley	No spray
Sole cowpea		2:4 maize/cowpea intercrop		2.2 maize/cowpea intercrop
2:2 maize/ cowpea intercrop		Sole cowpea		2:4 maize/cowpea intercrop
2:4 maize/cowpea intercrop		2.2 maize/cowpea intercrop		Sole cowpea

REP II

2 spray regimes	No spray	1 spray regime
2:2 maize/cowpea intercrop	2.4 maize/cowpea intercrop	Sole cowpea
2.4 maize/cowpea intercrop	Sole cowpea	2:2 maize/ cowpea intercrop
Sole cowpea	2:2 maize/cowpea intercrop	2:4 maize/ cowpea intercrop

REP III

No spray	1 Spray regime	2 spray regimes
2:2 maize/cowpea intercrop	2:4 maize/cowpea intercrop	Sole cowpea
2:4 maize/cowpea control	Sole cowpea	2:2 maize/cowpea intercrop
Sole cowpea	2:2 maize/cowpea intercrop	2:4 maize/cowpea intercrop

3.5 Experiment II: Effect of Spray Regime of Imidacloprid and Neem seed oil on Floweringand Post Flowering Pests on Btand Non-Bt cowpea.

Imidacloprid 20% SL was used as synthetic insecticide and neem seed oil as the bio-pesticide. Neem seed oil was purchased from National Research Institute for Chemical Technology (NARICT), while Imidacloprid was purchased from Farmers Escort Samaru Zaria.

Five (5) ml of the neem seed oil was emulsified with 15ml of mild liquid soap per litter of water as described by Degri and Sodangi (2013). The plot sizes for this experiment were 5m long in widthcontaining four ridges separated by a 1.0m boarder alley on all sides. A total of ten treatments (Table 3) were laid out in a randomized complete block design (RCBD) andreplicatedthrice. Three seeds were planted per hole and the seedlings were thinned to two per stand. The inter row spacing of 75cm and intra row of 20cm were used. The field was kept weed free by weeding manually at three weeks' intervals.

Two cowpea varieties; Bt cowpea (IT97KT) and non-Bt SAMPEA 15 were sown on the 15th of August, 2018 as recommended by Hakeem *et. al.,* (2012). Seeds were dressed with a fungicide (Dress force) at 1 Sachet of 10g to 2kg of seed to promote good germination and protect the seedling at emergence from fungal infection (Degri and Sodangi, 2013).

The spraying for experiment two commenced at 50% flowering, 49 days after sowing. Two spray regimesof Imidacloprid at manufacture's recommendation and Neem seed oil 5ml/L emulsified with15ml mild liquid soap and an untreated control were evaluated. one spray regime plots received insecticide treatment only at 50% flowering, two spray regimes plots received insecticide treatment at 50% flowering and 50% podding. These ten treatments were replicated three times in a Randomized Complete Block Design (RCBD).

Table 3. Experiment II Treatments

Treatment number	Treatment
1	Bt cowpea (IT97KT) with one spray of Imidacloprid
2	Bt cowpea with two sprays of Imidacloprid
3	Bt cowpea with one spray of neem oil
4	Bt cowpea with two sprays of neem oil
5	Bt cowpea Untreated control
6	Non-Bt cowpea (SAMPEA 15) with one spray of Imidacloprid
7	Non-Bt cowpea with two sprays of Imidacloprid
8	Non-Bt cowpea with one spray of neem oil
9	Non-Bt cowpea with two sprays of neem oil
10	Non-Bt cowpeaUntreated control

Table 4. ExperimentII layout

REP I	1m alley	REP II		REP III
1		9		3
5m long				
2		8		4
3		7		5
4		6		1
5		10		2
6		4		8
7		3		9
8		1		10
9		2		6
10		5		7

Parameters Evaluated

• Days to 50% Flowering: The number of days from planting to 50% flowering was recorded at the time when about half of the total plants in each plot have flowered.

• Days to Pod Maturity: The number of days from planting to maturity was recorded at the time when about 70% of the pods in each plot have matured and charge from green to brown color.

• Pod Yield Per Plot (g): The pods from each net plot was carefully harvested and placed in well labeled bags and weighed to give the pod yield per plot.

Number of pods per plant: One-meter length of cowpea row line was marked and the pod that fell within this distance was counted, the number of pods was divided by the number of cowpea plant

• 100 Seed Weight (g); 100 healthy seeds were selected at random from the seed lot of each plot and weighted to get the 100 seed weight per plot.

• Seed Yield Per Plot (kg/ha): The seed yield per plot was obtained after threshing and weighing each net plot. The seed yield per plot was then converted to kilograms per hectare.

3.6 Data Collection

Field data was collected from two middle rows of each plot while the two outer rows served as border rows. Twenty-four hours before and after each spray, 20 flowers were randomly picked per plot from discard rows and placed in jar containing 30% alcohol. These were taken to J. C. Deemung museumin the Department of Crop protection Ahmadu Bello University, Zariafor insect identification and counting; the flowers were dissected and observed under the microscope for the presence of lepidopteran pod borer larvae and thrips. The number of*M. vitrata*larvaeand *Megalurothrips sjostedti* observed were recorded according to Asante *etal*., (2001), and Dzemo *et al.*,(2010). *M. vitrata* and thrips countswere expressed in number per 20 flowers while Podsucking bugs population (PSBs), were also counted in the two middle rows of each plot, 24 hours before and after spray application by randomly selecting ten plants and counting the number of pod sucking bugs found on them.

Pod load (PL) and Pod damage (PD):these were assessed at 70 DAS (days after sowing), on each plot using a visual scale of 1-9 points modified to 1-5for pod load (Table 5a). For the PD, holes and frass on pods and sticking of pods were the *Maruca* damage index rated on a visual scale of 1-9 (Table 5b).

Pod evaluation index (PEI**):** This was determined by the formula – PL x (9 – PD), where PL is pod load and PD, pod damage (Jackai *et al*., 1988, Egho 2011).

Table 5a. Scale for rating *Maruca vitrata* damage to cowpea

Pod load (PL)	
Rating	Degree of podding
1	most (<60% peduncles bare (i.e. no pods)
2	31-50% peduncles bare
3	16-30% peduncles bare
4	Up to 15% peduncles bare
5	Occasional bare peduncles

After Jackai and Singh (1988)

Table 5b.

Rating	Pod Damage %
1	1-10
2	11-20
3	21-30
4	31-40
5	41-50
6	51-60
7	61-70
8	71-80
9	81-100

3.7Damage assessment

Number of aborted flowers/plant was assessed by counting the number of flowers that dropped on the ground from five stands selected randomly at 10 weeks after sowing (WAS).

Pod damage (shriveling, twisting, stunting, constriction and presence of entry/exit holes of Lepidopteran pod borer on pods) was assessed by examining 20 pods randomly selected from ten plants per sampling area. Damage was then expressed as percentage of the total number of pods assessed per plot (Dzemo *et al.*,2010).

When the pods were fully matured (at about 15% moisture content), all podsfrom ten plants randomly selected were harvested from the middle two rows to determine various yield and damage parameters. Seeds were observed for feeding symptoms such as wrinkling of the seed coat, browning or shriveling of the seeds and presence of suction punctures on the seeds.

Seed damage indices (SDI), was determined by sorting the seed lot from each plot into 3 categories as described by Gilman *etal*. (1982), Oyewale*etal* (2014). Category A consisted of seeds with no feeding damage; category B, seeds with obvious feeding punctures but with mild wrinkles and category C, seeds with holes or seeds that were severely wrinkled and shrunken to small sizes. The proportion of each category from each treatment plot was weighed and expressed as percentage of the total weight of seeds assessed.

To compute the SDI a slight modification of the method used by Gilman *etal*. (1982) was followed (that is using weights instead of counts) as illustrated below:

SDI = 0.5 (% seed weight in category B) + (% seed weight in category C).

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

3.8 Yield Assessment

Pods harvested from each plot were placed in separate polythene bag, labelled and taken to the laboratory where the pod and seed weights were measured using an electric balance (Mettle p323 model). Grain yield was recorded from threshed grains harvested from each plot. The pods and seed weights were calculated using the following formula used by Aliyu *et al*., (2011).

Seed/pod weight (kg/ha) $= \frac{a \times 10{,}000}{b \times 1{,}000}$

Where:

a = plot yield in grams (g),

b = Net plot size.

Area of hectare $=$ 10,000m^2

1 kilometer = 1000m

3.9 Data Analysis

The data collected was subjected to Analysis of Variance (ANOVA) using SAS package (SAS 2003). The Student Newman Keul test(SNK) was used to separate the means. Insect count and percentage data were square root transformed$\sqrt{x} + 0.5$ before analysis.

CHAPTER FOUR

4.0 RESULTS

4.1 Experiment I

4.1.1 Effect of cypermethrin spray regimes and maize/cowpea intercrop pattern on population of insect pests on Bt cowpea at Samaru during 2018 wet season.

The effect of cypermethrin spray regimes and maize/cowpea intercrop on population of insect pests on transgenic cowpea in Samaru during 2018 Wet Season is presented in Table 6.At 50% podding,there was significant (p>0.05) difference in population of thrips (*Megalurothrips sjostedti*) between the treated plots and untreated control. Plots that received one and two sprays had significantly lower population of thrips compared to the untreated control. Similarly, at second insect pest sampling done at 100% podding, the untreated control had higher record of thrips population (3.22) than the one (2.17) and two spray regimes of cypermethrin (2.21), which were similar. Population of *Maruca* larvae did not differ significantly between treated plots and the untreated control in the two insect pest sampling periods. However, thetreated plots recorded insignificantly lower number of *Maruca*larvae compared to the untreated control. Population of pod sucking bugs did not differ significantly between treated plots and untreated control at 50% and 100% podding.

In terms of cropping pattern,the number of *M. sjostedti* per 20 flowers were at par for sole cropping, 2:2 and 2:4 Maize/ cowpea intercrops at 50% and 100% podding. The results also showed no significant difference (p≥0.05) in the number of *Maruca* larvae recorded among the cropping patterns at 50% and !00% podding. Similarly, pod sucking bugs populations did not differ significantly among the cropping patterns at both first and second insect pest sampling periods.

Table 6:Effect of cypermethrin spray regimes and maize/cowpea intercrop patternon population of insect pest on Bt cowpea at Samaru during 2018 wet season.

Treatment	*Megalurothrips sjostedti/*20		*Maruca vitrata/*20 flowers		Pod sucking bugs/10 plant	
Sprays regimes	50% podding (8 WAS)	100% podding (10 WAS)	50% podding (8 WAS)	100% podding (10 WAS)	50% podding (8 WAS)	100% podding (10 WAS)
One spray	0.94[b]	2.17[b]	0.98	0.84	1.33	3.65
Two spray	1.12[b]	2.21[b]	0.98	0.86	1.09	2.45
Untreated Control	3.01[a]	3.22[a]	1.19	0.90	1.51	2.85
SE ±	1.15	0.59	0.12	0.03	0.21	0.62
Cropping patterns						
Sole crop	1.49	2.39	1.03	0.86	1.41	3.72

2:2 intercrop	1.87	2.82	0.94	0.90	1.07	2.56
2:4 intercrop	1.71	2.39	1.17	0.84	1.45	2.65
SE ±	0.15	0.24	0.08	0.12	0.17	0.46
Interaction						
Spray x cropping pattern	NS	NS	NS	NS	NS	NS

Means followed by same letter within the same column of any treatment group are not significantly different at 5% level of probability using Student Newman Keul test.

NS: not significant.

WAS: weeks after sowing

4.1.2 Effect of cypermethrin spray regimes and maize/cowpea intercrop pattern on percentage pod damage by*Maruca* and pod sucking bugson Bt cowpea at Samaru.

Effect of different spray regimes of cypermethrin and maize/cowpea intercrop pattern on pod damage by *Maruca* and pod sucking bugs is presented in Table 7. The results revealed that there was insignificant difference in the percentage pod damage caused by *Maruca*larvae on thepods in the different cropping patterns.There was significant difference ($p<0.05$) on the percentage pod damage caused by pod sucking bugs between treated plots and untreated control. The untreated control plots had significantly higher percentage of pod damaged by Pod sucking bugs (4.97) than plots that received two sprays and one spray of cypermethrinboth of which were at par. There was also no significant difference ($p>0.05$) observed in percentage pod damage due to *Maruca* between sole crop and the other cropping patterns. Pod sucking bugs damage also had no significant difference between sole crop and the intercrops.However, sole cowpea plots recorded highest percentage pod damage due to Pod sucking bugs(3.72), followed by 2:4 (2.65) and 2.2 (2.56) intercrops.

Table 7: Effect of cypermethrin spray regimes and maize/cowpea intercrop pattern on percentage pod damage due to *M. vitrata*and pod sucking bugs on Bt cowpea at Samaru during 2018 wet season.

