STUDIES ON POPULATION DYNAMICS OF *Agonoscelis versicolor* F. (Hemiptera: Pentatomidae) ON SUNFLOWER *(Helianthus annuus* L.) IN SAMARU-ZARIA, NIGERIA

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA,
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DEPARTMENT OF CROP PROTECTION,
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DECLARATION

I declare that the work in this Dissertation entitled “Studies on Population Dynamics of *Agonoscelis versicolor* F. (Hemiptera: Pentatomidae) on Sunflower (*Helianthus annuus* L.) in Samaru-Zaria, Nigeria" has been carried out by me in the Department of Crop Protection. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another Degree or Diploma at this or any other Institution.

Joyce Bunmi, ADEKUNLE	___________________	__________________
(Student)	Signature	Date

CERTIFICATION

This Dissertation entitled "STUDIES ON POPULATION DYNAMICS OF *Agonoscelis versicolor* F. (Hemiptera: Pentatomidae) on SUNFLOWER *(Helianthus annuus* L.) IN SAMARU-ZARIA, NIGERIA" by Joyce Bunmi, ADEKUNLE meets the regulations governing the award of the Degree of Master of Science in Crop Protection of the Ahmadu Bello University, and is approved for its contribution to scientific knowledge and literary presentation.

Prof. I. Onu (Chairman, Supervisory Committee)	______________ Signature	______________ Date
Prof. R. S. Adamu (Member, Supervisory Committee)	______________ Signature	______________ Date
Prof. A. B. Zarafi (Head, Department of Crop Protection)	______________ Signature	______________ Date
Prof. K. Bala (Dean, School of Postgraduate Studies)	______________ Signature	______________ Date

DEDICATION

I dedicate this work to Almighty God without whom this work would not have been a success, next to my darling husband and my lovely children.

ACKNOWLEDGEMENTS

To God be all the glory, without whom I can do nothing, for making the study a dream-come true. I acknowledge the relentless support, encouragements, patience and skillful supervision of my supervisors: Professor I. Onu and Professor R. S. Adamu in making this study a success. I wish to express my unreserved gratitude to Professor S. M. Misari who initiated this wonderful work for his useful contribution. I am also grateful to Professor A. B. Zarafi and the other Academic and non Academic members of the Department of Crop Protection for their advice and support during the cause of this study. My thanks go to Messrs: O. A. John of Data processing unit I. A. R, A. Abdullahi of Department of Crop Protection, I. P. Musa and S. Areh for their technical assistance.

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ABSTRACT

Field experiments were conducted at the Institute for Agricultural Research (I. A. R.), Samaru, Zaria (Latitude 11˚11' N and Longitude 7˚38' E), Nigeria for two years period (2009 and 2012) to study the population dynamics of *Agonoscelis versicolor* F. on sunflower. The effect of planting dates of sunflower at two weeks intervals and weather parameters were used to monitor the population build-up of *A. versicolor*, their damage and yield of sunflower. The experiments were laid out in randomized complete block design with three replications. Four planting dates each during the rainy season (July 21, August 04, August 18 and September 01) and dry season (October 27, November 10, November 24 and December 08) were employed and Sunflower 'Ex-Funtua' variety was sown with no insecticidal treatments. The result showed a significant difference ($p \leq 0.05$) in the mean bug population on the sunflower on the four different planting dates, with higher mean number of *A. versicolor* recorded during the dry season than the rainy season. Planting dates also had significant effect on percentage seed damage (19-30%) and seed yield. Relative humidity, rainfall and yield were negatively correlated to population of *A. versicolor* while temperature and sunshine were positively correlated to the population of *A. versicolor.*

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CHAPTER ONE

1.0 INTRODUCTION

Sunflower (*Helianthus annuus* L.) a dicotyledonous annual herb, native of North America belongs to the family Asteraceae and widely cultivated throughout the World (Groove and Summer, 2005). As a short season annual plant, it is characterized by a large bright yellow head. It is one of the most important oil crops cultivated globally on over twenty two million hectares with a production of over twenty six million metric tonnes with the highest quality vegetable oil on the market (Shirshikar, 2005; Skoric *et al.,* 2007). The worldwide production is about 34.6 million metric tonnes of seed (FAO, 2015).The world largest sunflower producers now are Russia, Ukraine and Argentina, in that order and they produce more than 50% of the sunflower seeds (FAO, 2015).In Nigeria, although there is an upward trend in sunflower production, (Amujoyegbe *et al*., 2013) statistical data on production level are not available. It is mainly cultivated in the Sudan, Guinea and Derived Savannah regions of the tropics which have monomodal rainfall pattern (Olowe *et al*., 2005; Amujoyegbe *et al*., 2013).

Sunflower can grow well in irrigated as well as rain fed conditions with adequate sunlight and constant source of water (CAADP, 2008) but grow best on well drained soils. It can be rotated with corn, soybean and/or sorghum. Sunflower is one of the most important crops of the world (Skoric *et al*., 2007). It has numerous uses from Medical to Industrial application as Livestock feeds as well as human consumption, etc.

Numerous insect species attack sunflower in Africa, while only a few species have high pest status, majority are of little importance. The pests that attack sunflower are largely polyphagous, also attacking a variety of crops and wild plants. They can be categorized into seedling pests, leaf pests and pests of sunflower heads. Seed and seedlings are mainly damaged by soil insects, while Lepidopteran larvae and Hemiptera species cause damage to sunflower heads.

In Northern Nigeria (Mani, 2004) reported *Pachnoda interrupta*, *Agonoscelis versicolor*, *Clavigralla* spp, *Anoplocnemis curvipes* and *Pyrgomorpha vignaudi* as insect infesting sunflower heads, stems and leaves. *Nezara viridula, Agrotis* spp., *Heliothis armigera,* several armyworm, grasshoppers and termites have also been reported on sunflower (Aslam *et al*., 2000). Insect damage occur from planting onwards to drying of seeds on the head.

1.1 Justification of the Study

Sunflower is one of the important oil seed crops that give quality oil and high returns to the farmers. Low yield may be attributed to several reasons such as occasional adverse climatic conditions, poor agronomic practices, prevalence of diseases and damage caused by insect pests. Many species of phytophagous pentatomids are important pests of sunflower such as *Plusia orichalcea, Heliothis armigera, Agrotis ipsilon, Nezara viridula, Sphaerocoris annulus* and *Agonoscelis versicolor* causing various levels of damage (Khaemba and Mutuku, 1992). Recent reports from Nigeria have indicated that sunflower production holds promise in the forest Agroecology, Northern Guinea and Southern savannah (Adebayo *et al*., 2012). However sunflower is susceptible to various kinds of diseases and pests. Misari (1990) reported that no stage of sunflower is devoid of insect attack, though not much work had been done on the entomological aspect of sunflower. However *Nysius stalli, Adelphocoris* sp., *Hallodapus* sp., *Macroteles* sp., *Sphaerocoris annulus* and *Agonoscelis versicolor,* etc. have been reported on sunflower in Northern Guinea savannah (Misari, 1990; Mani, 2004). Earlier report showed that *A. versicolor* compared to other Pentatomids occur in large number on sunflower plants but the damage caused are said to be non-significant. Furthermore, *A.*

versicolor has been reported on variety of crops such as millet, cotton, sesame, soyabean and their main host being sorghum and sesame (Adamu *et al*., 2001; Bijlmaker, 2008). The host switching nature of these insect may be due to absence of preferred host. This study is therefore motivated to investigate the prevalence of *A. versicolor* during rainy and dry season on sunflower and to determine how population build up can affect sunflower yield.