Treatments	% number of pods damaged by *Maruca*	% number of pods damaged by Pod sucking bugs
Spray regimes		
One spray	1.13	3.57[b]
Two sprays	1. 34	3.42[b]
Untreated Control	1.42	4.97[a]
S.E ±	0.12	0.85
Cropping patterns		
2:4 intercrop	1.12	2.65
2:2 intercrop	1.13	2.56
Sole crop	1.34	3.72

S.E ±	0.24	0.32
Interaction		
Spray X cropping pattern	NS	NS

Means followed by the same letter within same columnof any treatment group are not significantly different at 5% level of probability using Student Newman Keul test.

NS: Not significant.

4.1.3 Effectof cypermethrinspray regimes and maize/cowpea intercrop pattern on yield related components of Bt cowpea at Samaru during 2018 wet season.

Results on the effect ofdifferent cypermethrinspray regimes and maize/cowpea intercrop pattern on flower abortion due to insect pest, pod load and pod evaluation index of transgenic cowpea are presented in Table 8. There was a significant difference in the number of aborted flowers due to insect pest damage between the treated plot and untreated control ($p<0.05$). Untreated control had significantly ($p<0.05$) higher number of aborted flower (20.89) than the treated, followed by Cypermethrin at one spray (17.11) which in turn was significantly higher than two sprays of Cypermethrin (12.67). In terms of pod load, there was no significant difference ($p>0.05$)between treated plots and untreated control. However, untreated control had insignificantly lower pod load (2.67) when compared to Cypermethrinat one spray regime (3.78) and Cypermethrin at two spray regimes (3.33). Results for pod evaluationindex (PEI) showed that one spray regimehad insignificantly higher pod evaluation index (30.22) compared to two spray regimes (27.56) and untreated control (22.22).

Among the cropping pattern, there was no significant difference recorded amongst the treatments in each of the parameters assessed. However, 2:4 (Maize: Cowpea) intercrop recorded the highest mean number of aborted flowers (18.22) when compared to 2:2 intercrop (16.44) and sole crop (16.00). Sole crop had the highest pod load (3.33) when compared to 2:2 and 2:4 (maize/cowpea intercrop which both had lower pod load of (3.22).

There was no significant difference for pod evaluation index between sole crop (27.56), 2:2 intercrop (26.67) and 2:4 maize/cowpea intercrop (25.78).

Table 8: Effect of cypermethrin spray regimes and maize/cowpea intercrop patternon yield related component of Bt cowpea at Samaru during 2018 wet season.

Treatment	Mean number of Aborted flowers	Pod load index	Pod evaluation index
Spray regimes			
One spray	17.11[b]	3.78	30.22
Two sprays	12.67[c]	3.33	27.56
Untreated Control	20.89[a]	2.67	22.22
S.E $\pm$	4.12	0.56	4.07
Cropping patterns			
Sole crop	16.00	3.33	27.56
2:2 intercrop	16.44	3.22	26.67
2:4 intercrop	18.22	3.22	25.78

S.E ±	1.19	0.32	2.43
Interaction			
Spray X cropping pattern	NS	NS	NS

Means followed by the same letter within a column of any treatment groupare not significantly different at 5%level of probability using Student Newman Keul test.

NS: not significant.

4.1.4 Effect of cypermethrin spray regimes and maize/cowpea intercrop pattern on percentage seed damage indexof Bt Cowpea at Samaru during 2018 wet season.

The effect of cypermethrin spray regimes and maize/cowpea intercrop on the percentage seed damage indexof Bt cowpea is presented in Table 9. There was no significant difference at 5% probability in the percentage seed index of seed category A (undamaged seed) between treated plots and untreated control. However, plots sprayed twice with Cypermethrin had the highest weight of seed category A (9.49), while control had the least weight of seed category A (8.57).There was also no significant difference ($p \geq 0.05$) on percentage seed weight of seed category B (slightly damaged seed) between treated plots and untreated control. Percentage seed weight of seed category C (extremely damaged seed) were at par between treated plots and untreated control, although, higher category seed index C was reported in the untreated control.

In terms of cropping patterns, percentage seed weight of category seed index A between maize/cowpea intercropped plots and sole cowpea plot were at par although 2:2 maize/cowpea intercrop had the highest category seed index A. Sole cowpea plot had highest category seed index B but this did not differ significantly with the other patterns. There was also no significant difference between percentage seed weight of category seed index C of maize/cowpea intercropped plots and sole cowpea plots. However, the sole crop recorded highest weight of seed index C (27.56).

Table 9: Effect of cypermethrin spray regimes and maize/cowpea intercrops on percentage seed damage index of Bt cowpea at Samaru during 2018 wet season.

Treatments	Percentage seed index A	Percentage seed index B	Percentage seed index C
Spray regimes			
One spray	9.26	2.47	2.46
Two spray	9.49	1.93	1.93
Untreated Control	8.57	2.82	2.81
S.E ±	0.48	0.54	0.45
Cropping patterns			
Sole crop	8.82	3.18	2.74
2:2 intercrop	9.34	2.52	2.65
2:4 intercrop	9.17	3.08	2.56
S.E ±	0.28	0.29	0.29
Interaction			
Spray X cropping pattern	NS	NS	NS

Means followed by the same letter within the same column of any treatment group are not significantly different at 5% level of probability using Student Newman Keul.

NS: Not significant.

Seed index A= undamaged seed

Seed index B= moderately damaged seed

Seed index C= extremely damaged seed.

4.1.5 Effect of cypermethrinspray regimes and maize/cowpea intercrop patternon yield components of Bt cowpea at Samaru during 2018 wet season.

Results on the effect of different cypermethrin spray regimes and maize/cowpea intercrop pattern on number of pods per plant,100 seed weight, pod yield and grain yield of Bt cowpea at Samara are shown in Table 10. There was no significant difference between the treated plots and untreated control in the number of pods per plant. However, the control plots had insignificantly lower number of pods per plant (6.73) than at one spray regime (10.88) and two spray regimes (10.74). There was also no significant difference for the weight of 100 seeds between the Cypermethrin sprayed plots and the untreated control. There was significant difference ($P<0.05$) in pod yield between sprayed plots and untreated control. Plots sprayed once and twice with Cypermethrin had similar and higher pod yield per hectare (2067.9kg, 2508.4kg)than the untreated control (1168kgha^{-1}). Similarly, grain yield per hectare was also significantly different ($p<0.05$) between the sprayed plots and control. Two spray regimes recorded the highest grain yield(1804.5kg),which was at par with one spray regime (1690.9kg) and both were significantly higher than the untreated control (684.5kg). (Table 10)

For the different cropping patterns, sole crop plots recorded insignificantly lower number of pods per plant (8.21) compared to 2:2 and 2:4 intercrop patterns having mean number of pods of 10.31 and 9.97, respectively. The 100 seed weight was at par amongst all the cropping patterns. Sole plots however recorded the highest pod yield of 2177.1kg/h and grain yield of 1454.6 which were not statistically different from pod yield and grain yield of 2:2 (1929.6kg, 1300.0kg) and 2:4 (1637.5kg, 1425.2 kgha^{-1}) maize/ cowpea intercrops.

Table 10: Effect of cypermethrin spray regimes and maize/cowpea intercrop pattern on yield component of Bt cowpea at Samaru during 2018 wet season.

Treatments	Number of pods/plant	100 Seed weight (g)	Pod yield kg/ha	Grain yield kg/ha
Spray regimes				
One spray	10.83	17.46	2,067.5[a]	1,690.9[a]
Two sprays	10.74	17.86	2,508.4[a]	1,804.5[a]
Untreated Control	6.73	18.05	1,168.4[b]	684.5[b]
S.E ±	2.34	0.30	682.90	616.49
Cropping patterns				
Sole crop	8.21	10.18	2,771.1	1,454.6
2:2 intercrop	10.31	11.43	1,929.6	1,300.0
2:4 intercrop	9.79	10.88	1,637.5	1,425.2
S.E ±	1.02	1.09	244.14	138.45
Interaction:				
spray X croppingpattern	NS	NS	NS	NS

Means followed by the same letter within the same column of any treatment group are not significantly different at 5% level of probability using Student Newman Keul test.

NS not significant.

4.2.0 Experiment II

4.2.1 Effect of insecticide spray regimes on the population of insect pests in the flowers of Bt and non-Bt cowpea at Samaru during 2018 wet season.

Results showed that mean number of *Megalurothrips sjostedti*per 20 flowerswere significantlyhigher on the Bt cowpea (IT97KT) compared to non Bt cowpea (SAMPEA 15)during insect pest sampling at 50% flowering, but at 50% podding there was no difference between the two. IT97KT had significantly higher number of *M. sjostedti* (3.11)compared to SAMPEA 15 (with 2.30) during sampling at 50% flowering. At 50% podding Bt cowpea scored high *Megalurothripssjostedti* count than non-Bt variety. There was significant ($p>0.05$) difference between Imidacloprid treated plots and other treatments at 50% flowering only. Imidacloprid applied once and twice reduced the number of *M. sjostedti* than the two regimes of neem spray and the untreated control, all of which were at par. The three pest at podding and *M. vitrata*and pod sucking bugs at flowering were not significantly influenced by spray regime treatments.

There was significant difference ($p>0.05$) between the two cowpea cultivar in terms of the number of *Maruca* larvae found in their flowers at 7 WAS (50% flowering). The non-Bt cowpea (SAMPEA 15) had significantly higher number of *Maruca* larvae (2.84) compared to the Bt cowpea (IT97KT) (2.22).At 50% podding number of *Maruca* larvae in the flowers of both cowpea cultivars were at par. However, SAMPEA 15 had insignificantly higher number of *Maruca* larvae than IT97KT (1.76 and 1.39 respectively).Results showed that at 50% flowering and 50% podding, there was no significant ($p<0.05$) difference in the population of *Maruca* larvae between the treated plots and untreated control.Mean number of pod sucking bugs were at par for both cowpeas varieties at 50% flowering and 50% podding. However, at 50% flowering, IT97KT had insignificantly lower number of pod sucking bug (1.69) compared to SAMPEA 15

(1.79). At 50% podding SAMPEA 15 (2.84) had insignificantly lower number of pod sucking bug than IT97KT (3.29).

There was no significant ($p<0.5$) difference in the population of pod sucking bugs between treated plots and untreated control at 50%flowering and 50% podding. The untreated control and neem oil one spray regime had the highest number of pod sucking bug (1.97 and 3.45) at 50% flowering and 50% podding respectively.

Table 11: Effect of insecticide spray regimes on population of insect pests on Bt and non-Bt cowpea at Samaru during 2018 wet season.

Treatment	*Megalurothrips sjostedti* /20 flowers		*Maruca vitrata*/20 flowers		Pod sucking bugs/ 10 plant	
	50% flowering (7 WAS)	50% podding (9 WAS)	50% flowering (7 WAS)	50% podding (9 WAS)	50% flowering (7 WAS)	50% podding (9 WAS)
Cowpea cultivars						
Bt cowpea	3.11[a]	3.39	2.22[b]	1.39	1.69	3.29
Non-Bt cowpea	2.36[b]	2.75	2.84[a]	1.76	1.79	2.84
S.E	0.17	0.25	0.12	0.16	0.18	0.35
Spray regimes						
Imidacloprid one spray	1.96[b]	3.62	2.41	1.62	1.41	2.13
Imidacloprid two sprays	1.91[b]	2.75	2.46	1.83	1.79	3.33
Neem oil one spray	3. 08[a]	3.27	2.81	1.43	1.81	3.45
Neem oil two sprays	3.15[a]	2.99	2.74	1.14	1.73	3.25
Untreated Control	3.56[a]	2.49	2.26	1.87	1.97	3.17
SE ±	0.27	0.40	0.19	0.23	0.28	0.55
Interaction						
Spray X Cultivar	NS	NS	NS	NS	NS	NS

Mean followed by the same letter within the same column of any treatment group are significantly the same at 5% level of probability using Student Newman Keul test.

NS: not significant.

4.2.2 Effect of insecticide spray regimes on percentage pod damage by *m. vitrata* and pod sucking bugs on bt and non- bt cowpea at Samaru during 2018 wet season.

The effect of different insecticide spray regimes on percentage pod damage by *Maruca* and Pod Sucking Bugs on Bt (IT97KT) and non- Bt Cowpea (SAMPEA 15) are presented in Table 12. Non Bt cowpea had significantly ($p<0.05$)higher number of pods damaged by *Maruca*larvae (2.37) compared to the Bt cowpea (1.33).Pods damaged by *Maruca* larvae between treated plots and untreated control of the individual cowpea varieties were at par. However, untreated control had insignificantly highest pod damage by *Maruca*larvae (2.12).

The Bt cowpea had significantlylowerlevel of damage caused by pod sucking bugs (5.95) compared to SAMPEA 15 (6.92). The treated plots had significantlylower percentage of pods damaged by pod sucking bugs compared to their untreated plot. Plots sprayed twice with Imidacloprid had lower pod damage (5.32) than the untreated plots. The other treatments weresimilar to both the least (5.32) and greatest pod damage (7.46).

Table 12: Effect of insecticide spray regimes on percentage pod damage by *M. Vitrata*and pod sucking bug on Btand non- Bt cowpeaat Samaru during 2018 wetseason.

Treatment	% pod damage due to *Maruca* larvae	% pod damage due to pod sucking bugs
Cowpea cultivars		
Bt cowpea	1.33[b]	5.95[b]
Non- Bt cowpea	2.37[a]	6.92[a]
SE $\pm$	0.08	0.15
Spray regimes		
Imidacloprid One spray	1.95	5.84[ab]
Imidacloprid Two sprays	1.67	5.32[b]
Neem oil One spray	1.71	6.85[ab]
Neem oil Two sprays	1.81	6.73[ab]
Untreated Control	2.12	7.46[a]
SE$\pm$	0.13	0.24
Interaction		
Spray X Cultivar	NS	NS

Means followed by the same letter within the same column of any treatmentgroup are not significantly different at 5% level of probability using Student Newman Keul test.

NS: not significant.

Plate I: Healthy cowpeapods.

Plate II**:**Pods showing *Maruca* larvae damage sign

4.2.3 Effect of insecticide spray regimes on yield related components of Bt and non- Bt cowpea at Samaru during 2018 wet season.

Result on the effect of different insecticide spray regimes on yield related component (aborted flower, pod load, and pod evaluation index) are represented on Table 13. It revealed that there was no significant difference (p>0.05) in the yield related component assessed between the two varieties (IT97KT and SAMPEA 15). However, IT97KT consistently gave insignificantly higher number of aborted flowers, pod load index and pod evaluation index with 21.67, 2.33, and 18.67 respectively as against 19.20,2.20 and 16.67 recorded in SAMPEA 15 of therespectiveparameters.

4.2.4 Evaluation of number of days to 50% flowering, and physiological maturity between Bt and non- Bt Cowpea at Samaru during 2018 wet season.

Result for the evaluation of number of days to 50% flowering, and physiological maturity between Bt and non- Bt cowpea are presented in Table 14. It revealed that the Bt cowpea had significantly (p<0.05) lower number of days to 50% flowering (52 days) compared to non-Bt cowpeas(53.67). Number of days to 50% flowering between Treated plot compared to untreated control of the individual cowpea were at par.

The Bt-cowpea (IT97KT) recordedsignificantly lower number of days to physiological maturity (82.13)compared tonon- Bt cowpea,SAMPEA 15(85.4). Number of days to physiological maturity was not influenced by the insecticide spray regime. However, untreated control reached maturity later (85.5 days) than the treated plots and Imidacloprid two sprays attained maturity earlier (82.8 days) than other sprayed plot.

Table 13: Effect ofinsecticide spray regimes on yield related component of Bt and non- Bt cowpea at Samaru during 2018 wet season.

Treatments	Number of aborted flowers/10 plants	Pod load index	Pod evaluation index	Seed damage index
Cowpea cultivars				
Bt cowpea	21.67	2.33	18.67	9.79[a]
Non-Bt cowpea	19.20	2.20	16.53	16.68[b]
SE ±	1.20	0.16	1.28	0.38
Spray regimes				
Imidacloprid One spray	23.0	2.33	18.67	12.88
Imidacloprid Two sprays	19.17	2.50	19.16	9.14
Neem oil One spray	19.17	2.50	15.50	13.86
Neem oil two sprays	22.67	2.33	19.50	15.76
Untreated Control	18.17	2.0	15.00	14.56
SE ±	1.89	0.26	2.03	0.95
Interaction				
Cultivar x Spray	NS	NS	NS	NS

Means followed by the same letter within the same column of any treatment group are not significantly different at 5% level of probability using Student Newman Keul test.

NS: not significant.

Table 14: Mean number of days to 50% flowering, and physiological maturity on Bt and non- Bt cowpea at Samaru during 2018 wet season.

Treatments	Days to 50% flowering	Days to maturity
Cowpea cultivars		
Bt cowpea	52.00[b]	82.13[b]
Non-Bt cowpea	53.67[a]	85.4[a]
SE $\pm$	0.08	0.52
Spray regime		
Imidacloprid One spray	53.83	83.17
Imidacloprid two sprays	52.83	82.83
Neem oil One spray	52.83	83.50
Neem oil Two sprays	52.83	83.83
Untreated Control	52.83	85.50
SE $\pm$	0.12	0.83
Interaction		
Spray X Cultivar	NS	NS

Means followed by the same letter within the same column of any treatment groupare not significantly different at 5% level of probability using Student Newman Keul test.

NS Not significant.

4.2.5 Effect of insecticide spray regimes on yield component of Bt and non-Bt cowpea at Samaru during 2018 wet season.

Results for the effect of insecticide spray regimes on yield component of Bt and non-Bt cowpea at Samaru during 2018 wet season is presented on Table 15.There was no significant difference ($p \geq 0.05$) in the number of pods per plant between the Bt cowpea (IT97KT) (9.17) and non Bt cowpea (SAMPEA 15 (8.63).Similarly, between treated plots and untreated control, no significant difference ($p>0.05$) was observed in the number of pod per plant. However, plots that received two spray regimes of Imidacloprid had insignificantly high number of pods per plant (9.99), and plots that received two spray of neem seed oil had the least number of pod per plant (7.14) (Table 15).

There was no significant difference ($p>0.05$) in 100 seed weight between IT97KT (19.7) and SAMPEA 15 (20.79), similar trend was observed between the treated plot and untreated control. IT97KT had insignificantly higher pod yield (2137.8kg) and grain yield (1523.8kg) compared to SAMPEA 15 (1667.0kg, 1108.6kg) respectively. Plots that received two spray regime of Imidacloprid had the highest pod yield (2711.7kg) which was significantly different ($p<0.05$) compared to other treatments and untreated control. the plot that received one spray of neem oil had the lowest pod yield (1341.6kg). Two spray regimes of Imidacloprid also had the highest grain yield (1444.4kg) and one spray of neem oil had the least grain yield (989.8kg) however, this was notsignificantly different at 5% probability.

Table 15: Effect of insecticide spray regimes on yield component of Bt and non-Bt cowpea at Samaru during 2018 wet season.

Treatment	Number of pod /plant	100 seed weight	Pod yield (kg/hectare)	Grain yield (kg/hectare)
Cowpea cultivars				
Bt cowpea	9.17	19.70	2,137.8	1,523.8
Non-Bt cowpea	8.63	20.79	1,667.0	1,108.6
SE ±	0.55	0.79	183.79	141.46
Spray regimes				
Imidacloprid One spray	9.69	20.64	2,157.7[ab]	1,444.4
Imidacloprid two sprays	9.99	20.63	2,711.7[a]	1,817.8
Neem oil One spray	7.74	20.51	1,341.6[b]	989.8
Neem oil two sprays	7.14	20.72	1,772.6[ab]	1,218.6
Control	9.91	18.72	1,526.3[b]	1,110.4
SE ±	0.86	1.26	290.59	223.66
Interaction				
Spray X Cultivar	NS	NS	NS	NS

Means followed by the same letter within the same column of any treatment group are not significantly different at 5% level of probability using Student Newman Keul test.

NS:Not significant**.**

4.2.6 Effect of insecticide spray regimes on percentage seed damage index of Bt and non- Bt cowpea at Samaru during 2018 wet season.

The result for the effect of different insecticide spray regimes on seed damage index categories of Bt and non-Bt cowpea at Samaru is presented in figure III, IV, and V. There was no significant difference in the percentage of seed damage index A between the sprayed plots and untreated control of the Bt cowpea. plot sprayed twice with imidacloprid had value of 9.31, one spray of imidacloprid had 8.98, one neem spray had 8.82, two neem sprays had 8.79 and untreated control had 8.67. similar trend followed for the non Bt cowpea two sprays of imidacloprid had 8.74, one neem spray had 8.14, untreated control had 8.11 one spray of imidacloprid had 7.99, andtwo neem sprays had 7.67. Between each treatment on the cowpeas no significant difference.

For percentage seed damage index B, two imidacloprid sprays had value of 2.81, one imidacloprid spray had 3.19, one and two neem sprays had 3.48 and untreated control had 3.75 for the Bt cowpea. For the non Bt cowpea two sprays had 3.38, one neem spray had 3.98, two neem sprays had 4.36, untreated control had 4.43 and one imidacloprid spray had 4.51.These values were at par within the treatment on the cowpeas and between each treatment on the cowpeas.

There was no significant difference for percentage seed damage index C of the cowpeas, for Bt cowpea one imidacloprid spray had value of 2.19, one spray imidacloprid had 2.68, two neem sprays had 2.81, one neem spray had 3.01 and untreated control had 3.09. On the non Bt cowpea, two imidacloprid sprays had value of 3.30, untreated control had 3.57, one spray imidacloprid had 3.72, one neem spray had 4.11, and two neem sprays had 4.61

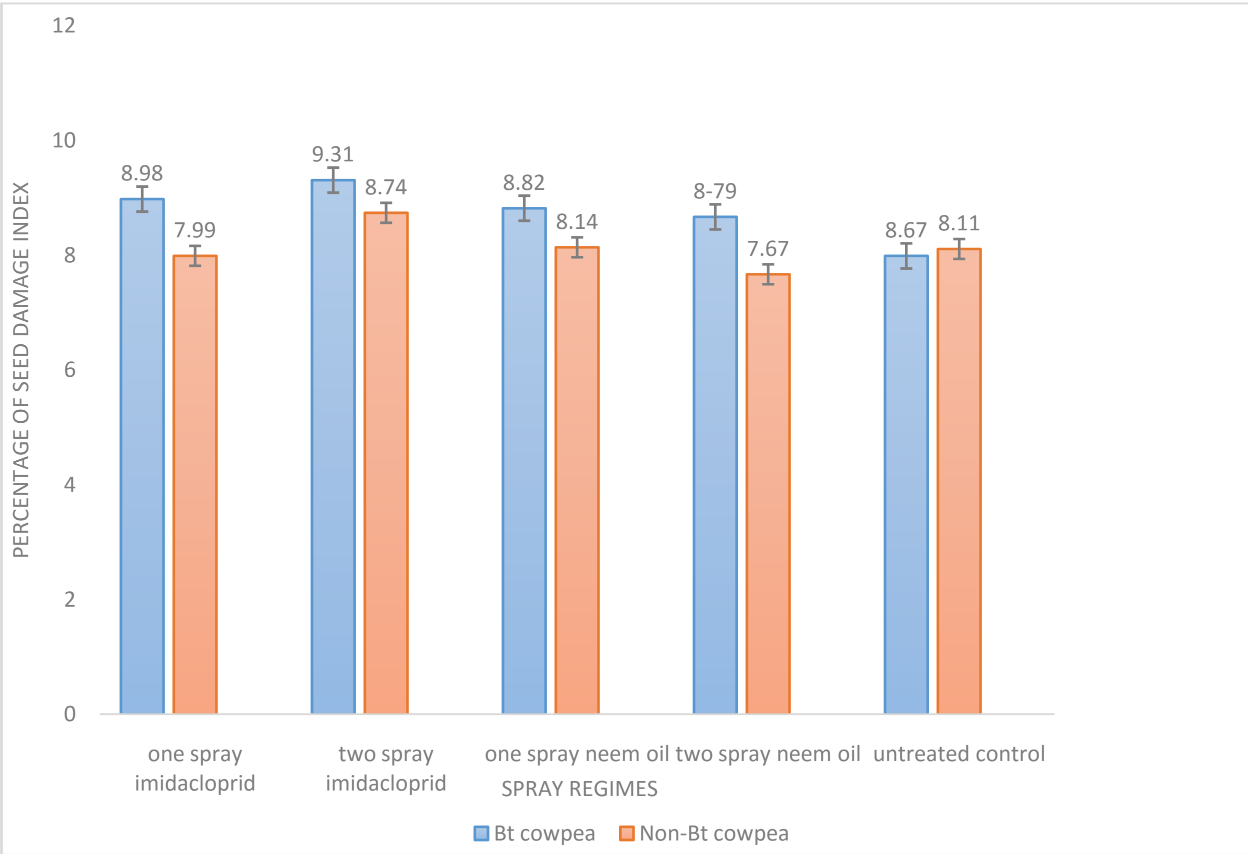

Figure I. Effect of insecticide spray regimes on percentage seed damage index A of Bt and non-Bt cowpea at Samaru.