Despite the potentials of sunflower, insect pest problems are a constraint to its production and no studies on population dynamics of *A. versicolor* on sunflower in Northern Guinea savannah has been carried out, which motivated this study in both the rainy and dry seasons to ascertain if sunflower could be referred to as a major host of *A. versicolor* in Samaru Zaria.

1.2 Objectives of the Study

The study was done with the following objectives:

1. To determine effect of planting date and season on the population dynamics of *A. versicolor* F. on sunflower.
2. To determine the effect of *A. versicolor* on seed damage and yield of sunflower in Samaru.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Sunflower

2.1.1 General description of sunflower

The Sunflower (*Helianthus annuus*) belongs to the family Asteraceae. It is an annual plant growing up to 4.6 m tall. It has large, rough and hairy leaves, oval to cordate in shape. Flower heads are large growing to 20-30 cm in diameter, consisting of numerous densely arranged florets (Knott, 2009). The flowers are made up of sterile outward ray of floret which varies in color and an inner disc florets which produces seeds. The flowers are always in a spiral pattern (Knott, 2010 and Bidlack *et al*, 2012) (Plate 3).

Sunflower is widely distributed in different habitats with both wild and cultivated species and it prefers full sun and well-drained, neutral to slightly alkaline soils (Hilty, 2014). It is physiologically matured when the back of the flower head is yellow and ready for harvest when the head turns brown on the back (Myers, 2008). Its total growing period ranges from 125 to 130 days (Table 1)

2.1.2 Uses of sunflower

Sunflower has numerous uses which include:

Food: Non-oil seed type of sunflower are used for human food such as snacks, bread and as bird feed .In Germany, seeds are sold as food for birds, cooked directly and used in salads. American-Indians uses sunflower for bread etc. (Nikneshan *et al*., 2011).The oil from sunflower seeds are used as salad, cooking oil and manufacturing of margarine (Bamgboye and Adejumo, 2007).

Industrial application: Sunflower is used as pesticide carrier and in the production of agrochemicals, surfactants, adhesives, plastics, fabrics, softeners, lubricants and coatings .The blend of sunflower oil and diesel fuel has greater potential

Table 1: Description of Sunflower Growth Stages

Stage	Description
Vegetative Emergence VE	Seedling has emerged and the first leaf beyond the cotyledons is less than 4 cm long.
Vegetative Stages V (number), i.e. V1 V2 V3 etc.	These are determined by counting the number of true leaves at least 4 cm in length beginning as V1, V2, V3, V4, etc. If senescence of the lower leaves has occurred count leaf scars (excluding those where the cotyledons were attached) to determine proper stage.
Reproductive Stages	
R1	The terminal bud forms a miniature floral head rather than a cluster of leaves. When viewed from directly above the immature bracts form a many-pointed star-like appearance.
R2	The immature bud elongates 0.5 to 2.0 cm above the nearest leaf attached to the stem. Disregard leaves attached directly to the back of the bud.
R3	The immature bud elongates more than 2.0 cm above the nearest leaf.
R4	The inflorescence begins to open. When viewed from directly above immature ray flowers are visible.
R5 (decimal) i.e. R5.1 R5.2 R5.3 etc.	This stage is the beginning of flowering. The stage can be divided into sub-stages dependent upon the percent of the head area (disk flowers) that has completed or is in flowering. Ex. R5.3 (30%), R5.8 (80%) etc.
R6	Flowering is complete and the ray flowers are wilting.
R7	The back of the head has started to turn a pale yellow colour.
R8	The back of the head is yellow but the bracts remain green.
R9	The bracts become yellow and brown. This stage is regarded as physiological maturity.

Schneiter and Miller (1981)

than the burning of pure vegetable oil. The American – Indians uses sunflower for dyes and body paints (Pelczar, 2012).

Medicinal uses: Sunflower raw seed has high content of dietary fiber, which aid in digesting food and even cure constipation. Sunflower seeds are a great source of vitamin C, which helps in preventing cardiovascular disease. Sunflower seeds can reduce the risk of certain types of cancer due to their high phytosterol content. Sunflower seeds are rich in magnesium which is also necessary for strong bones besides calcium. Choline, a compound found in sunflower seeds helps in improving memory and cognitive function. Sunflower seeds also have high amounts of potassium which helps to counterbalance the effect of sodium in the blood and lowers blood pressure, thus reducing the risk of developing hypertension (Sandeep, 2013).

Other uses: Sunflower are also locally grown in parks and gardens as ornamentals, as cut (fresh flowers), silage crop, and in manufacturing of paints, soap and other cosmetics (Bamgboye and Adejumo, 2007).

2.1.3 Insect pests of sunflower

Many agricultural insect pests build up large population on sunflower damaging its production through their feeding (Grazia *et al.*, 2008). The significant features of these species is that while some are widely distributed in all areas around the world where sunflower are grown, some are found in specific localities.

Survey carried out by Khaemba and Mutuku (1992) on insect pests of sunflower in Kenya, revealed that *Agonoscelis versicolor* adults and nymphs damage are of no economic importance as their occurrence were rare and did not occur throughout the areas where the survey was carried out. They reported *Plusia orichalcea*, *Heliothis armigera*, *Agrotis ipsilon*, (Hfn), and *Nezara viridula* as major insect pests causing serious damage. In tropical Africa, the notable pests include *Heliothis armigera*, *Nezara viridula*, *Agrotis* spp., *Calidea* sp. and *Schizonycha* sp., *Aphis gossypii* Glov, *Plusia orichalchea* F. and *Macrosiphum euphorbiae* Thos.

In Nigeria, Misari (1990) reported that no stage of sunflower was devoid of insect attack, with the highest incidence at flowering and heading stages. These insects include *Nysius stalli*, *Adelphocoris* sp., *Hallodapus* sp., and *Macroteles* sp., while *Sphaerocoris annulus* and *A. versicolor* have less effects on the crop. Mani (2004) identified *Pyrgomorpha vignaudi*, *Pachnoda cordata*, *Sphaerocoris annulus* and *A. versicolor* as insect pests of sunflower.

In North America, Charlet (1999) reported phytophagous insect pests on cultivated and native sunflower of economic importance, this include stem and root feeding species such as carrot beetle (*Ligyrus gibbosus* Degreer) and the sunflower weevil (*Cylindropcopturus adispersus* Le conte). The head and seed feeding species are the tarnished plant bug (*Lygus lineolaris* Palisot de Beauvois), the sunflower moth (*Homoesoma electellum* Hulst), and the red flower seed weevil (*Smicronyx fluvis* Le conte), among others.

In Brazil, Andrêa and Antônio (1998) reported in order of abundance, six species of pentatomid on sunflower plants they include *Euschistus heros* F., *Piezodorus guildinii*, *N. viridula* L., *Thyanta perditor* F. and *Colessa meditabunda* F. Their results revealed that most of the Pentatomids were pests of soyabean and are now adapting gradually to sunflower which serve as temporary host and source of nutrient after soyabeans is harvested before the bugs declines their feeding and reproductive activities during winter months that follows this period.

2.2 Insect Population Dynamics

Insect population dynamics refers to how the number of individual insect in a population changes over time. It is of interest to farmers as it is an important aspect in pest control measures. The abundance of individual insect in a population may fluctuate due to certain biotic or abiotic factors such as climatic, reproduction, mortality, flight and dispersal of insects. Climatic changes may involve a high frequency of abiotic disturbance, these alteration and gradual changes might affect the population dynamics parameter like development, reproduction diapause, winter mortality, flight and dispersal of insects (Warren *et al*., 2001). Temperatures above the specific optimum range lead to decreased growth rate, reduced fecundity and increase rate of mortality for a multitude of insects (Rouault *et al*., 2006)

2.3 *Agonoscelis versicolor* F.