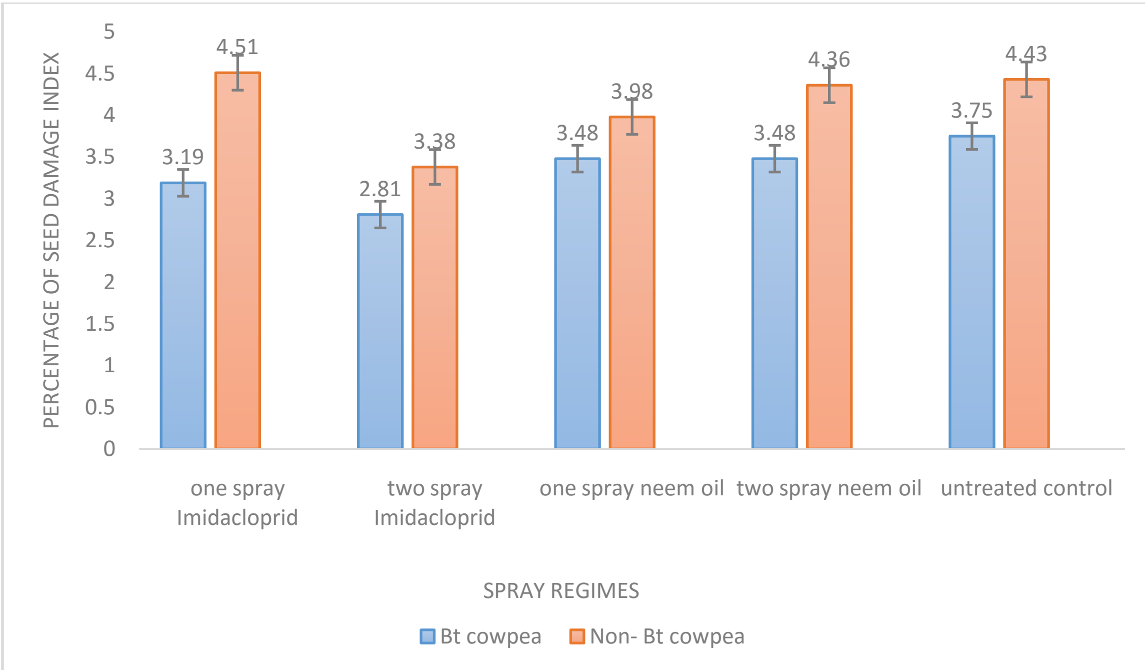

Figure II. Effect of insecticide spray regimes on percentage seed damage index B of Bt and Non-Bt cowpea at Samaru

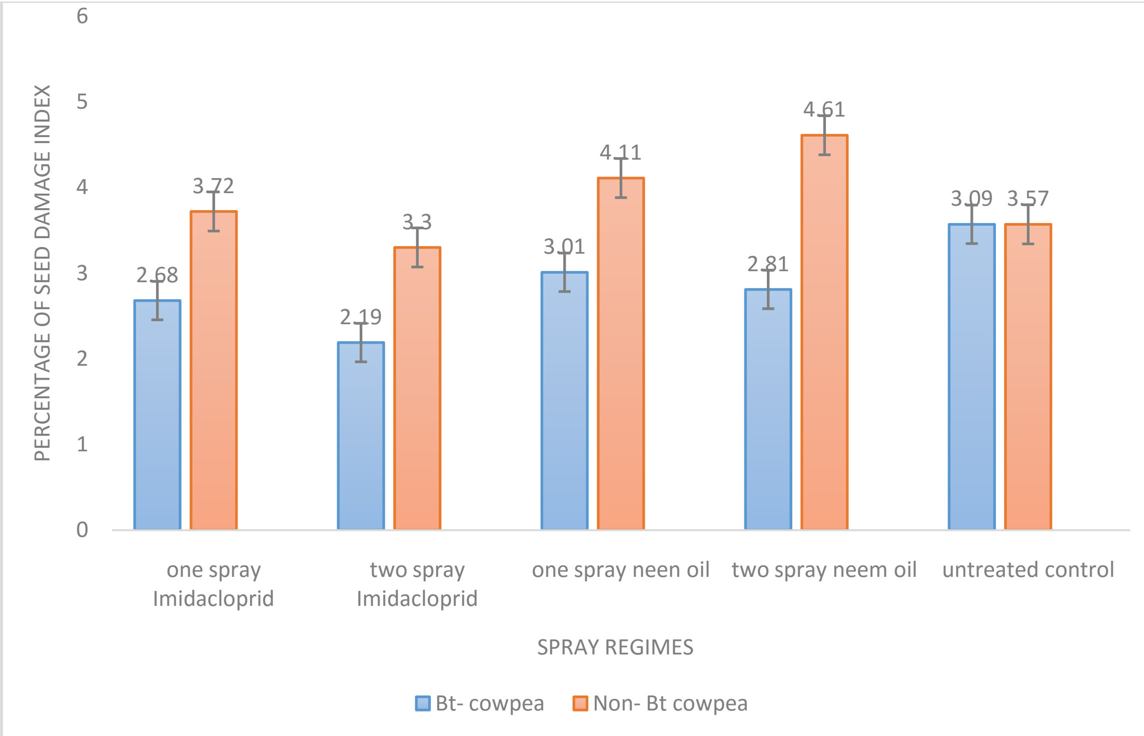

Figure III. Effect of insecticide spray regime on percentage seed damageindex C of Bt and non-Bt cowpea at Samaru.

Plate III: Seed damage index A= undamaged seeds.

Plate IV: Seed damage index B: moderately damaged see

Plate V: Seed damage index C: extremely damaged seeds

CHAPTER FIVE

5.0 DISCUSSION

5.1 Experiment I

5.1.1 Effect of cypermethrin spray regimes and maize/ cowpea intercrop pattern on the population of insect pest on Bt cowpea during 2018 wet season.

The significantly lower population of thrips observed on sprayed plots from this study, can be attributed to effectiveness of cypermethrin to reduce thrip population and supports the need for the use of chemical to control flower bud thrips. The 2:4 maize/cowpea intercrop had highest number of *Megalurothrips sjostedti*. This concur withOso and Falade (2010) who reported higher population of thrips in a 2:3 maize/cowpea intercrop than a 1:1 maize/cowpea intercrop.On the contrary Mensah (1997) confirmed a high population densityof flower pest (*M. sjostedti*) in a 1:2 sorghums/cowpeawhich is in conflict with Nampala *et al*. (2002) who reported lower thrips population in 2:4 sorghum/cowpea intercrop.

Population of *M. vitrata* did not differ among the cropping patterns under the different Cypermethrin spray treatments. This is because theBt cowpea was usedfor the experiment. This corroborates the report of Mohammed *et al*. (2014) who showed that transgenic lines and their hybrids produced enough Cry1Ab toxin to resist *Maruca* attack.Although population of pod sucking bugs was high on sole plots especially at 100% podding this was at par with population of pod sucking bugs on the intercrops.Jackai and Adalla (1997), had reviewed theeffects of intercropping on insect pests of cowpea, andreported that intercropping did not necessarily reducepest load in any given situation but that it depends on the crop(s) and pest(s) in question.

5.1.2 Effect of cypermethrin spray regimes and maize/cowpea intercroppattern on pod damage of cowpea dueto *Maruca* and pod sucking bugs.

Results from this study showed no significant difference in damage by*Maruca*between the spray regimes and among the cropping patterns.This can be attributed to the resistance by Bt cowpea carrying a Cry1Ab gene. According to Mohammed *et al* (2014) the result on infestation of *Maruca* larvae scored as number of damaged pod per plant gave a clear proof of the achievement of the goal of the genetic transformation of cowpea lines with Cry1Ab gene, As the Cry1Ab gene conferred a high degree of resistance to cowpea pod borer,the transgenic cowpea lines should be used as a precious insect-resistant line to be employed in traditional breeding programs to develop *Maruca* resistant cowpea varieties.

. The significant difference observed in the percentage of pods damaged by pod sucking bugs between cypermethrin treated plots and untreated control can be attributed to the effectiveness of cypermethrin in reducing pest population in treated plot resulting in lesser pod damage than the untreated control. One spray and two sprays of Cypermethrin were at par in reducing pod sucking bugs damage. This suggests that one spray was as effective as two spray of Cypermethrin because the insecticide was applied during the podding stage which was able to protect the pod during filling.

The higher damage percentage of cowpea pod by PSB observed for sole croppingcould be attributed to availability of food source with no barrier hindering the access to this food source hence the pod sucking bugs had no hindrance to feed on the pods of the cowpea unlike in the intercropped plots where the maize plants formed a barrier and therefore resulted in less pod damage by pod sucking bugs.This finding is contrary to Oso and Falade (2010) who reported that intercropping does not necessarily reduce pest incidence and damage.

5.1.3Effect of cypermethrin spray regimesand maize/cowpea intercrop pattern on yield related component of Bt cowpea.

The number of flower aborted due to insect pest as influenced by cypermethrin sprays being lower in treated plots than untreated control resulted from the fact that untreated control experienced greater activity of flower bud thrips which is in line with Oyewale *et al*., (2011), who reported highest number of aborted flowers in untreated control plot. Higher pod load and pod evaluation index was recorded for cypermethrin treated plots fromwhich could be attributed to the ability of cypermethrin to reduce flower bud thrips that causes flower abortion leading to poor pod load. Thisagrees with Egho *et al.,* (2011) who reported higher pod load for cypermethrin treated plots than untreated control. The author also reported higher pod evaluation index in cypermethrin sprayed plots than untreated control.Cowpea is known to shed up to 80 % of its flowers due to natural causes such as insect pest infestation during its development, and this could negatively affect pod formation (Dzemo *et al*., (2010), and Oyewale *et al.,* 2014). Pod set could also be affected by other factors such as growing conditions, soil fertility, moisture content and flower abortion/damage by insect pests. Applications of different insecticides at various rates on cowpea plants showed that *MegalurothripssjostedtiMarucavitrata* and pod sucking bug (*Clavigrallatomentosicollis*) control are essential to guarantee sustainable production of the cropOyewale *et al.,* 2014).

5.1.4 Effect of cypermethrin spray regime and maize/cowpea intercrop pattern on yield of Bt cowpea.

Sole cowpea having greater grain yield than the 2:2 and 2:4 maize/cowpea intercrop pattern could be due to reduced interspecific competition between the crops.This corroborates the findings byKermah *et al*. (2017) who reported that sole crop of legumes produced significantly more grain than 1:1 and 2:2 maize/cowpea intercrops.Similarly, Panhwar *et al*. (2004) reported greater grain yield for sole soybean than its intercrop with maize. Alla *et al*. (2014) reported that sorghum intercropped with cowpea exhibited greater potentiality and recorded higher values of grain yield/plant. However, grain yield per hectare was lower in intercropped pattern than sole pattern. Contrary to this present study, Mukhtar (2014) reported that cowpea intercropped with maize at 1:1 row arrangement recorded the highest grain yield per hectare, which was much more than sole cropping. This lower cowpea yield was attributed to competitive effect of maize in the intercropping system as reported by Sebethal *et al*.,(2014). Idoko (2005) also reported that cowpea grain yield declined significantly in Makurdi,Nigeria, under intercropping as compared to sole cropping, and noted that such decline varied with the genotype of cowpea used. These researchers attributed the reductions to interspecific competition as well as shading of thecowpea by the taller maize component.

5.2 Experiment II

5.2.1 Effect of insecticide spray regimes on population of insect pest on Bt and non-Bt cowpea flowers at Samaru.

The Bt cowpea had a high population of flower thrips compared to the non Bt cowpea suggestingit's high susceptibility to the flower bud thrips. This corroborates the findings of Kamara *et al.,* (2007) who reported higher number of thrips on some improved cultivars compared to other improved and non-improved varieties. The low population of thrips at 50% flowering from imidacloprid treated plots suggests that it was more effective than the neem seed oil extract in reducing the flower bud thrips. At 50% podding, two spray regimes of neem oil extract and imidacloprid had lower thrips population than one spray showing that a second spray is required to further reduce the flower bud pest.This agrees with Oyewale*et al.,* (2014), who considered two spray of insecticide to be effective in reducing thrips infestation.

This study found that lowerpopulation of *Maruca* larvae was observed onthe Bt cowpea compared to the non-Bt cowpea which can be attributed to its transformed status resulting in less *Maruca* larvae attacks, reduced damage level and high grain yield. imidacloprid spray regimes did not show any difference from neem oil spray regimes in the population of *Maruca* larvae observed on the individual cowpea both at 50% flowering and 50% podding, which shows that both insecticide had some level of control effect on the insect pest. This corroborates with Egho andEmosairue(2010) who reported that neem seedkernel extract has some inhibitory property on the larvae of *M. vitrata.*Dzemo *et al.*, (2010) reported that neem oil was equally effective against infestation by *M. vitrata*

Samplingof pod sucking bug at 50% flowering revealed that both cowpeas and the various treatments including untreated control had low population of pod sucking bug compared to thesampling at 50% podding which could be attributed to the fact that this sampling was done at 50% flowering, whennumber of pods present at this time were not yet sufficient to attract large population of pod sucking bugs. Olufemi and Odebiyi (2001) reported that in nature peak population of pod sucking do not occur at early flowering unless crops were planted late. At 50% podding sampling of pod sucking bugs showed that Bt cowpea had higher population of pod sucking bugs than the non Bt cowpea which could be attributed to higher pod load that could have triggered an influx of the pest at that time. The high population of pod sucking bug observed at 50% podding when compared to the population observed at 50% flowering suggests that two spray regimes of Imidacloprid and neem oil, may not be sufficient to tackle pod sucking bugs as there is likely to be more buildup of the pod sucking bugs. Ogah *et al*., (2011) reported that two sprays of insecticide did not effectively take care of pod sucking bugs.Mensah *et al*., (2017) also reported that the performance of neem oil on pod-sucking bugs is dose dependent with higher doses of neem oil comparatively giving better control.

5.2.2 Effect of insecticide spray regimes on pod damage due to *Maruca* and pod sucking bugs on a Bt and non Bt cowpea.

Results from this studies revealed that the non- Bt cowpea had higher number of pods damaged by *Maruca* larvae than the Bt cowpea which means that the Bt cowpeawas more resistant to *Maruca* larvae attack than the non Bt cowpea. This agrees with Mohammed *et al.*, (2014) who reported that non transgenic lines of cowpea had higher number of pods damaged by Maruca larvae than transgenic lines. Ishiyaku *et al*.(2010), and Mohammed *et al.*,(2014) reported complete protection of some transgenic cowpea lines expressing Cry1Ab gene, from *Maruca* damage under field conditions. Sachs *et al*. (1998) reported that cotton plants of different genetic backgrounds that possessed the Cry1Ab insecticidal protein were more resistant to tobacco budworm larvae than plants with other traits. In addition, Estruch *et al*., (1997) and Van-Rie (2000) evaluated plant stands of Bt cotton and non-Bt cotton, and found that the attack by bollworms and tobacco budworm were less on Bt cotton plants as compared to non-Bt cotton plants.

The insecticide treated plots had lower number of pods damaged by *Maruca* larvaecompared to the untreated control indicating that the use of insecticide for control of *Maruca* is still very important. The use of neem oil was slightly effective in reducing *Maruca* larvae damage. Mensah *et al.,* (2017) reported 5ml/L of commercial neem seed oil to be effective in reducing *M. vitrata* damage to cowpea pods. Higgins *et al.* (2010), reported that recent advances in transgenic cowpea have shown to have promising effect in their resistance to *Maruca,* the use of which would further reduce the need for insecticide protection significantly. However, if the transgenic varieties have no resistance to thrips and pod sucking bugs, insecticide use may not be completely eliminated in cowpea production. The Bt cowpea had less pod damage by pod sucking bud than the non-Bt cowpea. Two spray of Imidacloprid was more effective than other treatments in reducing pod damage by pod sucking bugs. This corroborates the findings of Ajeigbe *et al.,* (2012), and Oyewale*et al*. (2014),who reported that all insecticide treated plots had lower pod damage than untreated control.

5.2.3 Effect of insecticide spray regimes on percentage seed damage index of Bt and non- Bt cowpea at Samaru

The Bt cowpeahad a higher percentage of seed index category A, lower percentage of seed index category B and category C than the non-Bt cowpea might have resulted from its resistance to *Maruc*a larvae attack and lesser damage sustained from pod sucking bugs attack.It had been able to reduce *Maruca* pod damage by 28% and pod sucking bug damage by 7.5%.

Two sprays of imidacloprid had reduced pod sucking bug damage by 16% resulting in the least seed index category C among all the treatments.

5.2.4 Effect of insecticides spray regimes on the yield related components of Bt and non Bt cowpea

There was no significant difference in flower abortion between the Bt cowpea and non-Bt cowpea, however the insignificantly higher number recorded on the Bt cowpea could be attributed to the high population of flower bud thrips observed on the variety. Cowpea is known to shed up to 80 % of its flowers due to natural causes such as insect pests during development, and this could negatively affect pod formation (Dzemo *et al*., 2010). Pod load between Bt and non-Bt cowpea did not differ significantly, however, the higher numerical score recorded on the Bt cowpea can be traced to its resistance to *Maruca* infestation. Similarly, the treated plot and untreated control of the individual cowpea showed no significant difference for pod load index. However, untreated control and one neem oil spray had the least pod load showing that they had suffered more damage. This corroborates Egho, (2011) who reported least pod load from untreated control plot compared to treated plot. The Bt cowpea gave a higher pod evaluation index compared to the non-Bt cowpea.This could be attributed to its resistance to *M vitrata* larvae attack which led to less pod damage. Egho (2011) reported higher pod evaluation index for treated plots than untreated control as also observed in this experiment.

5.2.5 Effect of insecticides spray regime on yield component of Bt and non-Bt cowpea

One of the aims of any investigation on insect pest control schedule is to increase grain yield. There was Bt cowpea grain yield advantage of 27.4% over the non-Bt cowpea. The Bt cowpea gave a higher grain yield compared to the non-Bt cowpea which could be attributed to its resistance to the cowpea pod borer that causes much damage to cowpea and also less damage sustained from other insect pests. This agrees withTanko and Yusuf (2007) who recorded higher grain yield for improved varieties of cowpea over local varieties although they attributed this to mere chance.The results from this trial showed that pod and grain yield of cowpea plot that received two sprays of Imidacloprid was highest which shows that two spray regimes of Imidacloprid was more effective than other treatments in controlling the insect pests. Two spray regimes of Imidacloprid produced highest grain yield and one spray of Neem oil had the least grain yield. This finding is in line with Arjun *et al.,* (2017), who evaluated the efficacy of some insecticide against cowpea pests and recorded highest grain yield of cowpea from plots treated with Imidacloprid and also reported lowest yield for *Azadiractin* treated plots. However, Egho *et al.*, (2010) reported thataqueous neem seed kernel extract at 5% is an effective botanical (insecticide) on cowpea insect pests control, and the crop can be productive, as revealed by the moderate yields from the different treatments he tried. Higher grain yield recorded by Imidacloprid treated plots suggests better protection than neem seed oil. This aligns withthe report of Adesina and Enudeme (2018) who reported that synthetic pesticide increased yield tremendously as compared to spraying with botanical insecticide. Agona *et al*. (2006) also judged synthetic pesticide to be more effective than the botanical insecticide. Two spray regimes of Imidacloprid and neem seed oil had higher grain yield than their respective one spray concurring with the findings of Dzemo *et al*., (2010) who reported a significant reduction in pod pest infestation when insecticide was applied once, each at flower budding and early podding this indicates that the two insecticide spray (at flowering and at podding) could produce a good cowpea yield as three and five spray regimes.This is of critical importance from the point of view of lower costs, environmental hazards and the effects of spray frequencies and intensity on non-target organisms. The insecticide spray at flower budding controls early pod borer infestations and ensures optimal flower and pod protection. The second spray protects the pods from damage by pod borer and pod sucking bugs. The results agreewith the findings of Ajeigbe and Singh (2006), who showed that two insecticide sprays once at the onset of flowering and podding could reduce insect infestations as well as seed damage and increase seed yield.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION, AND RECOMMENDATION

6.1 Summary

From the results of this studies, it was evident from experiment I,that there was significant difference between sprayed plots and untreated control in the number of aborted flowers due to thrips andpod damage due topod sucking bugs, pod and grain yield. Untreated control had higher number of aborted flowers, and pod damage due to*Maruca* and pod sucking bugs than sprayed plots. There was no significant difference between sprayed plots and untreated control for pod damage due to *Maruca*, pod load index, pod evaluation index, number of pods/plant, 100 seed weight and seed damage index on Transgenic cowpea variety. Also there was no significant difference between sole crop and the intercrop patterns on insect pest populations, pod damage, seed damage, number of pods/plant, 100 seed weight, pod and grain yield per hectare. Two spray regimes of Cypermethrin to protect Bt cowpea (IT97KT) against thrips and PSB, gave a yield increase of 62% when compared to untreated control.

The Bt cowpea had significantly lower pod damage due to *Maruca* and pod sucking bugs compared to non-Bt cowpea. The non-Bt cowpea hadhigher seed damage index compared to the Bt cowpea. The Bt cowpea attained 50% flowering and physiological maturity earlier than the non-Bt cowpea. IT97KT had a grain yield of 1523.8kg while SAMPEA 15 had a grain of 1108.6kg per hectare. Thus, IT97KT had27.4% Yield advantage over SAMPEA 15. Two spray of Imidacloprid was significantly better than one spray, one and two sprays of Neem for parameters such as pod damage due to*Maruca*, pod sucking bugs, and seed damage index. Also its application gave the highest grain yields per hectare.

6.2 Conclusions

The Bt cowpea as a sole crop and intercrop with maize under two cypermethrin spray applicationapplied at 50% podding and 100% podding was effective in reducing thrips, and pod sucking bugs as well as increasing grain yield by 59.5%.

The Bt cowpea (IT97KT) performed better than non-Bt cowpea (SAMPEA 15) in terms of resistance to *M. vitrata* infestation and damage giving a yield of 415kg more than that of the non Bt cowpea and a yield advantage of 27.4%.

Two sprays of Imidacloprid resulted in significantly reduced thrips, *Maruca,* and pod sucking bugs populations when compared to one spray of Imidacloprid and the untreated control. Pod and seed damage, and increased grain yield than one spray of Imidacloprid, one or two spray of neem seed oil.

6.3 Recommendations: Based on the findings from this studies;

Two spray regimes ofCypermethrin applied at 50% and 100% podding can be recommended for control of pod sucking bugs on Bt cowpea (IT97KT), It reduced pod damage by pod sucking bugs by 18.5%.

Neem seed oil can serve as an alternative bio-insecticide, except that the frequency of application needs to be increased to more than two sprays.

Further studies should be conducted at other locations and seasons to confirm the findings of this studies, since this studies were conducted under a confined field condition.

REFERENCES

Abate T, Alene A.D., Bergvinson D., Shiferaw B., Silim S., Orr A. and Asfaw S. (2012). Tropical grain legumes in Africa and South Asia: Knowledge and opportunities. Nairobi, Kenya, ICRISAT Accessed August, 2019

African Agricultural Technological Foundation(2012) *Maruca* – Resistant cowpea, Progress report. http://www.aatf-africa.org>cowpeaAccessed September, 2019

African Agricultural Technological Foundation(2016) pod borer resistant cowpea. http://www.aatf-africa.org>cowpea Accessed September, 2019

Addo-Quaye, A.A., A.A. Darkwa and G.K. Ocloo, (2011). Yield and productivity of component crops in a maize-soybean intercropping system as affected by time of planting and spatial arrangement. *JournalofAgricultureandBiologicalSciences*, 6(9): 50-57.

Adesina J.M and Enudeme T. M (2018) Insecticidal efficacy of some plant aqueous extracts mixtures against post flowering insect pest of cowpea. Proceedings of the 36th annual conference of Horticultural society of Nigeria (Hortson) Lafia.

Agona A., Opolot H. N., Kyamanywa S., Mbata G. N., and Adipala E (2006) Integrated field management of cowpea pests using selected synthetic and botanical pesticides. *Journal of crop protection.* 25 (11):1145-1152

Ajeigbe HA, and Singh BB (2006). Integrated Pest Management in Cowpea: Effect of Time and Frequency of Insecticide Application on Productivity. *Crop Protection*. 25(9):920-925.

Ajeigbe,H. A. Rabiu S. A. and Bir. Bahadur Singh (2012)Yield performance of cowpea as influenced by insecticide types and their combinations in the dry savannas of Nigeria *African Journal of AgriculturalResearch* Volume. 7(44), pp. 5930 -593

Akande, M.O., F.I. Oluwatoyinbo, C.O. Kayode and F.A. Olowokere, (2006). Response of maize (*Zea mays*) and okra (*Abelmoschus esculentus*) intercrop relayed with cowpea (*Vigna unguiculata*) to different levels of cow dung amended phosphate rock. *World Journal of Agriculture Sciences*, 2(1): 119-122.

Akinfenwa S. (1975) Biological study of *Maruca testulalis*(Geyer)(Lepidoptera: pyralidae) in the Zaria area of Northern Nigeria, MSc thesis Ahmadu Bello University Zaria Nigeria.

Alghali A. M (1992). Insecticide schedules to reduce grain yield losses by insects of cowpea in Nigeria. *Insect Science and its Application.* 13(5): 725-730.

Alghali A. M (1993). Intercropping as a component of insect pest management for grain cowpea (*Vignaunguiculata* (L)Walps) production in Nigeria.*Insect ScienceanditsApplication*. 14(1): 49-53.