2.3.1 Description and biology of *Agonoscelis versicolor* F.

Pentatomids are members of the order Hemiptera, sub order Heteroptera and the family Pentatomidae characterized by sucking mouth parts. Entomologists have described over four thousand seven hundred species in nearly nine hundred genera of ten subfamilies (Slater and Baronowski, 2004). *Agonoscelis versicolor* (Plate I) formerly known as *Agonoscelis pubescens* belongs to the tribe Agonoscelidini, they are referred to as stink bug because they produce odour from the thoracic glands for self-defense (Capinera, 2008). Stink bugs are broad –shield shaped 5-18mm in size, 5-segmented antenna with large triangular scutellum, head relatively small and often tucked into a concavity in anterior margin of pronotum, with ocelli present (Robert and Peter, 2009). A major diagnostic feature is the greatly enlarged scutellum that completely covers the wings and the abdomen like a shield (Mike *et al*., 2004). *Agonoscelis versicolor* lays whitish or cream coloured, barrel-shaped eggs usually in groups of thirty on leaves or under

Plate I: *Agonoscelis versicolor*

Source: Thomas *et al*. (2003)

parts of leaves and hatch three to five days, the nymphs resemble the adults and they are wingless.

2.3.2 Distribution and habits of *Agonoscelis versicolor* F.

Agonoscelis sp is native to southern and eastern Africa, extending northwards to the Arabian Peninsula (Linnavouri, 1982). *A. versicolor* is now recorded in the New World, United States, including Arizona, New Mexico and Texas (Thomas *et al*, 2003). A majority of stink bug species are herbivorous, both nymph and adults of plant feeding species damage plants by piercing the plants tissues and thus opening a path for pathogens to enter the plant (Slater and Baranowski, 2004*). A. versicolor* feed by piercing its stylets through soft grains, while the labium acts merely as sheath or grip. Species of *Agonoscelis* are generally yellowish often with a red tinge and black punctures arranged in a pattern of irregular dark stripes and a distinctly hirsute dorsum (McDonald, 1976; Gross, 1976). According to Bijlmaker (2008),

2.3.3 Host range and economic importance of *Agonoscelis* sp.

Bijlmaker (2008) reported that the main hosts of *Agonoscelis versicolor* are sorghum and sesames, while alternative hosts are soyabeans, pigeon pea and sunflower. Adults and nymphs are capable of causing considerable damage by feeding on heads of sorghum thereby causing discoloration. Andrêa and Antonio (1998) reported Pentatomids which are pests of Soyabeans now adapting gradually to sunflower which serves as temporary host example *N. viridula*, amongst others.

Mani (2004) reported *Agonoscelis* sp. and *Sphaerocoris* sp. amongst other pests on sunflower causing damage, while Adamu *et al.* (2001) reported *Agonoscelis versicolor* as pod sucking pests of soyabeans. *Agonoscelis* sp. are often found along field borders, particularly along tree lines near their over wintering sites, later developing cultivated plants becomes attractive when the wild hosts dry down (Slater and Baranowski, 2004). *Agonoscelis* sp. are reported on a common horehound weed (*Marribium vulgare*) along pastures, on cut flowers shipped to United States from South Africa, the possible passage is due to availability of the *M. vulgare* throughout the year.

2.4 Control Measures for Sunflower Insect Pests

The need to reduce the gap in oil production thereby enhancing a higher yield in Sunflower production calls for measures to reduce, eliminate, or mitigate the incidence of pests and diseases. Many stink bugs are considered agricultural insect pest because they can create large populations which can feed on crops. They are threat to cotton, sorghum, soyabeans, and native ornamental trees, shrubs, vines, weeds and many cultivated crops (Grazia *et al.*, 2008).

2.4.1 Cultural method

Planting dates must be planned to reduce the effect of insect pests on the performance of Sunflower (Abdou *et al*., 2011).The cultural method of control by selecting dates of sowing cultivated Sunflower has been successfully used in managing certain insect pests (Adedokun and Adesiyun, 1992). Delayed sowing has shown efficacy in lowering larval densities of sunflower stem weevil (*Cylindrocopturus adisperus* Le conte) on sunflower stalk, early sowing of sunflower in northern plains of United States results in lower seed damage of plants by the red sunflower seed weevil *Smicronyx fluvis* (Knodel and Charlet, 2010).

Abdou *et al* (2011) emphasized the use of cultural control strategy in enhancing higher productivity in Sunflower against *Pachnoda interrupta* damage. Rotation and early planting dates are some of the options to manage Sunflower head moth (*Homeosoma* *electellum*) and Sunflower clipper weevil (*Haplorphynchites aeneus*) in Arkansas (Porter, 2002).

In Nigeria, Adedokun and Adesiyun (1992) reported that significant difference were obtained in the total number of sunflower stem weevil (*Cylindrocopturus adisperus* Le conte) collected on different planting dates. While crops sown in the mid July gave the highest number of insect population, those sown during the fourth week in July gave the least number of insects. Mani (2004) reported that there was significant difference between the number of insects on sunflower. Late planted sunflower had lower number of insects than the early sown crops in the rainy season, later sown crops and irrigated crops had higher insect population than earlier sown.

Generally, the manipulation of planting date helps to minimize pest damage by producing a synchrony between host plants and the pest or synchronizing insects' pests with their natural enemy or presence of alternative hosts of the pests (Dhaliwal and Arora, 2006).Adding Sunflower to an existing crop rotation can reduce pest problem such as corn borer of soybean, cyst nematode (Myers, 2008).

2.4.2 Chemical control

Insecticides applied in furrow was found to reduce the number of sunflower stem weevil (*Cylindrocopturus adisperus* Le conte). Insecticide application timed on plant developmental stages from late bud stage to early bloom was found to significantly reduce damage by sunflower head moth (*Homoeosoma electellum*) (Charlet and Brewer, 2004).

2.4.3 Integrated pest management

Integrated pest management approach is sustainable approach around the Dakota, Minnesota and Manitoba to reduce potential losses of sunflower from pests.

Information on life cycle, damage and pest management strategies are employed for the insect pests of sunflower. The approach combines biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks and maintains pest populations below levels that causes yield losses. For example in controlling flower moth (*Homeosoma electellum* Hulst), planting dates are adjusted to condition of moth flight and length of growing seasons, later sowing usually have lower infestations than earlier sowing , in case of two to three adult moths per five plants insecticides are employed using sex traps pheromones which lures them (Knodel and Charlet, 2010).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The study was carried out at the Institute for Agricultural Research (IAR) fields during the 2009/2010 and 2012/2013 cropping seasons in Samaru Zaria (Latitude 11º 11' N and longitude 7º 38' E) in the Northern Guinea Savanna of Nigeria. Zaria experiences distinct wet and dry seasons; the wet season (May - October) and dry season (October - April). The wet season was characterized by convectional rainfall, with mean annual rainfall of about 1000 mm and relative humidity during this season could be as high as 75% but could be as low as 21% or less during the dry season. The wet season was characterized by a period of low temperature (21ºC) while the temperature could be as high as (32ºC) during the hot dry days (Buhari and Sawa, 2011).

Two separate trials were carried out to determine the population dynamics of *Agonoscelis versicolor* during rainy and dry seasons. The rainy season trial was carried out from July 21 to September 01, 2009 and 2012, while the dry season (irrigation) trial commenced on October 27 and was terminated on December 8, 2009 and 2012.