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

Alla Hamd W. A., E M Shalaby, R A Dawood and A A Zohry (2014) Effect of Cowpea (vigna sinensis L.) with Maize (Zea mays L.) Intercropping on Yield and its Components. *International Journal of Agricultural and Bio-system Engineering*. Volume 8 No. 11 page 1258-1264

Ananthi 1.T., M. M. Amanullah, A. R. Mohammad Said Al-Tawaha *A Review On Maize-Legume Intercropping for enhancing the productivity and soil Fertility for Sustainable Agriculture*. (2017) Advances in Environmental Biology, Pages: 49-63 Available from: https://www.researchgate.net/publication/317400785 A Review On Maize Legume Intercropping for Enhancing the Productivity and Soil Fertility for SustainableAgriculture Accessed July, 2018

Arjun L. C., Akhter H., Mamta D. C., R. G. Samota and S. L. Jat (2017) Bio-efficacy of newer insecticides against aphid, *Aphis craccivora* Koch on cowpea *Journal of Pharmacognosy and Phyto-chemistry*; 6(4): 1788-1792

Arodokoun, D. Y., Tamò, M., Cloutier, C. and BrodeurJ., (2006). Agriculture, Ecosystems & Environment, 113: 320–325.

Asante SK, Tamo M, Jackai LEN (2001). Integrated management of cowpea insect pests using elite cultivars, date of planting and minimum insecticide application. *Journal of African Crop Science*. 9(4):655-665.

Bhatti, I.H., R. Ahmad, A. Jabbar, M. Nadeem, M.M. Khan and S.N. Vains, (2013). Agronomic performance of mash bean as an intercrop in sesame under different planting patterns. Emirates *Journal of Food and Agriculture*, 25: 52-57.

Boukar *et al* (2013) Cowpea. In: Mohar S, Upadhyaya HD, Bisht IS (eds) Genetic and genomic resources of grain legume improvement. Elsevier, *Amsterdam*, page 137–150.

Bond C., Buhl K., Stone D., (2012). Neem oil fact sheet; National pesticide information Centre, Oregon state university extension services. http:/npic.orst.edu/factsheets/neemgen.html Retrieved March, 2021.

Cox P. D., L. Matthew, R. J. Jacobson, P. Cannon, A. Macleod, and K. F. A Walkers (2006). Potential use of biological agents for the control of thrips palmi (Thysanoptera: Thripidae outbreaks) *Biocontrol Science Technology,* 16: 871-891

Das G. P., and Islam M. A. (1985) *Maruca testulalis*(Lepidoptera: pyralidae): an important pest of country bean in Bangladesh. *Bamgladesh Journal of Agriculture* 10:57-66

Davis D. W.,Oelke E. A.,Oplinger E. S.,Doll J. D.,Hanson C. V., and Putman D. H., (1991) Cowpea: Alternative field crop manual http://www.hort.prudue.edu/newcrop/afcm/cowpea.html. Retrieved March 2018.

Degri M. M.,and Sodangi I. A.,(2013) Effect of neem seed oil applications and cultivarson insects of cowpea (vigna unguiculata (l.) Walp) in the dry savanna of north eastern Nigeria. *Global Journal of Bio-Science and Bio-Technology*Volume 2 (4): 471-476

Dugje I, Omoigui L, Ekeleme F, Kamara A, Ajeigbe H. (2009). Farmers' guide to cowpea production in West Africa. *International Institute of Tropical Agriculture,* Ibadan, Nigeriapage 20

Dzemo W. D., Niba1 A. S. and Asiwe J. A. N. (2010) Effects of insecticide spray application on insect pest infestation and yield of cowpea [*Vigna unguiculata* (L.) Walp.] in the Transkei, South Africa. *African Journal of Biotechnology* Volume. 9(11), page 1673-1679.

Egho, E. O. and Emosairue S. O. (2010). Effect of neem seed kernel extract on major insect pests of Cowpea (*Vignaunguiculata* (L.) Walp and influence on yield under calendar and monitored sprays. *Annals of Biological Research*, 1(2): 210-220 http://scholarsresearchlibrary.com/archive.html

Egho, E. O. (2011). Management of major field insect pests and yield of cowpea (*Vigna unguiculata* (L) Walp) under calendar and monitored application of synthetic chemicals in Asaba, Southern Nigeria. *American Journalof Scientific and Industrial Research* http://dx.doi.org/10.5251/ajsir.2011.2.4.592.602

Ekesi, S., (1999). Insecticide resistance in field populations of the legume pod-borer, *Maruca vitrata* Fabricius (Lepidoptera: Pyralidae), on cowpea, *Vigna unguiculata* (L.), Walp in Nigeria. *International Journal for Pest Management*., 45: 57-59

Ericah C. (2014)Pod Sucking Bugs Plantwise Knowledge Bank http://www.plantwise.org/knowledgebank retrievedSeptember, 2018.

Estruch J. J, Carozzi N. B, Desai N, Duck N. B, Warren G. W, Koziel M. G (1997). Transgenic plants: An emerging approach to pest control. *National Biotechnology*. 15(2):137-141.

Fatokun C (2009). Designer (Cowpea) Plants. http://r4dreview.org/2009/03/designer-cowpea-plants/ Accessed on April 2018

Food and Agricultural Organization (FAO) Statistics, (2012) Gateway. Archived. retrieved September, 2019 from http://www.fao.org>faostat

Food and Agricultural Organization (FAO) Statistics, (2016) Nigeria cowpea dry production quantity Accessed September, 2019.

Federoff N. E., Vaughan A., and Barrett M. R. (2008) 'Environmental fate and effects division problem formulation for the registration review of Imidacloprid' US EPA. Retrieved May 17 2018.

Gervais, J.A.; Luukinen, B.; Buhl, K.; Stone, D. (2010). *"Imidacloprid Technical Fact Sheet". National Pesticide Information Center.*

Gianessi L. (2013) The increasing importance of herbicides in worldwide crop production. *Pest Management Science* 69 (10)

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

Gomez, A.A. and K.A. Gomez, (1983). Multiple Cropping in the Humid Tropics of Asia, IDRC Ottawa, Canada, page 248 (Palaniappan, P. and Sivaraman, K. Ed.).

Hakeem A. A., Rabiu S. A., and Singh B. B., (2012) Yield performance of cowpea as influenced by insecticide types and their combinations in the dry savannas of Nigeria. *African Journal of Agricultural Research* Vol. 7(44), page 5930 -5938, DOI: 10.5897/AJAR12.431

Herms D. A., D. G. McCullough, D. R. Smitley, C. Sadof, R. C. Williamson, P. L. Nixon (2009) 'Insecticide options for protecting ash trees from emerald ash borer' North central IPM Center Bulletin. Retrieved May 20 2018.

Heitholt J. J., A. Knutson, J.B. Faft, and B. Langston (2006) Early season thrips (Thysanoptera: thripidae) control and soybean yield in North Texas *Southwestern Emtomology* 31:113-120

Higgins TJ (2007). Bt Cowpea with Protection against Pod borer for Transfer to Africa.

https://publications.csiro.au/rpr/download?pid=csiro:EP124059&dsid=DS1

Higgins T.J., Gollasch S, Molvig L, Moore A, Popelka C, Armstrong J, Mahon R, Ehlers J, Huesing J,Margam V, Shade R, Murdock L (2010). Insect protected cowpea using gene technology. Book of Abstract, World cowpea conference, 27 September – 1 October 2010, PalmBeach Hotel, Saly Senegal, IITA Ibadan Nigeria

Huang C. C., W. K. Peng and N. S. Talekar (2003) Parasitoids and other natural enemies of Maruca vitrata feeding on Sesbania cannabina in Taiwan. *Journal of Biocontrol* 43 (4):407-416 DOI:10.1023/A:1024751300738

Ibeawuchi, I.I., (2007). Intercropping. A food production strategy for the resource-poor farmers. *Journal of Nature and Science*, 5(1): 00.00

International Institute of Tropical Africa (2011) Cowpea. retrieved from http://www.iita.org/cowpeaAccessed July, 2019

International Institute of Tropical Africa, (2021a) Guide to Cowpea Production in West Africa. www.iita.org/cropnews/cowpea Retrieved March, 2021.

International institute of tropical agriculture, (2021b) Maize. http://www.iita.org/cropnews/maize Retrieved March, 2021.

Idoko, J.A. (2005). Effects of cultivars and time of introducing cowpea on the performance of maize/cowpea intercropping systems in Makurdi. Ph.D. thesis, University of Agriculture Makurdi. page 59 (Unpublished),

Ishiyaku MF, Higgins TJ, Umar ML, Misari SM, Mignouna HJ, Nang'Ayo F, Stein Murdock LM, Obokoh M, Huesing JE (2010). Field Evaluation of some transgenic Marucaresistant Bt Cowpea for Agronomic traits under confinement in Zaria, Nigeria. Book of Abstracts of 5th World Cowpea Conference, Dakar, Senegal, page. 36-37

Isman, M. A. (2006) Botanical Insecticide, Deterrents and Repellents in Modern Agriculture and an increasingly regulated World" *Annual Review of Entomology*, 51: 45-66

Issoufou K. A. (2019) Nigeria commercializes first transgenic food crop African Agricultural Technology foundation; press release Accessed March, 2021

Jackai, L.E.N. and O.A. Oyediran, (1991). The potential of neem, *Azadirachta indica* for controlling post flowering pests of cowpea, *Vigna unguiculata* (L.) Walp-1. The pod borer, *Maruca testulalis* Geyer. *Insect Science and its Application*, 12: 103-109

Jackai L.E.N; (1995) Integrated pest management of borers of cowpea and beans. *Insect Science and its Application*, 16: 237 – 250

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

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., Roberts, J. M.F. and Singh, S.R. (1988) Cowpea seed treatment with carbosulfan potential for control of seedling pests. *Crop Protection* 7: 384-390.

Jacob C, Carrasco B, Schwember AR (2016) Advances in breeding and biotechnology of legume crops. Plant Cell Tissue, Organ Culture 127:561–584

Kamara, Y., Chikeye, D. Omoigui, L.O. and Dugje, I.Y. (2007) Influence of insecticide spraying regime and cultivars on insect pests and yield of cowpea in dry savanna of North eastern Nigeria, *Journal of foodAgriculture and Environment* 5(1):154-158

Kamara AY, Ekelemea F, Omoiguia LO, Abdoulayea T, Amaza P, Chikoye D, Dugje IY (2010). Integrating planting date with insecticide spraying regimes to manage insect pests of cowpea in North-Eastern Nigeria. *International Journal of Pest Management* 56, page 243-251

Kermah M., Angelinus C., Franke. Samuel Adjei-Nsiah. Benjamin D. K. Ahiabor, Robert C. Abaidooc, Ken E. Gillera (2017) Maize-grain legume intercropping for enhanced resource use efficiency and crop productivity in the Guinea savanna of northern Ghana, *Science direct*, Volume 213, , Pages 38-50

Kushwaha S., A.S. Musa, J. Lowenberg-DeBoer, and J. Fulton 2004. Consumer acceptance of Genetically modified orgamism; Cowpeas in Sub-Sahara Africa. *http://ageconsearch.umn.edu/bitstream/20216/1/sp04ku01.pdf* Retrieved May 2018

Lale N.S.E (2002) *Stored product entomology and acarology in tropical Africa*. Frist edition. ISBN 978.35120-9-9

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

Margam V. M., Coates B. S., Ba M. N. Sun W. Binso- Dabire C. L., Baoua I, Ishiayaku M. F., Shukle J.T., (2011) Geographical distribution of phylogenetically distinct legume pod borer, Maruca vitrata (Lepidoptera: Pyridae: Cambridae) *Molecular Biology Rep* 38: 893-903

Matteson, P.C., (1982). The effects of intercropping with cereal and minimal permethrin application on insect pests of cowpeas and their natural enemies in Nigeria. *Tropical Pest Managemen*t, 28: 373-380.

Mensah, G.W.K., 1997. Integrated Pest Management in cowpea through intercropping and minimal insecticide application. *Annals of Plant Protection Science.*, 5: 1-14.

MensahG.W.K., Appiah A., Anorbor E.C. and Anku L. (2017)Field Evaluation of Commercial Neem Oil in managing Insect Damage on Cowpea in the Forest Zone of Ghana. *Agricultural Science Research Journal* Volume 7(11): 329 – 336.

Mishra, A. K., Singh, N., Sharma, V.P. (1995) Use of Neem oil as a mosquito repellent in tribal villages of Mandla district, Madhya pradesh "*Indian Journal of Malariology*, 32 (3):99-103.

Mohammed, M.A., K. Vaiyapuri, A. Alagesan, E. Somasundaram, K. Sathyamoorthy and S. Pazhanivelan, (2006). Effect of intercropping and organic manures on yield and biological efficiency of cassava intercropping system (*Manihot esculenta*, crantz). *Research Journal of Agriculture and Biological Science*, 2(5): 201-208.

Mohammed, B. S., Ishiyaku, M. F., Abdullahi, U. S. and Katung, M. D. (2014)Response of transgenic Bt cowpea lines and their hybrids under field condition. *Journal of plant breeding and crop science.* Vol.6 (8) page 91-96

Murdock L.L., Coulibaly O, Higgins T.J.V., Huesing J.E., Ishiyaku M., Sithole-Niang I. Cowpea. In: Kole C, Hall TC, ed. (2008) Compendium of Transgenic Crop Plants: Transgenic Legume Grains and Forages. Oxford: Blackwell Publishing; 23-56.

Nampala P., M.W. Ogenga-Latigo, S. Kyamanywa, E. Adipala, N. Oyobo and L.E.N. Jackai. (2002) Potential Impact of Intercropping on Major Cowpea Field Pests in Uganda. *African Crop Science Journal,* Vol. 10. No. 4, pp. 335- 344.

NGICA, (2002). Network for the Genetic Improvement of Cowpea for Africa –*Reportof workshop on the genetic transformation of Cowpea* held in Capri, Italy, http://www.entm.purdue.edu/NGICA/reports/italy_proceedings.pdf. Retrieved May 2018

Nigerian Seed Portal,(2021) Improved seed varieties of all crops. www.seedportal.org.ng>variety Retrieved March, 2021.

Nkongolo KK, Bokosi J, Malusi M, Vokhiwa Z, Mphepo M (2009) Agronomic, culinary, and general characterization of selected cowpea elite lines using farmers' and breeder's knowledge: a case study from Malawi. *African Journalof Plant Science* 3(7):147–156

Ogah E.O, Omoloye AA, Nwilene FE, Nwogbaga, AC (2011). Effect of neem seed extracts in the management of rice stem borers in the field in Nigeria. *Nigerian Journal of Biotechnology*. 23: 13-21.

Olufemi o. R. Pitanand j. A. Odebiyi (2001) Crop losses in cowpea due to the pod-sucking bugs *riptortus dentipes, mirperus jaculus, anoplocnemis curvipes* and *nezara viridula Insect Science. Application.* Vol. 21, No. 3 pp. 237-241

Olatunde JA, Odebiyi HS, Jackai LEN (1991). Identification of sources of resistance in cowpea (*Vignaunguiculata*L. Walps) to *Clarigrallatomentosicollis*Stal. (Hemiptera: Coreidae). *Insect Science and its Application*. 12 (4): 455-461.

Oparaeke A.M., M.C. Dike and C.I. Amatobi, (2006). Insecticidal Efficacy of SABRUKA Formulations as Protectants of Cowpea Against Field Pests. *Journal of Entomology, 3: 130-135.*

Omoigui L.O., Kamara N. K., Ekeleme F., and Aliyu K. T., (2020) Guide to cowpea production in Northern Nigeria. IITA, Ibadan page 29-31

Oso A.A and M.J. Falade (2010)Effects of Variety and Spatial Arrangement on Pest Incidence, Damage and Subsequent Yield of Cowpea in a Cowpea/Maize Intercrop. *World Journal of Agricultural Sciences* 6 (3): 274-276.

Oyewale R.O., Bamaiyi L.J., Oparaeke A.M., Adamu R.S. (2014). Evaluation of four insecticides formulations for the management of insect pests of cowpea. *African Journal of Food Science Technology* volume 5(8):180-188

Panhwar M. A., Fida Hussain M., Mumtaz A. K. and Muhammad Ismail Soomro (2004). *Performance* of Maize in Intercropping System with Soybean under Different Planting Patterns and Nitrogen Levels, *Journal of Applied Sciences Volume* 4 (2): 201-204.

Preston R. (2007) 'A death in the forest'. *The New Yorker* Retrieved May 17 2018.

Prince A. (2010). Cowpea productivity improvement- guarding against *Maruca* infestation. African Agricultural Technology foundation http://www.aatfafrica.org/userfiles/Cowpea-brief.pdf Retrieved April, 2018

Puri H. S. (1999) Neem: The divine tree. *Azadirachta indica* A. Juss and other Meliaceous plants, Weinheim, New York,p 35-88

Qaim M (2009) The economics of genetically modified crops. *Annual Review Resource Economics* 1:665–693

Rangel, A., Domont, G. B., Pedrosa C., Fereira, S. T. (2003) "Functional properties of purified vicllins from cowpea (*Vigna unguiculata*) and pea (*Pisum sativum*) and cowpea protein isolate" *Journal of Agriculture and food chemistry* 51 (19): 5792-5797

Sachs S. E., Benedict H. J., Taylor F. J., Stelly M. D, Altman W. D, Berberich A. S, and Davis K.S., (1998). Expression and segregation of genes encoding *Cry1A* insecticidal proteins in cotton. *Crop Science* 38:1-11.

Seal D. R., M. Ciomperlik, M. L. Richards and W. Wassen, (2006) Comparative effectiveness of chemical insecticides against the chilli thrips, *Scirtothrips dorsalis* Hood (Thysanoptera) on pepper and their compatibility with natural enemies. *Journal of Crop Protection*. 25: 945-955

Shanower, T. G., Romeis, J. and Minja, E. M., (1999). Annual Review of Entomology, 44: 77-96

Sharma, H. C., Saxena, K. B. & Bhagwat, V. R., (1999) Information bulletin 55. Patancheru, India, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Singh B.B., Chambliss, O.L., Sharma, B. (2007) 'Recent advances in cowpea breeding" (pdf). In Singh B. B., Mohan, D.R., Dashiell, K. E., Jackai, L.E.N (eds). Advances in Cowpea Research. Ibadan, Nigeria: Institute of Tropical Agriculture and Japan international. Research Center for Agricultural Sciences.

Susan, A.J. and Mini C., (2005). Biological efficiency of intercropping in okra (*Abelmoschus esculentus*, L. Moench), *Journal of Tropical Agriculture*, 43(1-2): 33-36

Tanko M. U., and Yusuf M. (2017) Comparative studies of the yield performance of Improved vs local varieties of cowpea (*Vigna unguiculata* L. Walp) in Anyigba environment of Kogi state, Nigeria *InternationalJournal of Agronomy and Agricultural Research* Vol. 11, No. 2, p. 86-93

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.

Tamo M., Ekesi S., Maniania N. K., Cherry A. (2003) Biological control, a non-obvious component of IPM for cowpea. In: Neuenschwander P., Borgemeister C., Langewald J. (eds.) Biological control in IPM systems in Africa. CABI publishing, Wallingford page 295-309.

Taylor T. A. (1967) The bionomics of *Maruca Testulalis* (Geyer) Lepidoptera: pyrallidae) a major pest of cowpea in Nigeria. *Journal of West African Science Associations* 12:111-129

Timko M. P., and Singh B. B., (2008) Cowpea, a multifunctional legume. In: *Genomics of tropical crop plants*. Springer, New York, page 227–258

Ugine T. A., Wraight S. P. and J. P. Sanderson, (2007) Effect of manipulating spray-application parameters on efficacy of entomopathogenic fungus *Beavria bassiaria* against western flower thrip, *Frankhniella occidentalis*, infesting green- house impatiens *Crops Biocontrol Science Technology* 17:193-219.

USDA, (2016) United States Department of Agriculture. Foreign Agricultural Service. Circular series WAP 13-05. Retrieved from http://www.fas.usda.gov/wap/current/

Van-Rie J (2000). *Bacillus thuringiensis* and its use in transgenic insect control technology. *International Journal Medical. Microbiology*. 290(2-5):463-469

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

APPENDICES

Appendix I split plot Anova for population of *Megalorothrips sjostedti* at 50% podding

Source	Df	SS	MS	F value	Pr> f
Rep	2	0.033840	0.01692015	0.08^{NS}	0.9194
Spray	2	23.70349	11.85174809	59.27^{**}	<.0001
Error a	4	1.95361	0.48842042		
cropping	2	0.61239	0.30619722	1.53^{NS}	0.2557
Spray x intercrop	4	0.59973	0.14993296	0.75^{NS}	0.5769
Error b	12	2.399967	0.19997257		
Total	26	29.30281			

Appendix II split plot Anova for population of *Megalorothrips sjostedti* at 100% podding

Source	Df	SS	MS	F value	Pr> f
Rep	2	0.57488867	0.28744433	0.55^{NS}	0.5908
Spray	2	6.28832061	3.14416031	6.02^{*}	0.0155
Error a	4	7.06326453	1.76581613		
Cropping	2	1.07244375	0.53622187	1.03^{NS}	0.3878
Spray x intercrop	4	0.73638172	0.18409543	0.35^{NS}	0.8375
Error b	12	6.27052048	0.52254337		
Total	26	22.00581976			

Appendix III Split plot Anova for population of *Maruca*larvae at 50% podding

Source	Df	SS	MS	F value	Pr> f
Rep	2	0.54920722	0.27460361	4.65*	0.0319
Spray	2	0.27003392	0.13501696	2.29^{NS}	0.1439
Error a	4	0.87959318	0.21989830		
Cropping	2	0.24839348	0.12419674	2.11^{NS}	0.1646
Spray x intercrop	4	0.21989830	0.05497457	0.93^{NS}	0.4779
Error b	12	0.70793921	0.05899493		
Total	26	2.87506531			

Appendix IV Split plot Anova for population of *Maruca* larvae at 100% podding

Source	Df	SS	MS	F value	Pr> f
Rep	2	0.37079267	0.18539634	1.48^{NS}	0.2658
Spray	2	0.01927529	0.00963765	0.08^{NS}	0.9263
Error a	4	0.73796860	0.18449215		

Cropping	2	0.01927529	0.00963765	0.08^NS	0.9263
Spray x intercrop	4	0.58019796	0.14504949	1.16^NS	0.3760
Errorb	12	1.50056803	0.12504734		
Total	26	3.22807784			

Appendix V split plot Anova for population of pod sucking bugsat 50% podding

Source	Df	SS	MS	F value	Pr> f
Rep	2	0.79140784	0.39570392	1.46^NS	0.2717
Spray	2	0.81705467	0.40852734	1.50^NS	0.2616
Error a	4	0.93874035	0.23468509		
Cropping	2	0.76398352	0.38199176	1.41^NS	0.2829
Spray x intercrop	4	0.51431325	0.12857831	0.47^NS	0.7549
Error b	12	3.26222146	0.27185179		
Total	26	7.08772109			

Appendix VI Split plot Anova for population pod sucking bugs at 100% podding

Source	Df	SS	MS	F value	Pr> f
Rep	2	12.47199284	6.23599642	3.22^NS	0.0761
Spray	2	6.90405563	3.45202782	1.78^NS	0.2103
Error a	4	3.15965993	0.78991498		
Cropping	2	7.51624422	3.75812211	1.94^NS	0.1864
Spray x intercrop	4	2.40316027	0.60079007	0.31^NS	0.8659
Error b	12	23.26210501	1.93850875		
Total	26	55.71721791			

Appendix VII Split plot Anova for pod damage by *Maruca*larvae

Source	Df	SS	MS	F value	Pr> f
Rep	2	1.44910738	0.72455369	1.42^NS	0.2791
Spray	2	0.26781272	0.13390636	0.26^NS	0.7732
Error a	4	1.22949789	0.30737447		
Cropping	2	0.30848907	0.15424454	0.30^NS	0.7443
Spray x intercrop	4	0.84005261	0.21001315	0.41^NS	0.7967
Error b	12	6.11462921	0.50955243		
Total	26	10.20958888			

Appendix VIII split plot Anova for pod damage by pod sucking bugs

Source	Df	SS	MS	F value	Pr> f
Rep	2	126.0000000	63.0000000	4.88*	0.0281
Spray	2	304.8888889	152.4444444	11.81**	0.0015
Error a	4	209.1111111	52.2777778		

Cropping	2	24.8888889	12.4444444	0.96^{NS}	0.4090
Spray x intercrop	4	72.8888889	18.2222222	1.41^{NS}	0.2887
Error b	12	154.8888889	12.9074074		
Total	26	892.6666667			

Appendix IX Split plot Anova for pod load

Source	Df	SS	MS	F value	Pr> f
Rep	2	3.62962963	1.81481481	1.96^{NS}	0.1834
Spray	2	5.62962963	2.81481481	3.04^{NS}	0.0855
Error a	4	13.92592593	3.48148148		
Cropping	2	0.07407407	0.03703704	0.04^{NS}	0.9609
Spray x intercrop	4	2.81481481	0.70370370	0.76^{NS}	0.5709
Error b	12	11.11111111	0.92592593		
Total	26	37.18518519			

Appendix X Split plot Anova for pod evaluation index

Source	Df	SS	MS	F value	Pr> f
Rep	2	170.6666667	85.3333333	1.60^{NS}	0.2421
Spray	2	298.6666667	149.3333333	2.80^{NS}	0.1005
Error a	4	810.6666667	202.6666667		
Cropping	2	14.2222222	7.1111111	0.13^{NS}	0.8765
Spray x intercrop	4	241.7777778	60.4444444	1.13^{NS}	0.3867
Error b	12	640.000000	53.333333		
Total	26	2176.000000			