3.2 Methods

The experimental land was harrowed and ridged at spacing of 75 cm apart. A mixture of Grammoxone plus Butachlor at 250 ml per 20 litres of water was applied two days after planting as weed control treatment which was later complimented by three hoe weeding operations to keep the field free of weed during the growing seasons. Twelve plots measuring **5** X **5** meters each were laid out in randomized complete block design giving three blocks of four plots each with one meter space. Four planting dates were employed for this study, an open pollinated variety of sunflower (Ex-Funtua) obtained from Plant Science Department, Faculty of Agriculture, Institute for Agricultural

Research, Ahmadu Bello University was sown with a predetermined interval of two week each.

Five seeds were planted per hole at 30 cm spacing and thinned to two plants per stand at two weeks after planting. The sunflower were sown as sole crops with no insecticidal treatments and routine recommended agronomic practices were carried out throughout the experimental period. Ten (10) plants were randomly selected and tagged per plot on which counting of *A. versicolor* on the sunflower were carried on weekly basis. The on – the –spot visual counting of the insects from time of occurrence to maturity of the crops was done in the morning between 0700 – 0900 hours according to the methods used by Dike (1983), Arya *et al.* (1995) and Mani (2004).

Initially, visual counting were done, but as insect population builds up, the use of a baft bag (Plate II) was employed, the sunflower head are bent and the insects shaken into the baft bag, from where they were transferred into a labeled container containing cotton wool with ethyl acetate to immobilize the insects before they are counted (Plate III). Weather data records on rainfall, air temperature, relative humidity and wind speed obtained from IAR Meteorological Station were used to monitor the insect population dynamics.

3.2.1 Population of *A. versicolor*

The population change of *A. versicolor* was determined by the number of each insect counted on the sunflower plants per plot.

Hence,

$$\text{Mean number of insect per plot} = \frac{\text{Total number of insects}}{\text{Total number of plots}}$$

Plate II: Baft Bag

Plate III: Insect Collection Container

3.2.2 Seed yield and damage to seed by *A. versicolor*

On maturation the yield was assessed for the whole plot for both rainy and dry season, the harvested heads were dried, threshed and winnowed; the weight of each sample per plot was taken and recorded.

The number of seeds damaged by the insect was assessed using a standard measuring cup (4cm length by 7cm diameter) to sample one thousand seeds from each plot. The samples were obtained after a thorough mixing of the achenes from each plot and the assessment of the damaged seeds were based on the number of shrunken and shriveled seeds per 1000 sampled seeds (Mani, 2004). Percentage seed damage was determined from the mean weight of the ten plants randomly selected per plot

$$\text{hence,} \quad \%\ \text{Seed damage} = \frac{\text{Number of damage seed}}{\text{1000 seeds taken .}} \times 100$$

3.3 Data Analysis

Data collected on insect counts from the experiment were transformed using square root transformation √ (X + 0.05) where X is the number of insect counted. The transformed data and results on seed yield per plot were converted to kilogram per hectare (kg/ha) and damage to seeds per plot were analyzed using Analysis of variance (ANOVA) and means were separated using Students Neuman's Keuls (SNK) and correlation analysis were carried out on the weather parameters collected from I.A.R. Meteorological weather station, yield of sunflower and insect population, using Statistical Analysis Software (SAS, 2002).

CHAPTER FOUR

4.0 RESULTS

4.1 Population of *A. versicolor*

The result of planting dates on the population of *Agonoscelis versicolor* on sunflower during the 2009 rainy season indicates that, there was a significant difference($p \leq 0.05$) in the mean bug population on the crops sown on the four different planting dates. The first planting date (P1) had a mean insect population of 70 (20%), the second planting date (P2) was 33 (10%) while a peak population of 166.3 (48%)was attained on the third planting date (P3) followed by a decline in the population to 78.3 (22%) at the fourth planting date (P4) of the total mean insect count for this season. The third planting date (P3) had the highest mean insect population while the second planting date (P2) had the least mean insect count as indicated on Figure 1. The 2009 dry season result showed that there was a steady increase in the mean number of *A. versicolor* from the first planting date (P1) to the fourth planting date. The first planting date (P1) had 186.3 (13%), the second planting date was 206.3 (15%), with an increase to 257 (19%) on the third planting date and a peak population of 724 (53%) at the fourth planting date (Figure 2).

The second year trial (2012) followed a similar pattern for the rainy and dry season. During the rainy season an initial population of 84 (23%) was recorded on the first planting date (P1) which reduced to 43 (12%) by the second planting date (P2) followed by a peak bug population of 158 (42%) at the third planting date (P3).The population count then decreased to 87 (23%) on the fourth planting date (P4) (Figure 3). On the other hand there was persistent increase in the bug population during the dry season. The mean number of bug at the first planting date (P1) was 186.3 (20%) followed by 206.3 (23%) at the second planting date (P2) with an increase to 250.3 (28

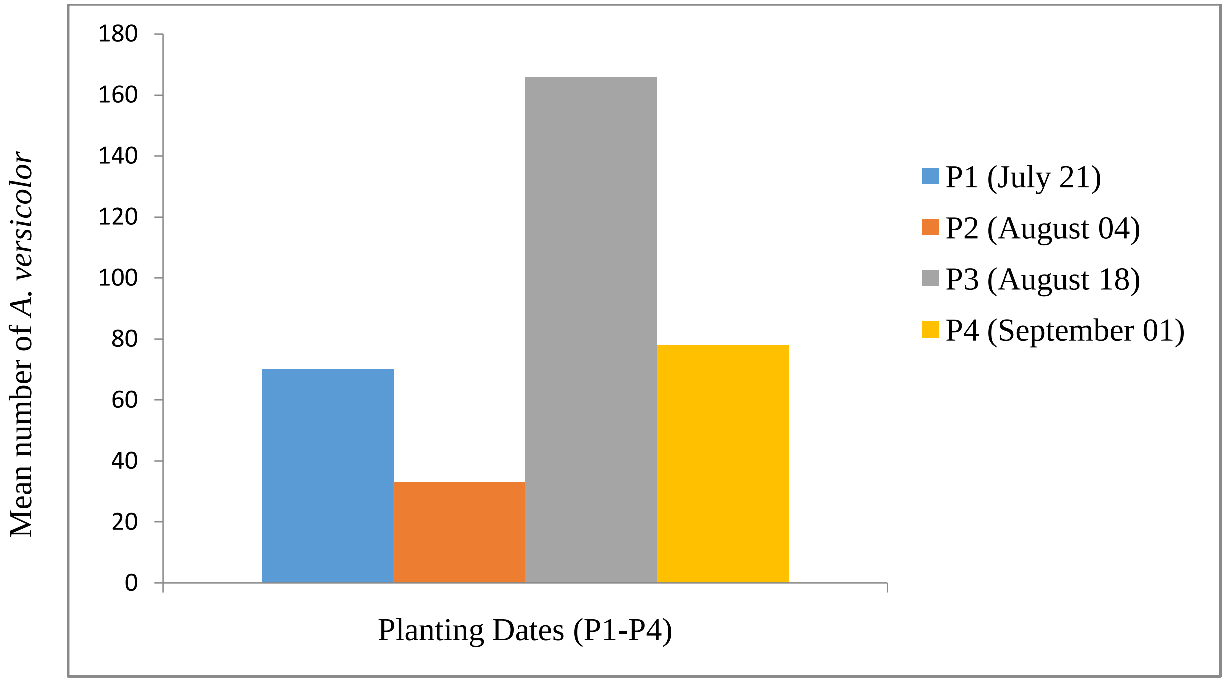

Figure 1: Effect of Planting Dates on the Population of *A. versicolor* on Sunflower during 2009 Rainy Season

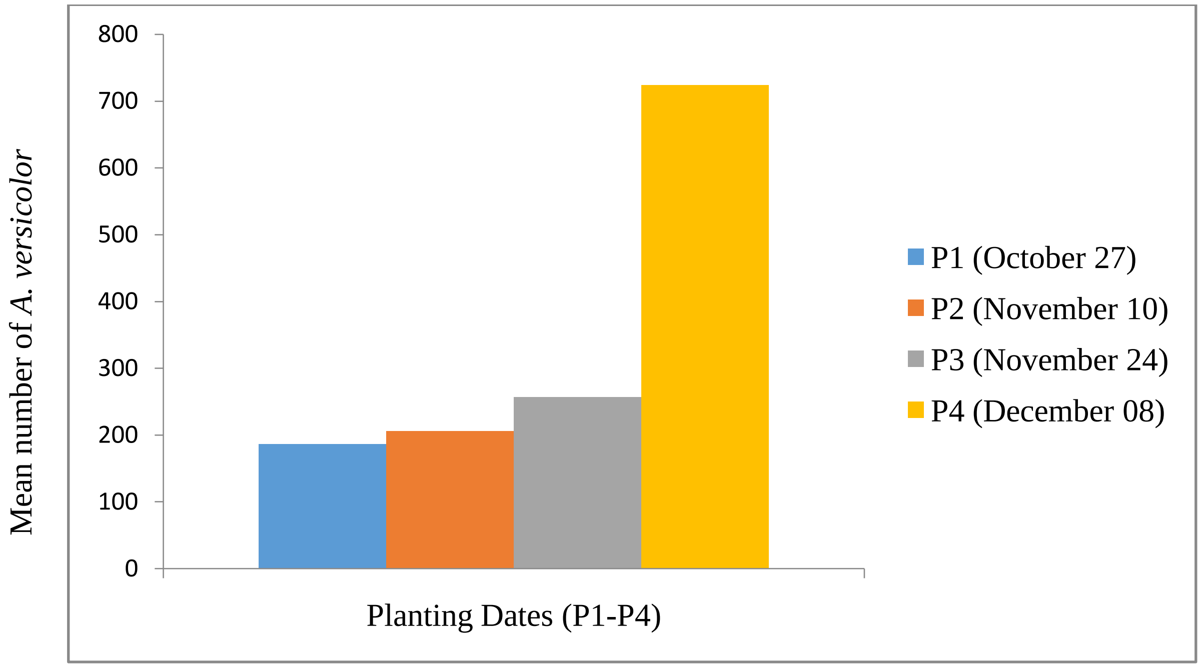

Figure 2: Effect of Planting Dates on the Population of *A. versicolor* on Sunflower during 2009 Dry Season

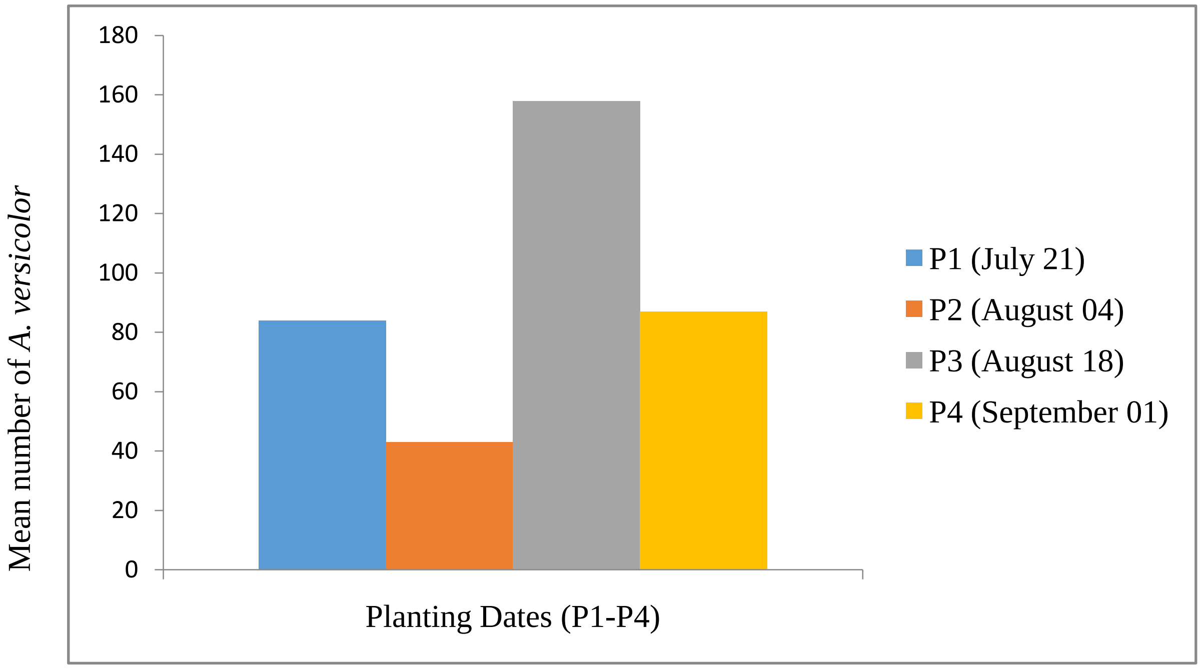

Figure 3: Effect of Planting Dates on the Population of *A. versicolor* on Sunflower during 2012 Rainy Season

%) at the third planting date (P3) and 262.6 (29%) on the fourth planting date (P4) (figure 4).

4.2 Seed Damage

Planting dates had significant effect ($P \leq 0.05$) on mean seed damage (Table 2). During the 2009 rainy season, the highest mean seed damage were on sunflower sown on August 18 (31.11) which was at par to those sown on August 4 (29.78) and were both significantly ($P \leq 0.05$)) higher than those sown on July 21 (20.0) and September 01 (23.56), which were at par. During the dry season, same year, there was no significant difference in seed damage among all the planting dates ($P > 0.05$).

In 2012 rainy season, mean weight of seed damage / percentage seed damage between August 4 (31.11) and August 18 (31.11) planting dates were significantly similar, but were both significantly ($P \leq 0.05$) higher than those of July 21 (21.33) and September 01 (26.67), which were the same. During the dry season, same year, there was no significant difference in seed damage among November 10 (25.33), November 24 (28.89) and December 8 (23.11), but they were all significantly higher that of October 27 (16.89) planting date. 27 and the other planting dates. However the mean seed damage between the second planting date (25.3), third (28.9) and fourth (23.1) planting dates were significantly similar (Table 3).