Appendix XI split plot Anova of 100 seed weight

Source	Df	SS	MS	F value	Pr> f
Rep	2	56.57649630	28.28824815	2.66^{NS}	0.1105
Spray	2	1.64349630	0.82174815	0.08^{NS}	0.9260
Error a	4	50.22470370	12.55617593		
Cropping	2	19.01698519	9.50849259	0.89^{NS}	0.4343
Spray x intercrop	4	90.05261481	22.51315370	2.12^{NS}	0.1412
Error b	12	127.5222667	10.6268556		
Total	26	345.0365630			

Appendix XII split plot Anova for seed index category A

Source	Df	SS	MS	F value	Pr> f
Rep	2	4.0788036	2.0394018	0.44^{NS}	0.6529
Spray	2	135.9088576	67.9544288	14.72^{**}	0.0006
Error a	4	38.3524415	9.5881104		
Cropping	2	7.0616724	3.5308362	0.76^{NS}	0.4868
Spray x intercrop	4	7.3518684	1.8379671	0.40^{NS}	0.8063
Error b	12	55.3888723	4.6157394		

Total	26	248.1425158			

Appendix XIII split plot Anova for seed index category B

Source	Df	SS	MS	F value	Pr> f
Rep	2	4.29975459	2.14987729	2.91^{NS}	0.0931
Spray	2	3.50182828	1.75091414	2.37^{NS}	0.1355
Error a	4	5.77176476	1.44294119		
Cropping	2	0.50126684	0.25063342	0.34^{NS}	0.7187
Spray x intercrop	4	8.18791756	2.04697939	2.77^{NS}	0.0764
Error b	12	8.85644927	0.73803744		
Total	26	31.11898130			

Appendix XIV split plot Anova for seed index category C

Source	Df	SS	MS	F value	Pr> f
Rep	2	2.06481379	1.03240689	1.94^{NS}	0.1860
Spray	2	3.45604568	1.72802284	3.25^{NS}	0.0745
Error a	4	7.92395066	1.98098767		
Cropping	2	0.15745329	0.07872665	0.15^{NS}	0.8639
Spray x intercrop	4	1.64900781	0.41225195	0.78^{NS}	0.5621
Error b	12	6.38133452	0.53177788		
Total	26	21.63260575			

Appendix XV split plot Anova for number of pod per plant

Source	Df	SS	MS	F value	Pr> f
Rep	2	75.32518519	37.66259259	5.28^{N*}	0.0458
Spray	2	98.72074074	49.36037037	4.03^{*}	0.0226
Error a	4	30.65037037	7.66259259		
Cropping	2	21.51629630	10.75814815	1.15^{NS}	0.3489
Spray x intercrop	4	71.73925926	17.93481481	1.92^{NS}	0.1720
Error b	12	112.1711111	9.3475926		
Total	26	410.1229630			

Appendix XVI split plot Anova for pod yield

Source	Df	SS	MS	F value	Pr> f
Rep	2	948894.778	474447.389	0.88^{NS}	0.4382
Spray	2	8394405.747	4197202.874	7.82*	0.0067
Error a	4	4888950.544	1222237.636		0.1210
Cropping	2	1313173.925	656586.963	1.22^{NS}	0.3283
Spray x intercrop	4	2350527.847	587631.962	1.10^{NS}	0.4024

Error b	12	6437121.30	536426.78		
Total	26	24333074.14			

Appendix XVII split plot Anova for grain yield

Source	Df	SS	MS	F value	Pr> f
Rep	2	120269.894	60134.947	0.35	0.7126
Spray	2	6840990.743	3420495.371	19.83	0.0002
Error a	4	2027563.930	506890.983		
Cropping	2	121295.659	60647.829	0.35	0.7106
Spray x intercrop	4	1624265.686	406066.421	2.35	0.1126
Error b	12	2070259.23	172521.60		
Total	26	12804645.14			

Appendix XVIII RCBD Anova for populationof *Megalorothrip sjostedti*at 50% flowering

Source	Df	SS	MS	F value	Pr> F
Rep	2	0.85850420	0.42925210	0.99	0.3907
Spray	4	4.31920940	4.31920940	9.97	0.0055
Variety	1	13.48359747	3.37089937	7.78	0.0008
Spray X variety	4	1.76806870	0.44201717	1.02	0.4235
Error	18	7.80012845	0.43334047		
Total	29	28.22950822			

Appendix XIXRCBD Anova for populationof *Megalorothrip sjostedti*at 50% podding

Source	Df	SS	MS	F value	Pr> F
Rep	2	0.56312241	0.28156121	0.29	0.7505
Spray	4	2.27720691	2.27720691	2.36	0.1420
Variety	1	4.63200299	1.15800075	1.20	0.3451
Spray X variety	4	0.77862303	0.19465576	0.20	0.9342
Error	18	17.37729381	0.96540521		
Total	29	25.62824916			

Appendix XX RCBD Anova for populationof *Maruca* larvae at 50% flowering

Source	Df	SS	MS	F value	Pr> F
Rep	2	0.00173515	0.00086758	0.00	0.9963
Spray	4	2.83845094	2.83845094	12.23	0.0026
Variety	1	1.27419242	0.31854811	1.37	0.2826
Spray X variety	4	0.58983339	0.14745835	0.64	0.6437
Error	18	4.17643800	0.23202433		
Total	29	8.88064990			

Appendix XXIRCBD Anova for populationof *Maruca*larvae at 50% podding

Source	Df	SS	MS	F value	Pr> F
Rep	2	1.10821889	0.55410945	1.78	0.1975

Spray	4	2.14109111	0.53527278	1.72	0.1901
Variety	1	1. 00864856	1.00864856	3.24	0.0888
Spray X variety	4	1.58646454	0.39661613	1.27	0.3173
Error	18	5.61112341	0.31172908		
Total	29	11.45554650			

Appendix XXIIRCBD Anova for population of pod sucking bugsat 50% flowering

Source	Df	SS	MS	F value	Pr> F
Rep	2	0.54943191	0.27471595	0.58	0.5704
Spray	4	1.01809191	0.25452298	0.54	0.7106
Variety	1	0.07651311	0.07651311	0.16	0.6926
Spray X variety	4	1.97063933	0.49265983	1.04	0.4145
Error	18	8.53571363	0.47420631		
Total	29	12.15038989			

Appendix XXIIIRCBD Anova for population of pod sucking bugs at 50% podding

Source	Df	SS	MS	F value	Pr> F
Rep	2	4.23934806	2.11967403	1.17	0.3339
Spray	4	6.75957217	1.68989304	0.93	0.4685
Variety	1	1.50820759	1.50820759	0.83	0.3743
Spray X variety	4	4.74923888	1.18730972	0.65	0.6319
Error	18	32.70398441	1.81688802		
Total	29	49.96035111			

Appendix XXIVRCBD Anova for pod damage by *Maruca* larvae

Source	Df	SS	MS	F value	Pr> F
Rep	2	0.46233701	0.23116851	2.20	0.1396
Spray	4	0.82871079	0.20717770	1.97	0.1421
Variety	1	8.15438945	8.15438945	77.64	<.0001
Spray X variety	4	0.66663987	0.16665997	1.59	0.2208
Error	18	1.89062146	0.10503453		
Total	29	12.00269858			

Appendix XXV RCBD Avova for pod damage by pod sucking bugs

Source	Df	SS	MS	F value	Pr> F
Rep	2	3.57162743	1.78581372	1.47	0.2566
Spray	4	17.50252502	4.37563125	3.60	0.0253
Variety	1	7.01311847	7.01311847	5.77	0.0273
Spray X variety	4	3.04866203	0.76216551	0.63	0.6495
Error	18	21.88944105	1.21608006		
Total	29	53.02537400			

Appendix XXVIRCBD Anova for aborted flower

Source	Df	SS	MS	F value	Pr> F
Rep	2	121.8666667	60.9333333	2.82	0.0860
Spray	4	119.5333333	29.8833333	1.38	0.2792
Variety	1	45.6333333	45.6333333	2.11	0.1633
Spray X variety	4	119.5333333	29.8833333	1.38	0.2792
Error	18	388.8000000	21.6000000		
Total	29	795.3666667			

Appendix XXVIIRCBD Anova for pod load

Source	Df	SS	Ms	F value	Pr> F
Rep	2	6.06666667	3.03333333	7.51	0.0042
Spray	4	1.53333333	0.38333333	0.95	0.4585
Variety	1	0.13333333	0.13333333	0.33	0.5726
Spray X variety	4	0.86666667	0.21666667	0.54	0.7106
Error	18	7.26666667	0.40370370		
Total	29	15.86666667			

Appendix XXVIII RCBD Anova for pod evaluation index

Source	Df	SS	MS	F value	Pr> F
Rep	2	297.6000000	148.8000000	6.04	0.0099
Spray	4	105.2000000	26.3000000	1.07	0.4016
Variety	1	34.1333333	34.1333333	1.38	0.2546
Spray X variety	4	46.5333333	11.6333333	0.47	0.7557
Error	18	443.7333333	24.6518519		
Total	29	927.2000000			

Appendix XXIXRCBD Anova for 100 seeds weight

Source	Df	SS	MS	F value	Pr> F
Rep	4	24.29800667	12.14900333	1.27	0.3047
Spray	4	17.43430000	4.35857500	0.46	0.7670
Variety	1	8.89985333	8.89985333	0.93	0.3474
Spray X variety	2	24.77824667	6.19456167	0.65	0.6356
Error	18	172.1144600	9.5619144		

Total	29	247.5248667			

Appendix XXX RCBD Anova for seed indexcategory A

Source	Df	SS	MS	F value	Pr> F
Rep	2	0.40075493	0.20037746	0.40	0.6792
Spray	4	2.12653718	0.53163430	1.05	0.4098
Variety	1	4.63850178	4.63850178	9.15	0.0073
Spray X variety	4	0.39637329	0.09909332	0.20	0.9375
Error	18	9.12309880	0.50683882		
Total	29	16.68526597			

Appendix XXXIRCBD Anova for seed index category B

Source	Df	SS	MS	F value	Pr> F
Rep	2	1.37244298	0.68622149	0.80	0.4630
Spray	4	3.51927985	0.87981996	1.03	0.4184
Variety	1	4.64424386	4.64424386	5.44	0.0315
Spray X variety	4	0.64868454	0.16217114	0.19	0.9405
Error	18	15.36563073	0.85364615		
Total	29	25.55028196			

Appendix XXXIIRCBD Anova for seed index category C

Source	Df	SS	MS	F value	Pr> F
Rep	2	0.63016798	0.31508399	0.40	0.6747
Spray	4	3.33891316	0.83472829	1.07	0.4021
Variety	1	9.16643897	9.16643897	11.70	0.0030
Spray X variety	4	1.33969444	0.33492361	0.43	0.7868
Error	18	14.09979494	0.78332194		
Total	29	28.57500949			

Appendix XXXIIIRCBD Anova for days to 50 % flowering

Source	Df	SS	MS	F value	Pr> F
Rep	2	11.66666667	5.83333333	63.00	<.0001
Spray	4	0.00000000	0.00000000	0.00	1.0000
Variety	1	20.83333333	20.83333333	225.00	<.0001
Spray X variety	4	0.00000000	0.00000000	0.00	1.0000
Error	18	1.66666667	0.09259259		
Total	29	34.16666667			

Appendix XXXIVRCBD Anova for days to maturity

Source	Df	SS	MS	F value	Pr> F
Rep	2	20.86666667	10.43333333	2.54	0.1063
Spray	4	25.86666667	6.46666667	1.58	0.2232
Variety	1	80.03333333	80.03333333	19.52	0.0003
Spray X variety	4	8.80000000	2.20000000	0.54	0.7107
Error	18	73.8000000	4.1000000		
Total	29	209.3666667			

Appendix XXXVRCBD Anova for pod yield

Source	Df	SS	MS	F value	Pr> F
Rep	2	109.3765400	54.6882700	12.20	0.0004
Spray	4	43.7316867	10.9329217	2.44	0.0845
Variety	1	2.2797633	2.2797633	0.51	0.4850
Spray X variety	4	14.4075533	3.6018883	0.80	0.5389
Error	18	80.7137267	4.4840959		
Total	29	250.5092700			

Appendix XXXVI RCBD Anova for grain yield

Source	Df	SS	MS	F value	Pr> F
Rep	4	360666.713	90166.678	0.30	0.8738
Spray	4	2558705.027	639676.257	2.13	0.1188
Variety	1	1293094.733	1293094.733	4.31	0.0525
Spray X variety	2	7332508.585	3666254.292	12.21	0.0004
Error	18	5402600.82	300144.49		
Total	29	16947575.88			

Appendix XXXVII Average / Monthly Weather data for 2018 Cropping Season.

location	Samaru	Samaru	Samaru	Samaru
Month	Mean %RH	Mean daily temp. (Max.) ^{o}C	Mean daily temp. (Min) ^{o}C	Total rainfall (mm)
June	75	33	24	195.5
July	80	31	23	238.1
August	82	29	23	279.5
September	77	32	23	311.6
October	70	34	25	64.2
November	31	33	18	Nil