4.3 Seed Yield

The results showed there were significant difference in the mean seed yield among the planting dates (Table 4). In the rainy season 2009, sunflower plants sown on July 21 had the highest mean seed yield (4,370 kg/ha) which was significantly higher than those obtained with other planting dates. This was followed by those sown August 04 (3888 kg/ha) which was at par that of September 01 (3619 kg/ha). The least mean seed

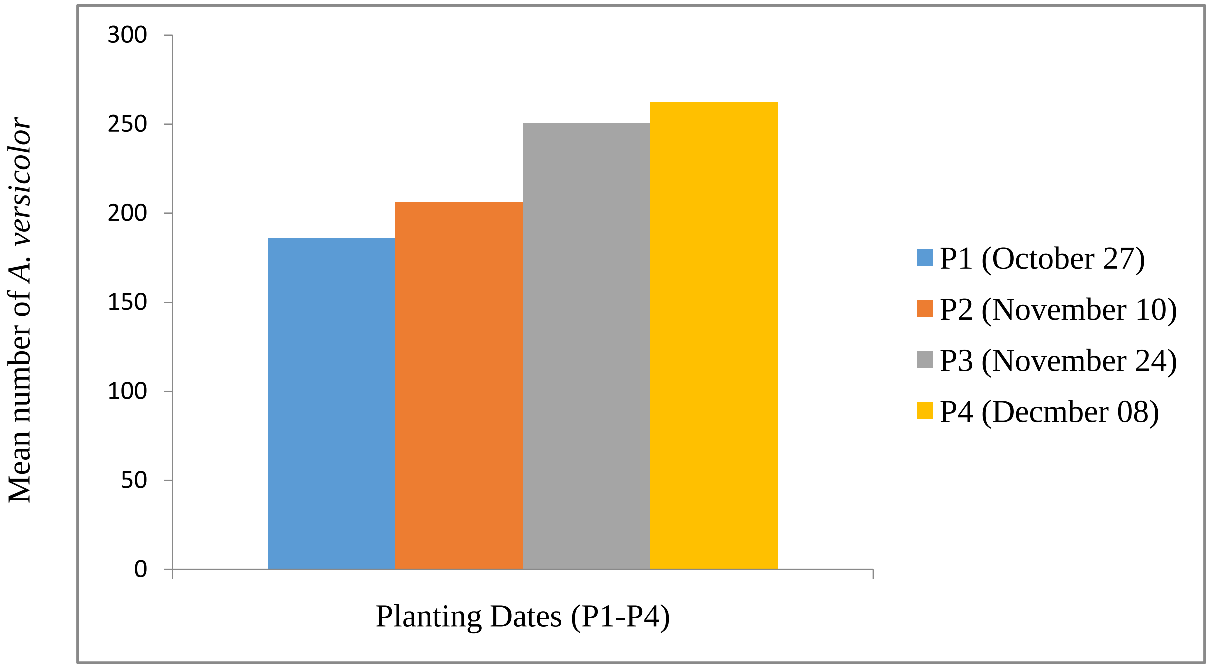

Figure 4: Effect of Planting Dates on the Population of *A. versicolor* on Sunflower during 2012 Dry Season

Table 2: Effect of Planting Dates on the Damage caused by *A. versicolor* on Sunflower in Samaru during 2009 Rainy and Dry Seasons.

Planting dates (Rainy Season)	Mean Seed Damage (kg/ha) / % seed damage		Planting dates (Dry Season)	Mean Seed Damage (kg/ha) % seed damage	
July 21 (P1)	20.00[b]	19%	Oct 27 (P1)	27.56	27%
Aug 4 (P2)	29.78[a]	28%	Nov 10 (P2)	23.56	23%
Aug 18 (P3)	31.11[a]	30%	Nov 24 (P3)	27.56	27%
Sept 1 (P4)	23.56[b]	23%	Dec 8 (P4)	23.56	23%
S.E ±	6.07		S.E ±	6.07	

Means in each column followed by the same letter are not significantly different at P = 0.05 using SNK

Table 3. Effect of Planting Dates on the Damage caused by *A. versicolor* on Sunflower in Samaru during 2012 Rainy and Dry Seasons

Planting dates (Rainy Season)	Mean Seed Damage (kg/ha) / % seed damage		Planting dates (Dry Season)	Mean Seed Damage (kg/ha)/ % seed damage	
July 21 (P1)	21.33[b]	20%	Oct 27 (P1)	16.89[b]	17%
Aug 4 (P2)	31.11[a]	28%	Nov 10 (P2)	25.33[a]	23%
Aug 18 (P3)	31.11[a]	28%	Nov 24 (P3)	28.89[a]	27%
Sept 1 (P4)	26.67[b]	24%	Dec 8 (P4)	23.11[a]	23%
S.E ±	6.07		S.E ±	6.07	

Means in each column followed by the same letter are not significantly different at P = 0.05 using SNK

Table 4. Effect of Planting Dates on Yield of Sunflower in Samaru during 2009 Rainy and Dry Seasons.

Planting dates (Rainy Season)	Mean Seed yield per Head (kg/ha)	Planting dates (Dry Season)	Mean Seed yield per Head (kg/ha)
July 21 (P1)	4,370.37[a]	Oct 27 (P1)	4,037.04[a]
Aug 4 (P2)	3,888.89[b]	Nov 10 (P2)	3,768.89[a]
Aug 18 (P3)	2,964.44[c]	Nov 24 (P3)	2,398.52[b]
Sept 1 (P4)	3,619.26[b]	Dec 8 (P4)	3,555.56[a]
S.E ±	431.68	S.E ±	494.39

Means in each column followed by the same letter are not significantly different at P = 0.05 using SNK

yield was recorded on plants sown on August 18 (2964 kg/ha). During the dry season, same year, the crops sown on October 27 (4037 kg/ha) had the highest mean seed yield but it was similar to those of November 10 (3768 kg/ha) and December 8 (3555 kg/ha) and were all significantly higher than that of November 24 (2398 kg/ha).

The difference in the mean seed yield among planting dates in the 2012 rainy season was significant ($P<0.05$) (Table 5). Mean yield of sunflower plant sown on August 04 (4122 kg/ha), September 01 (4099 kg/ha) and July 21 (3838 kg/ha) were significantly similar, but those of August 04 and September 01 were significantly higher than that of August 18, which was at par with July 21. The mean seed yield for sunflower plant sown in October 27 (4358 kg/ha) during the dry season, same year, was significantly higher than those of other planting dates. However, the mean seed yield among November 10 (3672 kg/ha), November 24 (3482 kg/ha) and December 08 (3560 kg/ha) planting dates were significantly similar.

The effect of season on the population *A. versicolor* was significant ($P<0.05$) for both 2009 and 2012 (Table 6). Dry season had a significantly higher population of *A. versicolor* than the rainy season. There was no significant difference in the mean seed damage between the two seasons for both years. The mean seed yield recorded during the dry season of 2009 was significantly higher than that recorded in the rainy season of the same year. But there was no significant difference in the mean seed yield of both rainy and dry season of 2012.

Comparing the two year trials (Table 7), results showed that the two years were significantly different ($p \leq 0.05$), with the 2012 trial having a significantly higher mean seed yield (3844 kg/ha) than that of 2009 (3575 kg/ha), but there were no significant

Table 5. Effect of Planting Dates on Yield of Sunflower in Samaru during 2012 Rainy and Dry Seasons.

Planting dates (Rainy Season)	Mean Seed yield per Head (kg/ha)	Planting dates (Dry Season)	Mean Seed yield per Head (kg/ha)
July 21 (P1)	3,838.52[ab]	Oct 27 (P1)	4,358.52[a]
Aug 4 (P2)	4,122.96[a]	Nov 10 (P2)	3,672.59[b]
Aug 18 (P3)	3,620.74[b]	Nov 24 (P3)	3,482.96[b]
Sept 1 (P4)	4,099.26[a]	Dec 8 (P4)	3,560.00[b]
S.E ±	415	S.E ±	282

Means in each column followed by the same letter are not significantly different at P = 0.05 using SNK).

Table 6: Effect of Season on Population of *A. versicolor*, Seed Damage and Seed Yield: 2009 and 2012

Season	2009			2012		
	Mean No of *A. versicolor*/ Head	Mean of seed Damage (kg/ha)	Mean Seed Yield (kg/ha)	Mean No of *A. versicolor*/ Head	Mean of seed Damage (kg/ha)	Mean Seed Yield (kg/ha)
Rainy	8.69[b]	25.60[a]	3440[b]	9.30[b]	23.60[a]	3769[a]
Dry	34.34[a]	26.10[a]	3711[a]	22.64[a]	27.60[a]	3920[a]
S.E ±	0.37	3.02	254	0.35	3.02	178

Table 7: Effect of Year on Population of *A. versicolor* Seed Damage and Seed Yield: Combined Data.

Year of Trials	Mean number of *A. versicolor*/Head	Mean seed Damage (kg/ha)	Mean seed Yield (kg/ha)
2009/2010 First Trial	21.52	25.80	3,575[b]
2012/2013 Second trial	15.97	25.60	3,844[a]
S.E ±	4.00	2.13	156

Means in each column followed by the same letter are not significantly different at P = 0.05 using SNK

differences in the mean number of *A. versicolor* and mean seed damage between the two years.

4.4 Correlation Between Seed Yield of Sunflower, *A. versicolor* Population and Weather Parameters

Table 8 and 9 show correlation coefficients of population of *A. versicolor*, weather parameters and yield of sunflower in Samaru, for both rainy and dry seasons of 2009 and 2012. In the rainy season, 2009 (Table 8), temperature and sunshine hours had positive effect ($r = 0.107, 0.127$) on the population of *A. versicolor* but not significant ($P > 0.05$), while relative humidity was negatively correlated with the population of *A. versicolor* ($r = -0.221$) which was significant ($P<0.05$). Rainfall had negative correlation with the population of *A. versicolor* but not significant ($r = -0.030$; $P>0.05$). Effect of population of *A. versicolor* on the yield of sunflower was negative ($r = -0.338$) and highly significant ($P<0.01$). In the dry season, 2009 (Table 9), temperature had non-significant but positive correlation ($r = 0.036$; $P>0.05$) with the population of *A. versicolor*, while effect of sunshine hours on the population of *A. versicolor* was positive and highly significant ($r = 0.397$; $P<0.01$). Relative humidity had negative but non-significant effect on the population of *A. versicolor* ($r = -0.267$; $P>0.05$). Effect of population of *A. versicolor* on the yield of sunflower was negative but not significant ($r = -0.164$; $P>0.05$)

In the rainy season, 2012, temperature had significant positive effect on the population of *A. versicolor* ($r = 0.178$; $P<0.05$), while sunshine hours had positive but non-significant effect on the population of *A. versicolor* ($r = 0.013$; $P>0.05$). The correlation of relative humidity and population of *A. versicolor* was negative but not significant ($r = -0.144$; $P>0.05$). Similarly, rainfall had non-significant negative correlation with the population of *A. versicolor* ($r =-0.060$; $P>0.05$). The population of *A. versicolor* had

Table 8: Correlation Coefficients of Population of *A. versicolor*, Weather Parameters and Yield of Sunflower in Samaru Rainy Seasons, 2009 and 2012

		Insect population	Relative Humidity	Temperature	Rainfall	Sunshine hours	Yield
Insect Population	2009	1.000					
	2012	1.000					
Relative Humidity	2009	-0.221*	1.000				
	2012	-0.144	1.000				
Temperature	2009	0.107	-0.134	1.000			
	2012	0.178*	-0.599*	1.000			
Rainfall	2009	-0.030	0.227**	-0.218*	1.000		
	2012	-0.060	0.303**	-0.322**	1.000		
Sunshine hours	2009	0.127	-0.390**	0.457**	-0.200*	1.000	
	2012	0.013	-0.577*	0.686**	-0.200*	1.000	
Yield	2009	-0.338**	-0.313**	-0.393**	-0.007	0.102	1.000
	2012	-0.236**	0.107	-0.169	-0.024	-0.108	1.000

*Significant at P = 0.05
**Significant at P = 0.01

Table 9: Correlation Coefficients of Population of *A. versicolor*, Weather Parameters and Yield of Sunflower in Samaru Dry Seasons, 2009 and 2012.

		Insect population	Relative Humidity	Temperature	Sunshine hours	Yield
Insect Population	2009	1.000				
	2012	1.000				
Relative Humidity	2009	-0.267**	1.000			
	2012	-0.144	1.000			
Temperature	2009	0.036	-0.234**	1.000		
	2012	0.331**	-0.169	1.000		
Sunshine hours	2009	0.397**	-0.575**	0.218*	1.000	
	2012	0.115	0.140	0.214*	1.000	
Yield	2009	-0.164	0.120*	-0.136	-0.185*	1.000
	2012	-0.033	0.187*	-0.121	-0.172	1.000

*Significant at P = 0.05
**Significant at P = 0.01

negative and highly significant effect on the yield of sunflower ($r = -0.236$; $P<0.01$). In the dry season, 2012, the correlation of temperature and the population of *A. versicolor* was positive and highly significant ($r = 0.331$; $P<0.01$), while that of sunshine hours was positive but not significant ($r = 0.115$; $P>0.05$). Relative humidity had negative but non-significant effect on the population of *A. versicolor* ($r = -0.144$; $P>0.05$). The correlation of population of *A. versicolor* and yield of sunflower was negative but not significant ($r = -0.033$; $P>0.05$).

CHAPTER FIVE

5.0 DISCUSSION

5.1 Population of *A. versicolor*

The study showed that *Agonoscelis versicolor* is a common bug occurring during the rainy and the dry seasons but more prevalent during the dry season between vegetative stage of sunflower to maturity. The population of *A. versicolor* varies significantly with planting date and this was probably influenced by weather parameters such as rainfall, relative humidity and temperature prevalent in Samaru during the course of the study. The seasonal fluctuations of weather parameters affected its population dynamics. During the month of July to September being the peak of the rainy season, the bug population drastically reduced while the gradual decrease in rain from October to absence of rain in the month of December gradually leads to the bug population increase getting to a peak at December this may be likely due to the biology of *A. versicolor* as good fliers, it moves rapidly when disturbed as observed during the course of the study. This concurs with Osman (2004) who reported that low humidity and high temperature during dry season favours the clustering activities of *A. versicolor* on sorghum in Sudan thereby enhancing their reproductive activities. On the other hand he reported that, high humidity and rainfall during rainy season tends to confine *A. versicolor* to weed and other hiding places such as trees etc. The result from the present study showed that high temperature and low humidity favours population build-up of *A. versicolor*. The findings support an earlier report by Vennila *et al.* (2007) that high temperature and scanty rainfall aggravate the severity of sucking pest.

The observation in this study is also in line with Murugen and Uthamasamy (2000) who reported that meteorological parameters play an important role in the population fluctuation of sucking insects. The significant difference($P \leq 0.05$) in the bug population with planting dates as observed during the study, may be due to the gradual absence of preferred hosts from the field as the bugs are known to feed on several other crops such as cowpea, soyabean, sorghum etc., as some insects have adapted to utilize sunflower as an alternative host (Adamu *et al.,* 1999; Alawia and Bilal, 2003; Mani, 2004; Malgwi and Dunuwel, 2013) and this could be related to the fact that *A. versicolor* tends to move from older plants to younger ones in other to feed or suck sap.

5.2 Sunflower Seed Damage

Though information on the losses as a result of *Agonoscelis versicolor* on cultivated sunflower is still very limited, the findings from the present studies shows varying percentage of seed damage with planting date. Percentage seed damage between 19 - 30% was obtained with planting dates as the insect population fluctuate, though the difference was not significant. Earlier findings by Alawia and Bilal (2003) showed that seed damage by *A. versicolor* depends on the crop in question, its distribution and location. For instance in South Africa, the bug population on sunflower is low that control is seldom necessary. In Sudan, Alawia and Bilal (2003) reported that seed damage of 20-30% of sorghum is possible or in certain times total loss of crop may occur. Osman (2004) also reported that *A. versicolor* as minor pest of sorghum feeds on heads of sorghum resulting in pod damage and discoloration however usually no control is needed in the area where he carried out his research in Sudan. In Nigeria, Malgwi and Dunuwel (2013) reported *A. versicolor* having less effect amongst other panicle insect pests of sorghum. As hardy as Bambara groundnut, *A. versicolor* caused significant damage and when effectively controlled using insecticide the yield was doubled compared to unprotected crops which had an average of yield of 450- 1000 kg/ha (Dike, 1997). In addition Khaemba and Mutuku (1992) reported that *A. versicolor* adult and nymphs damage on sunflower are of no economic importance in

Kenya. Bijlmaker (2008) reported *A. versicolor* as minor pests of sunflower in Ethiopia while Mani (2004) identify *A. versicolor* as one of the major pests of sunflower crops in Samaru Zaria which tallies with the findings of this present study.

Mani (2004) reported that *A. versicolor* occurred on sunflower more during the dry season compared to the rainy season at vegetative growth stages causing no significant damage to the plant, however, high temperature and low humidity during the dry season favoureds the population build-up of *A. versicolor*. Also, Osman (2004) reported that low humidity and optimum temperature during dry season favour the clustering activities of *A. versicolor,* resulting in increased population while the bugs tend to confine to weeds during the rainy season

There was no significant difference between the planting dates in terms of seed damage during the rainy and dry seasons despite the high bug population on the sunflower sown on August 18 and those of December 08. The non-significant mean seed damage recorded with each planting date and between the season may be due to the fact that sunflower seed are covered by hard shell, which deterred the bugs from feeding on them. This agrees with Paul (2015), that though nearly all parts of sunflower are targeted by pests, most pests ignore the seed as the seed are often hardy. This finding also agrees with Khaemba and Mutuku (1992) that *A. versicolor* adults and nymphs damage on sunflower are of no economic importance.. In Nigeria, Mani (2004) reported that *A. versicolor* have less effect amongst other pests identified on sunflower crops in Samaru Zaria.

5.2 Sunflower Seed Yield

Planting date significantly affect the seed yield, earlier sown (July) sunflower gave a higher yield than those sown on later dates (August), however, irrigated sunflower gave better yield than rain fed crop which may be as a result of regulated and constant water control necessary for good crop growth and establishment. This supports an earlier finding by Mani *et al*. (2010) that irrigated sunflower had a higher yield compare to sunflower grown under rain fed condition. In addition, Anon (1998) reported that rain-fed sunflower yield of 800-1000kg /ha is obtainable, while with irrigation, the yield is 2000kg /ha.

The findings in this study however disagree with Adedokun and Adesiyun (1992) who reported that sunflower crops sown in mid-July gave the highest number of insect population while those sown during the fourth week in July gave the least number of insects in the derived savannah zone. Sunflower is largely determined by prevailing weather condition throughout its life cycle Kaleem *et al*. (2011). Season has significant effect on yield of sunflower, there was a higher yield per head during the dry season compare to the rainy season as observed in this study.

The study indicated that earlier sown sunflower gave a higher yield than those later sown however, irrigated sunflower gave better yield than rain-fed which may be as a result of regulated and constant water control necessary for good crop growth and establishment.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

Field experiments were conducted at the Institute for Agricultural Research Samaru Research Farm to study the population dynamics of *Agonoscelis versicolor F.* on sunflower. The effect of planting date and weather parameters were used to monitor the population build-up of *Agonoscelis versicolor,* their damage and yield of sunflower. The experiments were laid out in randomized complete block design with three replications. Four planting dates were employed and Sunflower 'Ex-Funtua' variety were sown during the rainy (July–September) and dry seasons (October-December) with no insecticidal treatments. The result showed a significant difference ($p \leq 0.05$) in the mean bug population on the crops sown on the four different planting dates, with higher mean number of *Agonoscelis versicolor* during the dry season compared to the rainy season. Planting date also had a significant effect on percentage seed damage and seed yield. Relative humidity, rainfall and yield were negatively correlated to population of *Agonoscelis versicolor* while temperature and sunshine were positively correlated to the population of *Agonoscelis versicolor.*

6.2 Conclusions

Agonoscelis versicolor was found to be among other numerous pest of sunflower occurring in both rainy and dry seasons in Samaru. The highest peak population is in December during the dry season while the peak population during the rainy season is in late August. Planting dates and season significantly influence the population of *Agonoscelis* species, seed damage and yield of sunflower crops. Furthermore, sunflower can be sown either as rain-fed or irrigation conditions from July 21 to August 4 and October 27 to November 10 to achieve a good yield respectively.

Observations during the course of the study revealed that *A. versicolor* suck saps from under leaves, stems and achenes of young sunflower plants thereby inflicting damage on sunflower. Also, *A.* versicolor caused seed damage of 19-30% but this had no significant effect on the yield of sunflower.

6.3 Recommendations

Based on the findings of this study, the following recommendations are suggested:

1. There is need for research into suitable pest control measures to manage *Agonoscelis versicolor* in other to boost sunflower production in Nigeria.
2. More studies should be encouraged on entomological aspect of sunflower as there is need for database to ease future field / research studies.

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APPENDICES

Appendix 1: Summary of Samaru Weather Report for 2009 Trial

	July 21-December, 2009		Oct. 27, 2009-March, 9, 2010	
	TOTAL	AVERAGE	TOTAL	AVERAGE
Rain fall in mm	959.6	20.4	0.0	0.0
Open pan evaporation mm/day	1008.6	6.9	1247.4	9.3
Total Average wind km/day	16933.8	114.4	16252.7	121.3
total Temp ˚C 10am	3831.9	25.9	3346.6	25.0
Total temp ˚C 4pm	3997.9	27.0	3549.7	26.7
Total Sunshine hours	1000.8	6.9	1149.8	8.6
%RELATIVE HUMIDITY 10am	9235.0	62.4	2843.0	21.2
%RELATIVE HUMIDITY 4pm	7940.0	54.4	2636.0	19.7
AIR TEMP ˚C MAX	4702.0	31.8	4635.0	34.6
AIR TEMP ˚C MIN	2736.0	18.5	2035.0	15.2

Appendix 2: Summary of Samaru Weather Report For 2012 Trial

	July 21-December, 2012		Oct. 27, 2012-March, 9, 2013	
	AVERAGE	TOTAL	AVERAGE	TOTAL
Rain fall in mm	865.6	19.7	0.0	0.0
Open pan evaporation mm/day	721.8	4.9	990.0	7.2
Total Average wind km/day	15947.3	107.8	17186.1	121.9
total Temp ˚C 10am	3952.6	26.7	3703.3	26.3
Total temp ˚C 4pm	3852.4	26.0	3660.4	26.0
Total Sunshine hours	956.4	6.5	1137.0	8.1
% RELATIVE HUMIDITY 10am	9267.0	62.6	3646.0	25.9
% RELATIVE HUMIDITY 4pm	8054.0	54.4	2614.0	18.5
AIR TEMP ˚C MAX	4743.0	32.0	4841.0	34.3
AIR TEMP ˚C MIN	2834.0	19.3	2539.0	18.1